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Attention is Modulated by Motivational Relevance: A Behavioural and ERP Investigation of Affective Picture Processing

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CHAPTER 1: OVERVIEW OF THE THESIS

The motivational model of attention and affective states proposed by Lang and colleagues (Bradley & Lang, 2000; Lang, 1995; Lang, Bradley, & Cuthbert, 1990; Lang, Bradley, & Cuthbert, 1997) has become an increasingly attractive theoretical framework for current research in the area of emotional processing. This model posits that the stimulus dimensions of hedonic valence and arousal elicit activation in the underlying appetitive and aversive systems. Typical findings of enhanced electrophysiological responses to both pleasant and unpleasant stimuli compared to neutral stimuli (e.g., Amrhein, Mühlberger, Pauli, & Wiedemnn, 2004; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Diedrich, Naumann, Maier, Becker, & Bartussek, 1997; Johnston, Miller, & Burleson, 1986; Keil, Bradley, Hauk, Rockstroth, Elbert, & Lang, 2002; Loew, Bradley, Ashley, Keller, & Lang, 2003; Meinhardt & Pekrun, 2003; Mini, Palomba, Angrilli, & Bravi, 1996; Palomba, Angrilli, & Mini, 1997; Schupp, Cuthbert, Bradley, Birbaumer, & Lang, 1997; Schupp, Junghöfer, Weike, & Hamm, 2003a; Schupp, Cuthbert, Bradley, Hillman, Hamm, & Lang, 2004a; Schupp, Junghöfer, Weike, & Hamm, 2004b) are often taken as evidence that attention is more deeply engaged by motivationally relevant stimuli (i.e., stimuli that activate the appetitive and aversive systems) (e.g., Amrhein et al.; Cuthbert et al.; Keil et al.; Meinhardt & Pekrun; Schupp et al., 1997, 2003a, 2004a, 2004b). Another body of research suggests that electrophysiological responses are enhanced in response to unpleasant compared to pleasant and neutral stimuli, termed the negativity bias (Carretié, Hinojosa, Martín-Loeches, Mercardo, & Tapia, 2004; Carretié, Mercardo, Tapia, & Hinojosa, 2001a; Delplanque, Lavoie, Hot, Silvert, & Sequeira, 2004; Delplanque, Silvert, Hot, & Sequeira, 2005; Delplanque, Silvert, Hot, Rigoulot, & Sequeira, 2006; Ito, Larsen,

Smith, & Cacioppo, 1998a; Smith, Cacioppo, Larsen, & Chartrand, 2003). Both lines of enquiry have been limited by methodological issues and one of the primary aims of the current dissertation is to disentangle previous research theories through a systematic investigation of the effect of hedonic valence, arousal, and semantic content on behavioural and electrophysiological responses.

This introductory chapter (Chapter 1) details the structure of the current thesis and is followed by a chapter reviewing the evolution of the emotional or affective system and the cognitive-emotional interactions that underlie the perception and experience of emotion (Chapter 2). An overview of the affective space model, motivational model of attention and affective states, evaluative space model, and Öhman and Minkea's (Öhman & Mineka, 2001; Öhman & Mineka, 2003; Mineka & Öhman, 2002) evolved fear module [which encompasses aspects of Seligman's (1970, 1971) preparedness theory] are outlined in the subsequent subsections of Chapter 2. A summary emphasising the value of the motivational model of affective states both to research in the area of emotional processing and to the current thesis concludes Chapter 2.

The physiological and neurophysiological correlates of affective processing are reviewed in Chapter 3. The various models of hemispheric lateralisation of affect are discussed with particular focus on the regional activation hypotheses proposed by Heller (1990, 1991) and Davidson and colleagues (Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Davidson, 1992; 1993a). This is followed by a review of the sex differences in behavioural, physiological, and neurophysiological responses to affective stimuli. An operational definition of event-related potentials (ERPs) is then presented along with a discussion of the utility of ERP measures in experimental research. This subsection includes a review of the ERP components that are of particular importance

within the scope of the current thesis and related research, namely the P1 and N1 components, the P2 and N2 components, and the subcomponents of the Late Positive Complex [LPC: novelty P3, P3b, and Positive Slow Wave (PSW)]. Chapter 3 also includes a review of ERP studies of affective picture processing and involves a discussion of the relevant theories and methodological issues. ERP evidence of facial recognition and the communication of affect via facial expressions are also discussed. Chapter 3 concludes with a summary of key points with a focus on the conflicting models of affective picture processing evident in the ERP literature.

The first three chapters are concerned with setting an empirical and theoretical framework for the current thesis, emphasising the relevant models and methodological issues that may have hampered previous research efforts in the area. Chapter 4 begins the review of a more applied aspect of the thesis, illustrating how affective or motivationally relevant stimuli can influence processes of attentional orienting. Relevant models of visual spatial attention and covert orienting are discussed, emphasising the research from peripheral cueing paradigms that form the basis of the empirical studies in Phase 2. A subsection reviewing the literature on covert orienting and emotion and the attentional mechanisms thought to operate in anxious populations during threat detection follows. Chapter 4 concludes with a summary of key points.

Chapter 5 provides a general rationale and outlines the general aims for the empirical studies. Chapter 6 provides the details of the empirical studies included in Phase 1, outlining the specific rationale, methodology, results, and discussion of each experiment successively. Phase 1 consists of three experiments; Experiments 1 and 2 are aimed at investigating the effect of valence, arousal, and motivational relevance on behavioural and ERP measures by addressing the methodological issues present in previous research in an attempt to identify the most definitive model of affective picture

processing (quadratic effect or motivational model versus the negativity bias). Experiment 3 is concerned with the effect of social content on affective information processing.

Phase 2 is outlined in Chapter 6 and also involves three experiments that are discussed successively. Experiments 4 and 5 are aimed at investigating the effect that motivationally relevant stimuli have on processes of attentional orienting, and in addition, standard trial-by-trial cueing effects are investigated by manipulating stimulus parameters such as the stimulus onset asynchrony (SOA). Experiment 6 is aimed at investigating the effect of differentially prepared stimuli (e.g., threatening animals - evolutionarily associated with threat versus threatening humans and/or objects - culturally associated with threat). The dissertation concludes with a general discussion of the empirical findings with subsections pertaining to Phase 1 and Phase 2 followed by a general conclusion (Chapter 8).

CHAPTER 2: MODELS OF EMOTION, AFFECTIVE SPACE, AND THE EVOLUTION OF THE EMOTIONAL SYSTEM

Evolution of the Emotional System and Cognitive-Emotional Interactions

Rudimentary forms of approach and withdrawal responses were sufficient for the adaptive problem solving behaviours of primitive species, however as the interactions between higher order species and their environment became increasingly more complex, a separate neural system was required to facilitate information processing. The emotional or affect system is thought to have evolved from the subcortical structures of primitive species that responded to primary reinforcers (Öhman & Mineka, 2001), and the neural networks that underpin the emotional system in humans are assumed to be directly connected to the brain's primary motivational systems (Lang, Davis, & Öhman, 2000). The emotional system is proposed to involve various brain structures including the brain stem, limbic system, and the cerebral cortex (Lewis & Stiben, 2004). The limbic system theory provided the dominant framework for interpreting the function and origin of the emotional system, and although the connection between limbic system structures and the emotional systems is quite valid, there are some inherent limitations to the theory, namely that the cognitive and emotional systems are viewed as separable entities (Damasio, 1995; for a review of the limbic system theory see LeDoux, 2000). The key concept of the limbic system theory is that the human emotional system evolved from subcortical brain structures of primitive species that did not have an evolved neocortex. Highly developed thinking, reasoning, and problem solving is largely a human specialisation associated with the evolution of the mammalian neocortex (LeDoux) and the conceptualisation of emotions as largely subcortical in origin and

cognitions as largely cortical in origin (Panksepp, 2003) has lead to the assumption that the two systems are relatively independent. Neurological models that posit emotion and cognition as two separable systems fail to recognise the necessary interplay between subcortical and cortical structures for the overt expression and experience of emotion. Descending projections from higher cortical levels to the limbic system and brain stem allow for cognitive regulation of emotion, while ascending projections from limbic structures to higher cortical structures enable perceptual and cognitive processing of emotional responses (Derryberry & Tucker, 1992) (for reviews on the brain structures involved in the emotional system see Calder, Lawrence, & Young, 2001; Damasio, 1995; Davidson, 1992; Derryberry & Reed, 1996; Derryberry & Tucker, 1992; LeDoux, 1989; 2000; Patterson & Schmidt, 2003).

If it is agreed that the emotional or affect system evolved from rudimentary approach and avoidance systems in primitive species with a primordial cortex, it must be conceded that the emotional system evolved before the cognitive system. This is not to suggest that the two systems are entirely independent, however concern over the primacy of each system has fuelled the debate now known as the classic Zajonc-Lazarus debate (Zajonc, 1980; 1984; Lazarus, 1982; 1984: for further review see Leventhal & Scherer, 1987; Panksepp, 2003). The debate centres around whether or not affect can be evoked in the absence of cognition or whether cognitive appraisal is a necessary precondition for emotion. Panksepp warns that the debate was not founded on a thorough review of the relevant brain structures or evolutionary theories and no consideration was made as to the brain's somatic and visceral responses as distinguishing features of the affective and cognitive systems.

Zajonc (1980) agrees that the cognitive and emotional systems ordinarily operate together, however he argues that there are occasions where affective responses precede

full cognitive appraisal. The key observations that Zajonc presents to support his view on the primacy of affect are that affective reactions and/or approach and avoidance responses are universal for all animal species, whereas cognitive processes such as language are not. Panskepp (2003) adds that emotions generate systematic changes in facial and bodily expression as well as prosodic voice changes while cognitions do not, and the non-verbal expression of emotion is universal for human and higher order primates (Zajonc). Affective reactions or at least the actual experience of emotion is argued to be involuntary and ballistic, and there are instances where affective appraisals can occur before and/or independent of cognitive appraisals, for example the instantaneous preferences of like and dislike that are made about an individual before evaluation of their personal make up is complete (Zajonc).

Lazarus (1982; 1984) argues against the views of Zajonc (1980; 1984) and proposes that cognition is a necessary precondition for emotional experience. He suggests that rather than being automatic, emotional responses are elicited only after evaluative perception, and classes both sensory-perceptual and complex appraisals as 'cognitive'. Zajonc (1984) however only classes evaluation that is post-perceptual as cognitive. Emotion in Lazarus's (1982; 1984) view is assumed to arise as a result of cognitive appraisal and the intensity of the emotional response depends on the relevance of the event to the individual's well being. Lazarus (1984) does not deny that rapid and immediate responses can be elicited by emotionally charged stimuli; however he argues that such responses result from the activation of schemata that form from previous experience with emotionally charged (e.g., threatening) stimuli. The argument that cognition is a necessary pre condition for affective responses is therefore anchored in Lazarus's (1982; 1984) definition of emotion; as Zajonc (1984) notes, if emotional

reactions are defined as requiring cognitive appraisal, it must be assumed that cognitive processing occurred if an emotional response is observed.

In order for behavioural responses to be adaptive when dealing with complex social and emotional situations, it cannot be denied that some degree of interaction is required between the cognitive and emotional systems. This relationship has been argued to be mediated by separate but interacting systems in the brain (Gainotti, 2000; LeDoux, 1989). Complex emotions (e.g., vanity, remorse, and shame) are made up of blends of different basic emotions (e.g., happiness, fear, anger, disgust, sadness, surprise, and contempt) which would not be possible without an interaction between emotional schemata and cognitive evaluations (Gainotti). While for the most part, the relationship between the cognitive and emotional systems appears to be highly reciprocal, the cognitive system is argued to exert a higher influence over overt responses than the emotional system (Gainotti), which is particularly important for emotional regulation. In agreement with the partial independence of the cognitive and emotional systems, affective evaluations can occur outside of conscious recognition as shown from backwards masking studies (see Esteves, Parra, Dimberg, & Öhman; 1994; Öhman & Soares, 1993, 1998), and the relative independence of the two systems is unquestionable based on the different evolutionary origins of the cognitive and affective systems.

Bipolar Dimensions of Affective Space

Cognitive and emotional interactions are fundamental to the perception and experience of emotion. However, as will be discussed, a distinction is made between emotional states which largely involve tactical responses, and affective states that largely involve strategic responses (Lang, et al., 1997). Tactical responses are more diverse and context

dependent than strategic responses that are argued to be based on two broad dimensions of hedonic valence and arousal. Various models of affective space have been proposed, which for the most part, can be seen as encompassing the strategic dimensions of affect. Multidimensional models of emotion were popularised by theorists such as Russell (1979, 1980) and have become the primary focus of current physiological and neurophysiological models of emotion and affective states (see Lang et al., 1990; Lang et al., 1997). Hedonic valence (pleasant-unpleasant) and arousal (calm-excited) are identified as the two principle components along which affective states are organised, however the shape of affective space as defined by these two bipolar variables has been debated. Factor-analytic studies that formed the basis of early models of affective space relied heavily on self-report measures of affect and were fraught with methodological issues (Russell, 1979). Acquiescent responding, non-asymmetrical response formats, inadequate sampling of affective terms, instructions to describe feelings over a long period of time which may allow for several possibly opposite feelings to be reported, and proximity error (the tendency to respond similarly to items that appear close in time and space) were among the methodological concerns raised by Russell (1979). A factor-analytic study was conducted by Russell (1979) in an attempt to provide a more valid illustration of the structure of affective space. The factor analysis involved 58 adjective items that corresponded to 11 commonly used affect scales (general activation, high activation, general de-activation, de-activation-sleep, pleasure, displeasure, arousal, sleepiness, dominance, submissiveness, and depression). Russell (1979) showed that the 11 affect scales did indeed load onto two principal components of pleasure-displeasure and level of arousal, thus concluding that affective space is defined by two bipolar variables. In a further investigation of the bipolar structure of affective space, Russell (1980) argued that the shape of affective space may be more suitable to a circumplex

model of measurement, where the circular ordering of variables is arbitrary (see Guttmann, 1954), rather than the then commonly used factor-analytic models. The circumplex model of affective space as defined by Russell (1980) is illustrated in Figure 1.

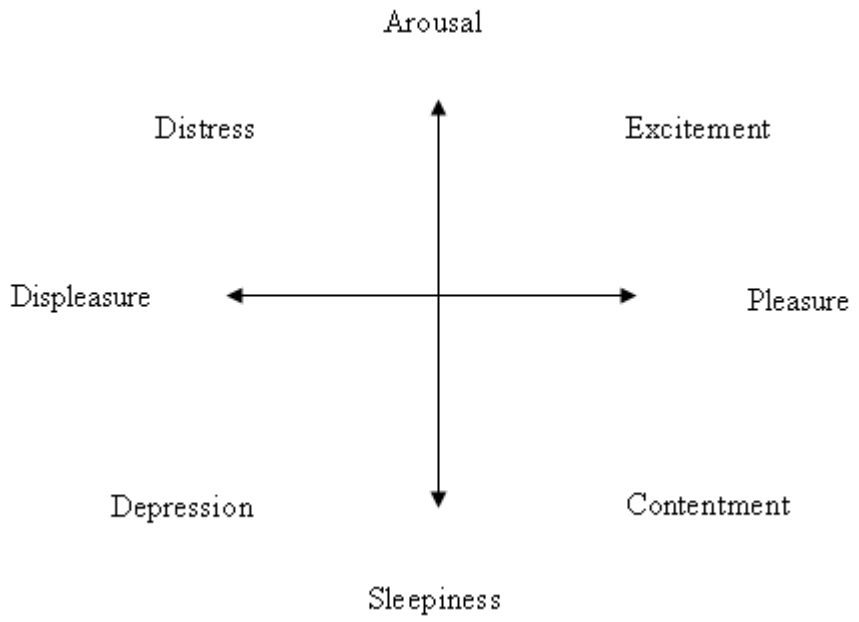


Figure 1. Russell's (1980) circumplex model of affect (adapted from Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*, 1161-1178).

As can be seen in Figure 1, the horizontal axes are defined by pleasure-displeasure, the vertical axes by arousal-sleep, and the remaining variables of excitement, contentment, depression, and distress define the quadrants of affective space. Russell (1980) tested the applicability of this model by instructing participants firstly to categorise 28 affective words according the eight pre-determined affective categories, then to arrange the eight categories around the circular space so that similar

constructs were close together and distant constructs were opposite in the circular space. Again it was found that the majority of the variance was accounted for by two bipolar dimensions of pleasure-displeasure and level of arousal. A circumplex model of affective space was argued to be the best fitting model as the 28 items were shown to be spread more or less continuously around the perimeter of the circle rather than clustering around the two bipolar axes. The shape of affective space as defined by valence and arousal factors has been debated by researchers such as Watson and Tellegen (1985), who primarily argue against the utility of arousal as a defining factor of affective space. These researchers instead argue that the shape of affective space can be accounted for by two bipolar dimensions of positive and negative affect, where the high end of each dimension represents a state of emotional arousal, and the low end of each factor represents the relative absence of arousal. As will be discussed in the next subsection, the motivational model of attention and affective states developed by Lang and colleagues (Bradley & Lang, 2000; Hamm, Schupp, & Weike, 2003; Lang, 1995; Lang et al., 1990; Lang et al., 1997) is consistent with the biphasic structure of affective space however the shape of affective space defined by the motivational model is not indicative of a balanced circumplex.

Motivational Models of Attention, Emotion, and Affective States

The framework surrounding the model of motivated attention and affective states proposed by Lang and colleagues (Bradley & Lang, 2000; Hamm et al., 2003; Lang, 1995; Lang et al., 1990; Lang et al., 1997) is based on the evolutionary associations between the emotional system and primitive approach and avoidance systems. A key feature of the model is that the dimensions of valence and arousal are identified as important components for the activation of the underlying appetitive and aversive

systems. The reliance on self-reported affective experiences, which dominated early attempts to define the shape of affective space have been removed in the model proposed by Lang and colleagues, which focuses on the perception of emotionally salient stimuli. The utility of the model of motivated attention and affective states for explaining the range of human emotional responses has proven much greater than earlier circumplex models.

The model of motivated attention and affective states (also referred to as the motivational model throughout the course of the current dissertation) is best suited to the investigation of primary emotional responses. These emotions show an innate relationship with the underlying motivational systems and respond to primary reinforcers while secondary emotions arise in response to the experience and perception of the primary emotional episode (Damasio, 1995). The production of primary emotions is associated with the activation of underlying drive states, or the nervous processes that control preservative (e.g., hunger, sexual, and curiosity drives) and protective (e.g., fear drive) functions (Kornorski, 1967). Like the appetitive and aversive systems, drive states are also influenced by primary reinforcements, with the successful fulfilment of drive states activating the reward receptors in the brain and the unsuccessful fulfilment of drive states activating the punishment receptors (Kornorski). Drive states are therefore effective at eliciting approach and avoidance behaviours and can be considered somewhat analogous with the underlying motivational systems. Kornorski refers to drive states as purely physiological processes, however the subjective feelings that correspond to particular drives and anti-drives (or the feeling of contentment and satisfaction once a drive is fulfilled) are referred to as emotions. Livesey (1986) in accordance with Kornorski also refers to drive states in his definition of emotions, suggesting that

emotions are the learned anticipatory feelings that coincide with the successful fulfilment of drive states.

Lang and colleagues (Bradley & Lang, 2000; Hamm et al., 2003; Lang, 1995; Lang et al., 1990; Lang et al., 1997) provide an operational definition of human emotions as action dispositions. Emotional cues can evoke heightened levels of attention and the autonomic nervous system prepares the body for specific responses, however unlike lower order species, humans can suppress or entirely inhibit the overt emotional response. As mentioned previously, Lang and colleagues (Lang et al., 1990, Lang et al., 1997) make an important distinction between tactical and strategic emotions. The strategic dimension of affect is defined along the dimensions of hedonic valence and arousal. The motivational model holds that all emotional responses are organised along underlying appetitive and aversive systems that respond to primary reinforcers (Lang, 1995). Pleasant states that promote approach responses are driven by the appetitive system, unpleasant states that promote withdrawal responses are driven by the aversive system, and arousal reflects the level of energy that is mobilised by either system (Lang et al., 1990; Lang et al., 1992; Lang et al., 1997). Emotions that are organised according to this biphasic structure are therefore referred to as strategic because the general direction of the behaviour and the amount of energy required can be specified even in the absence of an overt response (Lang et al., 1990). Tactical responses are more diverse, variable, and context dependent and refer to the highly individualised reactions that occur in response to affective stimuli and/or events (for a detailed review of tactical and strategic emotions see Lang et al., 1990; 1992; 1997).

As mentioned, one of the key benefits of the motivational model over previous models of affect is the focus on the perception of emotional stimuli rather than self report. Lang and colleagues (Lang, Bradley, & Cuthbert, 1999) developed a picture set

of over 700 images intended for use in emotion-attention research. The most recent International Affective Picture System (IAPS) developed by Lang et al. (1999) includes images that vary on both the valence (pleasant, neutral, and unpleasant) and arousal continuum and also includes images from a range of semantic categories. The shape of affective space has been investigated by plotting individual ratings of valence and arousal for a wide range of IAPS stimuli, inferring the relationship between these two variables via correlational analyses. Consistently, the shape of affective space has not been identified as a balanced circumplex. Motivational vectors, or the degree to which stimuli engage the brain's motivational systems has been inferred from regression lines that are based on the correlation between ratings of valence and arousal (Bradley, Codispoti, Cuthbert, & Lang., 2001a). The shape of affective space as identified by these motivational vectors takes the form of a boomerang, with two arms that reach from a non-affective, neutral centre to high arousing pleasant and high arousing unpleasant quadrants (Bradley et al.; Lang et al., 1999). A strong linear relationship is therefore shown between ratings of valence and arousal, such that, pictures that are rated as increasingly more pleasant or unpleasant are also rated as increasingly more arousing. The boomerang shape of affective space is therefore highly consistent with the biphasic structure of affective states, where the valence dimension determines the direction of the behavioural or physiological response and the arousal system determines the strength of the response. The shape of affective space as defined by Lang and colleagues has been found to be stable over several years of picture research and is the same for pictures, sounds, and word stimuli (for reviews see Bradley, 2000; Bradley et al.; Bradley & Lang, 2000; Hamm et al., 2003; Lang, 1995; Lang et al., 1997; Lang, Greenwald, Bradley, & Hamm, 1993). Bradley and Lang do however suggest that arousal level correlates more highly with unpleasant valence than pleasant valence, with very few

unpleasant stimuli depicted in the calm or low arousal quadrant. There are also sex differences in the correlation between valence and arousal dimensions that will be discussed in the subsection of Chapter 3.

As discussed, emotions can be thought of as dispositions towards action given that the body prepares the organism for action despite the possibility of inhibiting the overt response. Extensive research has identified specific behavioural and physiological responses that covary with either the valence or arousal dimensions. Facial muscle activity, heart rate, and ratings of pleasantness correlate highly with an hedonic valence factor, while skin conductance response (SCR), arousal ratings, interest ratings, and viewing time covary more strongly with an arousal factor (see Bradley, 2000; Bradley & Lang, 2000; Hamm et al., 2003; Lang et al., 1997). Functional Magnetic Resonance Imaging (fMRI) studies have shown activation in the visual cortex that is also assumed to covary with arousal. Emotional (pleasant and unpleasant) stimuli evoke greater activation in the visual cortical areas compared to neutral stimuli, and increased activity is shown in response to high arousing pleasant and unpleasant stimuli compared to respective low arousing stimuli (Bradley, Sabatinelli, Lang, Fitzsimmons, King, & Desai, 2003; Lang, Bradley, Fitzsimmons, Cuthbert, Scott, Moulder, & Nangia, 1998; Lane, Chua, & Dolan, 1999). Conflicting research however suggests that both valence and arousal contribute to increased activation in the visual cortical regions (see Mourão-Miranda, Volchan, Moll, de Oliveira, et al., 2003). The slow cortical potentials have also been proposed to covary with rated arousal (see Cuthbert et al., 2000; Hamm et al.; Lang et al.) however, there are some methodological limitations inherent in a large proportion of studies investigating electrophysiological responses to affective stimuli that are discussed in Chapter 3.

The startle reflex, a primitive defensive reflex that serves to protect the eye (Lang et al., 1990) has been proposed to covary more strongly with the valence dimension and has been extensively studied in the context of motivational priming (for a review on the motivational priming of the startle reflex see Lang et al., 1990; 1992; 1995; 1997). The motivational priming hypothesis states that an individual's current affective state can modulate subsequent responses such that defensive reflexes are enhanced during unpleasant emotional states and are inhibited during pleasant emotional states (Lang, 1995). In support of the motivational priming hypothesis, it has been consistently shown that the magnitude of the startle reflex is enhanced in an unpleasant context and is reduced in a pleasant context (see Lang et al., 1990; 1992; 1995; 1997). The motivational priming hypothesis has also been studied using ERP measures. Kenter-Mabiala and Pauli (2005) presented painful and non-painful electric shocks in the context of pleasant, unpleasant, and neutral images and found that the pain specific N150 component was most enhanced in response to painful stimuli presented in an unpleasant context and was least enhanced in response to painful stimuli presented in a pleasant context.

Certain physiological responses, which will be discussed more fully with a specific reference to sex differences in Chapter 3, covary with the broad dimensions of hedonic valence and arousal. However, research by Bradley et al. (2001a) suggests that certain physiological responses are modulated as a function of specific picture content. The defensive system can be activated in response to symbolic images of danger or threat such as images of human mutilation, human/animal attack, and injury. Differences in defensive activation can be investigated by comparing images of high motivational relevance (e.g., depict scenes that are relevant for survival) and images of the same hedonic valence but of low motivational relevance and arousal such as images of

contamination, illness, loss, and pollution. The same holds for pleasant categories of pictures, with images of erotic couples and opposite sex nudes activating the appetitive system to a greater degree than equally pleasant images of food, nature scenes, animals, babies, or family/romantic interactions, or images of adventurous sport that are of the same valence and arousal level but differ in motivational qualities. Bradley et al. found that images of animal attack and mutilation evoked the largest changes in SCR followed by images of human attack, and the lowest changes in SCR were associated with images of contamination, illness, loss, and pollution. Heart rate was not differentially modulated as a function of specific picture content, however the startle reflex elicited the largest amplitudes in response to images of human/animal attack and mutilation while startle responses in the context of the low arousing images were inhibited. Similar results were shown for the activation of the appetitive system. Images of erotic couples and opposite sex nudes elicited the largest changes in SCR compared to all other pleasant images which did not differ significantly. Heart rate was differentially modulated as a function of specific picture content for pleasant images, with the greatest initial deceleration and peak acceleration associated with images of erotic couples. Erotic couples and opposite sex nudes also elicited the smallest startle reflexes, indicating the greatest mismatch between the defensive reflex and the positivity of the affective state. Physiological responses therefore vary not only as a function of the underlying dimensions of valence and arousal, but as a function of specific picture content, with the greatest physiological responses exhibited in response to the most motivationally relevant appetitive and aversive contents.

Evaluative Space Model: Positivity Offset and Negativity Bias

The evaluative space model is important within the context of the current thesis as it provides an alternative perspective to the model of motivated attention and affective states in terms of the strength of activation of the underlying appetitive and aversive systems. Whereas the motivational model suggests that that the underlying appetitive and aversive systems are organised along a valence dimension and the strength of activation of the appetitive and aversive system is determined by an arousal dimension, the evaluative space model specifies the strength of activation between the appetitive and aversive system differs in response to pleasant and unpleasant stimuli. As will be discussed, the evaluative space model is based on early animal conflict behaviour models and proposes that activation of the aversive system is greater than the activation of the appetitive system in response to equally intense appetitive and aversive cues.

Fulfilment of appetitive needs associated with hunger and sexual reproduction serves to promote long term survival, however immediate survival largely depends on how efficiently one can discriminate harmful from hospitable stimuli in a given environment. Pleasant events tend to occur more frequently than unpleasant events and the consequences of a failed response to an unpleasant event are more likely to be catastrophic compared to a failed response to a pleasant event (Rozin & Royzman, 2001). Based on these assumptions it is likely that natural selection has favoured a system that facilitates rapid responses to aversive stimuli, and the observation that responses are more rapid and prominent to aversive compared to equally arousing appetitive stimuli has been termed the negativity bias (for reviews see Cacioppo & Berntson, 1994; Cacioppo, Gardner, & Berntson, 1997; Ito & Cacioppo, 2005; Ito, Cacioppo, & Lang, 1998b; Miller, 1944, 1959; Rozin & Royzman, 2001). Negative

potency, which refers to the notion that extremely unpleasant events are more threatening than equally extreme pleasant events are beneficial (Rozin & Royzman), is one of the major principles underlying the negativity bias. Negative events are generally experienced with greater intensity than positive events and responses to negative events and stimuli tend to be more varied, contributing to the greater potency of negative events (Rozin & Royzman).

Early fear conditioning studies with animals provided the framework for the understanding of the aversive system in humans. Miller (1944; 1959) was one of the early researchers in the area of behavioural motivation who developed a conflict behaviour model based on animal fear conditioning studies. He suggested that the animal conflict behaviour model could be applied to the study of human behaviour given the common variables of approach, withdrawal, pain, fear, and appetitive/aversive drives. Miller proposed that conflict occurs when opposing approach and withdrawal systems are co-activated and that conflict can be explained in terms of the strength of the response and the proximity between the subject and the eliciting stimulus. The conflict behaviour model (as shown in Figure 2) holds that the approach tendency is stronger when the subject is far from the eliciting stimulus or goal and the avoidance tendency is stronger the closer the subject is to the eliciting stimulus and/or goal. The avoidance gradient is proposed to be steeper than the approach gradient because the fear drive is elicited by external cues and thus rises more steeply in response to the proximity of the feared stimulus. The approach gradient is flatter than the avoidance gradient because approach drives such as hunger are more reliant on internal cues and would not be expected to vary as strongly as the avoidance gradient in response to the proximity of the eliciting stimulus.

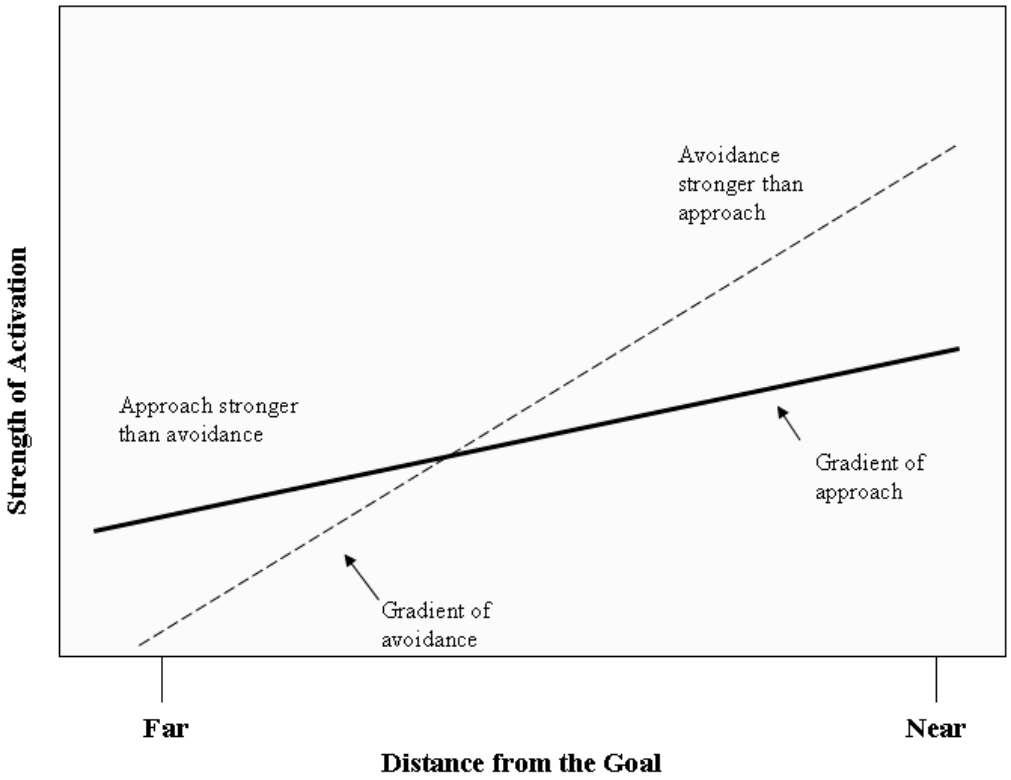


Figure 2. Miller's (1959) animal conflict behaviour model. (adapted from Miller, N. E. (1959). Liberalization of basic S-R concepts: Extensions to conflict behaviour, motivation, and social learning. In S. Koch (Ed.), *Psychology: A study of a science. General systematic formulations, learning, and special processes*. USA: McGraw-Hill Book Company).

The gradients of the approach and avoidance slopes for human conflict behaviour may be more varied given the more complex range of motivationally relevant stimuli, however the assumption that the avoidance gradient is steeper than the approach gradient is widely accepted (Cacioppo & Berntson, 1994; Cacioppo, et al., 1997; Ito et al., 1998b). The strength of both approach and avoidance tendencies are also assumed to vary with the strength of the underlying drive state, and thus increases in drive state raise

the overall height of each gradient (Miller, 1944; 1959). Miller's (1944; 1959) conflict behaviour model indicates that when approach and avoidance tendencies are co-activated and thus in conflict, the subject will approach when distant from the goal. When the subject comes closer to the goal the strength of the avoidance gradient rises until the point where the two gradients intersect and the subject will typically stop. According to Miller (1944), vacillation behaviours, or fluctuations between approach and avoidance responses, are often observed at this point because as the subject approaches the goal they become increasingly hesitant and may withdraw when they feel too close and approach again when at a comfortable distance from the goal. The point of intersection also varies depending on the strength of the underlying drive state with the intersection points becoming closer to the goal as the height of each gradient is increased. Miller (1944) notes that if either of the gradients is sufficiently elevated through increased hunger or pain resulting from increased intensity of electric shocks, the two gradients will be parallel and the subject will be free to fully approach or fully retreat from the goal.

Cacioppo and colleagues (Cacioppo & Berntson, 1994; Cacioppo et al., 1997) extended and adapted Miller's (1944; 1959) conflict behaviour model in order to develop their bivariate model of evaluative space, which conceives of approach and avoidance tendencies as relatively independent systems that can be reciprocally activated, singularly activated, and co-activated. The resulting states from positive-negative interactions can range from low levels of positivity and negativity (neutrality) to high levels of positivity and negativity or maximal conflict characterised by feelings of ambivalence (Cacioppo & Berntson; Cacioppo et al.; Ito et al., 1998b). Ambivalence as defined by Cacioppo and colleagues is similar to vacillation behaviour described by Miller (1944). The bivariate model of evaluative space can therefore account for a wider

variety of behavioural responses than models that posit positivity and negativity as endpoints on a bipolar continuum.

Two major principles referred to as the positivity offset and negativity bias underlie the bivariate model of evaluative space and these principals are based on the approach and avoidance gradients of Miller's (1944; 1959) conflict behaviour model. Positivity offset refers to the stronger tendency for approach behaviours when a subject is in an environment with low evaluative input (Cacioppo & Berntson, 1994; Cacioppo et al., 1997), which is slightly different to Miller's approach gradient where approach behaviours are stronger the further the subject is from a conflict goal. The starting point for approach behaviours is higher than for avoidance behaviours, and the slope of the avoidance gradient is steeper than the approach gradient, which is consistent with Miller's conflict behaviour model. The structure of the positivity offset and negativity bias can be operationalised in terms of a regression equation where the positivity offset represents the constant with an intercept value of zero, and the negativity bias represents the slope of the regression equation (Ito et al., 1998b). Positive activation occurs when there is no evaluative input and the intercept is zero. If a positive input is then provided only the positive system would be activated. If negative inputs are also provided co-activation of positivity and negativity can result in states of maximal conflict and feelings of ambivalence and as Miller's conflict behaviour model suggests, when two opposing states are co-activated, the stronger tendency (avoidance) will dominate. The positivity offset has been proposed to facilitate exploratory behaviours towards novel objects and contexts when in a neutral environment, whereas the negativity bias has been proposed to facilitate rapid responses to aversive stimuli to optimise survival (Cacioppo & Berntson; Cacioppo et al.; Ito et al.; Ito & Cacioppo, 2005). The positivity

offset and negativity bias therefore have evolutionary significance for fostering exploratory and protective behaviours.

The effect of the positivity offset, negativity bias, and co-activation of the two systems has been illustrated by Cacioppo et al.'s (1997) research on impression formation. Positive impressions were formed about a hypothetical character "Sam" when neutral information was presented and positive impressions increased when additional positive information was presented. When negative information followed neutral information, an increase in negative impressions occurred and additional negative information had a more profound affect on attitude change than did additional positive information. Finally, when neutral information was followed by negative or mixed information, participants reported more ambivalent impressions than when neutral information was followed by positive or additional neutral information. A positivity offset and negativity bias have also been shown for impression formations of a hypothetical aguaphone fish (Cacioppo et al.), and when rating picture sets for levels of valence and arousal (Ito et al., 1998b).

The underlying appetitive and aversive motivational systems guide the evaluation of environmental stimuli and facilitate survival and social cohesion. The principles of the positivity offset and negativity bias are fundamental to the operation of the two motivational systems as defined by the evaluative space model. As Miller's (1944; 1959) conflict behaviour model and Cacioppo and colleagues' (Cacioppo & Berntson, 1994; Cacioppo et al., 1997) evaluative space model suggest, approach and avoidant responses can be elicited in a fashion that creates conflict or can be reciprocally activated along distinct approach and avoidant dimensions. The evaluative space model can be conceived as accounting for a wider range of motivational responses than the motivated model of attention and affective states proposed by Lang and colleagues.

Öhman and Mineka's Evolved Fear Module and Theories of Preparedness

The model of motivated attention and affective states (Bradley & Lang, 2000; Hamm et al., 2003; Lang, 1995; Lang et al., 1990; Lang et al., 1997) has been pivotal to the investigation of emotional-motivational interactions; however a great deal of research has been concerned with the aversive or defensive system, especially in light of evidence of a negativity bias and the prevalence of affective disorders such as specific phobias and anxiety that may stem from a lowered threshold for defensive activation (Yiend & Matthews, 2001). The concept of an evolved fear system that assists animals in the detection of, and response to, threatening stimuli was proposed by Öhman and Mineka and is tightly associated with the negativity bias (for reviews see Mineka & Öhman, 2002; Öhman & Mineka, 2001; Öhman & Mineka, 2003). The fear defence system is mediated by specific neural circuitry in evolutionarily old regions of the brain, such as the aforementioned limbic structures, and is thus relatively independent of, and resistant to, cognitive influences (Mineka & Öhman; Öhman & Mineka, 2001). The fear defence system is also highly selective to, and automatically activated by, stimuli that have been associated with fear throughout the course of mammalian evolution (Mineka & Öhman; Öhman & Mineka, 2001). The fear-defense system can be activated after minimal evaluation of stimuli and evidence from fear conditioning with backwards masking studies (e.g., Esteves et al., 1994; Öhman & Soares, 1993; 1998), suggests that evolutionary (or phylogenetically) fear-relevant stimuli are processed pre-consciously. Backwards masking paradigms involve the presentation of an experimental stimulus followed immediately (<30ms) by a mask that precludes conscious recognition of the experimental stimuli. Fear conditioning studies in which the acquisition phase occurs under backwards masking conditions have shown enhanced conditioning effects

(enhanced SCR) during the extinction phase for fear-relevant (e.g., snakes, spiders, angry faces) compared to fear-irrelevant (e.g., flowers, mushrooms, happy faces) stimuli (Esteves et al., 1994; Öhman & Soares, 1993; 1998). The results of these studies suggest that learned associations can form between fear-relevant stimuli and aversive outcomes outside of conscious awareness and after minimal, even preconscious, processing and also that such learned associations are selective for phylogenetically fear-relevant stimuli.

Before the evolved fear module was conceptualised, Seligman (1970; 1971) proposed a theory of preparedness to account for the observation that fears and/or phobias are commonly associated with stimuli and experiences that have been evolutionarily associated with threat (phylogenetic: e.g., fear of specific animals/insects, fear of heights, the dark, open spaces), compared to stimuli that have been culturally associated with threat (ontogenetic: e.g., guns/knives), even though these stimuli are more likely to be associated with trauma. Human phobias are argued to be evolutionarily prepared or learned through a process of Pavlovian conditioning that differs from classical conditioning on the basis of increased selectivity to the unconditioned stimulus, greater resistance to extinction, rapid acquisition with minimal exposure to the eliciting stimulus, and largely non-cognitive conditioning (Seligman, 1970; 1971). De Silva, Rachman, and Seligman (1977) and Zafiropoulou and McPherson (1986) provide supporting evidence for preparedness theory, showing that the majority of phobias reported in their clinical sample were associated with evolutionary prepared stimuli, and clinical obsessions showed some degree of preparedness though to a lesser extent than phobias (De Silva et al.). These authors acknowledged that the identification of a phobia as prepared was not related to any therapeutic outcome. Although the research is quite dated, it is highly relevant in terms of the evolutionary origins of the emotional system.

Certain animal species, particularly reptiles, have strong evolutionary associations with fear based on the predatory threat reptiles posed for the ancestral man. Strong evidence for biological or phylogenetic preparedness comes from a series of observational fear conditioning studies conducted by Cook and Mineka (1989; 1990) with lab reared rhesus monkeys. The primates viewed video tapes of other primates reacting fearfully to a toy snake and a toy flower, and non-fearfully with the same stimuli. Observational conditioning resulted in the acquisition of a fear response for the primates who viewed the fearful snake reaction, but no fear response was demonstrated by the primates who viewed the fearful flower reaction. Fear conditioning was also shown in response to a toy crocodile but not in response to a toy rabbit, and since the primates had no prior experience with the experimental stimuli, the results suggest that fear conditioning was specific to phylogenetically fear-relevant stimuli, and may be associated with a more general anti-reptile defense system as outlined by Öhman (1986).

Stimuli with strong cultural or ontogenetic associations with fear also activate the fear system and although conditioned responses to both phylogenetic and ontogenetically fear-relevant stimuli show resistance to extinction, greater resistance to extinction is shown for phylogenetically fear-relevant stimuli (Hugdahl & Käker, 1981). Superior conditioning as an index of enhanced selectivity for phylogenetically fear-relevant stimuli cannot be accounted for by the association between the physical sensation of the shock presented as the unconditioned stimulus (UCS) and a snake/spider bite, as superior conditioning was demonstrated for snake/spider shock compared to damaged electrical cord shock pairings that were rated as more highly associated (Hugdahl & Käker). In contrast, Hugdahl and Johnsen (1989) argue that previous fear conditioning studies have been confounded by the orientation of the fear eliciting stimulus and the choice of the UCS. Phylogenetically fear-relevant stimuli (snakes) did

not show enhanced conditioning compared to ontogenetically fear-relevant stimuli (guns) when both stimuli were directed towards the participant, or when highly associated UCS were used (e.g., snake/shock; gun/noise). There are thus some inconsistencies within the fear conditioning literature as to the level of preparedness for phylogenetic and ontogenetic stimuli.

Selective associations between fear-relevant stimuli and aversive outcomes are thought to represent a covariation bias that is responsible for enhanced fear conditioning (Tomarken, Mineka, & Cook, 1989). 'Illusory correlation paradigms' have been widely implemented in the study of covariation biases (see de Jong, Merkelbach, & Arntz, 1995; Kennedy, Rapee, & Mazurski, 1997; Pury & Mineka, 1997; Tomarken et al, 1989; Tomarken, Sutton, & Mineka, 1995). This paradigm involves the random pairing of fearful and non-fearful stimuli with aversive and non-aversive outcomes, and participants are asked to judge the relationship between picture stimuli and outcomes (Tomarken et al.). The covariation bias is assumed to enhance and/or maintain fear in highly fearful participants as highly fearful participants overestimate the relationship between fear-relevant stimuli and aversive outcomes compared to low fear participants (Tomarken et al.), and untreated spider phobics overestimate the relationship between phobic stimuli and aversive outcomes compared to treated spider phobics (de Jong et al.). Low fear participants have also been shown to demonstrate a covariation bias when the aversive outcome is presented more frequently (at 50% of trials compared to 33%: Tomarken et al.), suggesting that a covariation bias can be elicited regardless of an individual's fear level when fear-relevant stimuli are made to appear more highly associated with aversive outcomes. Participants with high or low fear of blood/injury were both shown to demonstrate a covariation bias (Pury & Mineka), however this result is likely to be accounted for by participants previous experience with injury and aversive

outcomes. Covariation biases are not assumed to be a result of stimulus features such as salience, as the bias remained for fear-relevant stimuli and aversive outcomes when an equally salient chime-plus-light outcome was included (Tomarken et al.). The covariation bias is thought to occur during purely aversive contexts only, as Kopp and Altman (2005) showed a covariation bias to occur when phobic images were followed by an electrical shock or no outcome, however no covariation bias was demonstrated when the appetitive (coin) and aversive (shock) outcomes were randomised or during the purely appetitive context. It has also been proposed that the covariation bias is specific to phylogenetically fear-relevant stimuli as larger biases have been shown for snakes/shock pairings compared to damaged electrical cord/shock pairings, despite these pairings being rated as more highly associated (Tomarken et al.). Kennedy et al. further argue that high fear alone cannot account for the covariation bias, as participants that had a high fear of snakes/spiders and damaged electrical cords demonstrated a covariation bias for the phylogenetically fear-relevant snake/spider stimuli only. Fear in Kennedy et al.'s study however was measured on a five-point Likert scale which may not provide an adequate evaluation of fear, and it is likely that fear of snakes/spiders and fear damaged electrical cords involve different emotional responses.

Mühlburger, Wiedemann, Hermann, and Pauli (2006) addressed some of the methodological limitations identified in previous studies of phylogenetic and ontogenetic covariation biases by comparing participants who feared either ontogenetic (flight phobic) or phylogenetically (spider phobic) fear-relevant stimuli and presented phylogenetic and ontogenetically fear-relevant stimuli during an illusory correlation paradigm. To date this is the first study to measure physiological (SCR) and ERP responses to phylogenetic and ontogenetically fear-relevant stimuli. Both groups displayed an expectancy bias for their respective fear-relevant stimuli at pre-

experimental ratings, however only spider-phobic participants displayed a covariation bias at post-experimental ratings. Both groups also exhibited enhanced SCR for their respective fear-relevant stimuli during the first experimental block, however assessment during the second experimental block revealed that this effect continued for spider phobic participants only. In terms of ERP responses, both groups exhibited enhanced P3b, PSW and early Contingent Negative Variation (CNV) component amplitudes in response to their respective fear-relevant stimuli. This effect for P3b and PSW however was more widely distributed across electrode sites for phylogenetically fear-relevant stimuli for spider phobic participants compared to ontogenetically fear-relevant stimuli among flight phobic participants. The authors therefore concluded that phylogenetically fear is associated with deeper and/or more biased processing of the fear-relevant stimuli.

Summary

Motivational models maintain that affective states are organised along a simple biphasic structure based on the dimensions of hedonic valence and arousal identified by early factor analytic studies. The main advantage of the motivational model of attention and affective states that has lead to the increasing popularity of motivational interpretations of affective responses is that affective responses are organised along the dimensions of valence and arousal and are tied to the underlying appetitive and aversive systems, common to all animal species. The development of a picture set (IAPS) that allows for the systematic manipulation of the valence and arousal dimensions means that valid investigations can be made regarding the approach and avoidant tendencies of human participants that were not possible with measures such as self-reported affective states which dominated the early factor-analytic models. Whereas it cannot be denied that accurate responses to both appetitive and aversive cues are fundamental to species

survival, the negativity bias specified by the evaluative space model, indicates that the aversive or fear-defense system is more pivotal to survival. There is mixed evidence as to the best fitting model of affective states and disentangling the lines of evidence in favour of the motivational model or negativity bias forms the foundation of the current thesis.

CHAPTER 3: PHYSIOLOGY AND NEUROPHYSIOLOGY OF EMOTION

Hemispheric Lateralisation of Approach and Withdrawal

A number of theories have been proposed concerning the hemispheric lateralisation of affect. The right hemisphere model dominated the interpretation of early lateralisation research, proposing that the right hemisphere is specialised for the perception and experience of emotion independent of hedonic of valence (for a review, see Demaree, Everhart, Youngstrom, & Harrison, 2005). Much of the research underpinning the right hemisphere model involved the perception of facial affect and affective prosody, with the general finding that damage to the right hemisphere was associated with poor ability to recognise facial and tonal expressions of affect. Although the right hemisphere model has taken a backseat to more recent motivational models of hemispheric lateralisation, the model is far from redundant with recent electroencephalographic (EEG) research providing data consistent with the right hemisphere model (see for example, Hagermann, Hewig, Naumann, Seifert, & Bartussek, 2005).

The valence hypothesis proposes that the perception and experience of emotion is differentially lateralised within the left and right cerebral hemispheres, with pleasant emotions lateralised towards the left hemisphere and unpleasant emotions lateralised toward the right hemisphere (for a review see Damaree et al., 2005). Viewing happy videos has been associated with greater left hemispheric activation compared to viewing sad and disgust videos which evoke greater right hemispheric activation (Jones & Fox, 1992). Similar results have been obtained with still images, with larger event-related synchronisation (ERS) in the theta band over the right hemisphere in response to unpleasant images compared to pleasant and neutral images, and larger ERS in response

to pleasant images over the left hemisphere (Aftanas, Varlamov, Pavlov, Makhnev, & Reva, 2001). Canli, Desmond, Zhao, Glover, and Gabrieli (1998) also showed that when participants' experience of valence is equated for level of arousal, overall brain activity is lateralised toward the left hemisphere in response to pleasant images and toward the right hemisphere in response to unpleasant images.

A variant of the valence hypothesis that has become quite influential in the study of emotional processing and emotional disorders is the approach-withdrawal model (for a review see Damaree et al., 2005). This model developed by Davidson and colleagues (Davidson et al., 1990; Davidson, 1992; 1993 a, b) can be seen as extending Lang and colleagues' (Bradley & Lang, 2000; Hamm et al., 2003; Lang, 1995; Lang et al., 1990; Lang et al., 1997) model of motivated attention and affective states, by proposing that the approach and withdrawal systems are lateralised within the left and right hemispheres and maintaining that the direction of the affective response is determined by the valence dimension and the strength of the response is modulated by the arousal dimension. Davidson and colleagues' (Davidson et al., 1990; Davidson, 1992; 1993 a, b) approach-withdrawal model posits that approach related emotions (predominately appetitive, but may also include attack behaviours) are lateralised toward the left hemisphere whereas withdrawal related emotions (predominately aversive) are lateralised toward the right hemisphere. Unlike the valence hypothesis, the approach-withdrawal model proposes that lateralisation of affect occurs within the left and right frontal regions (Davidson et al., 1990). Research investigating emotional disorders such as depression have strengthened support for the approach-withdrawal model, with evidence suggesting that depressive symptomatology that is characterised by a lack of positive affect and approach related behaviours is associated with decreased left frontal activation (Henriques & Davidson, 1990; 1991).

The model of regional activation proposed by Heller (1990; 1991) integrates aspects of the right hemisphere and approach-withdrawal models, proposing that the frontal regions are involved with the mediation of emotional valence and the right parietal region is involved in the mediation of cortical and autonomic arousal associated with both pleasant and unpleasant states. Figure 3 illustrates the lateralisation of valence and arousal on the basis of different patterns of regional activation, and also displays an integrated system to account for the production of various emotions.

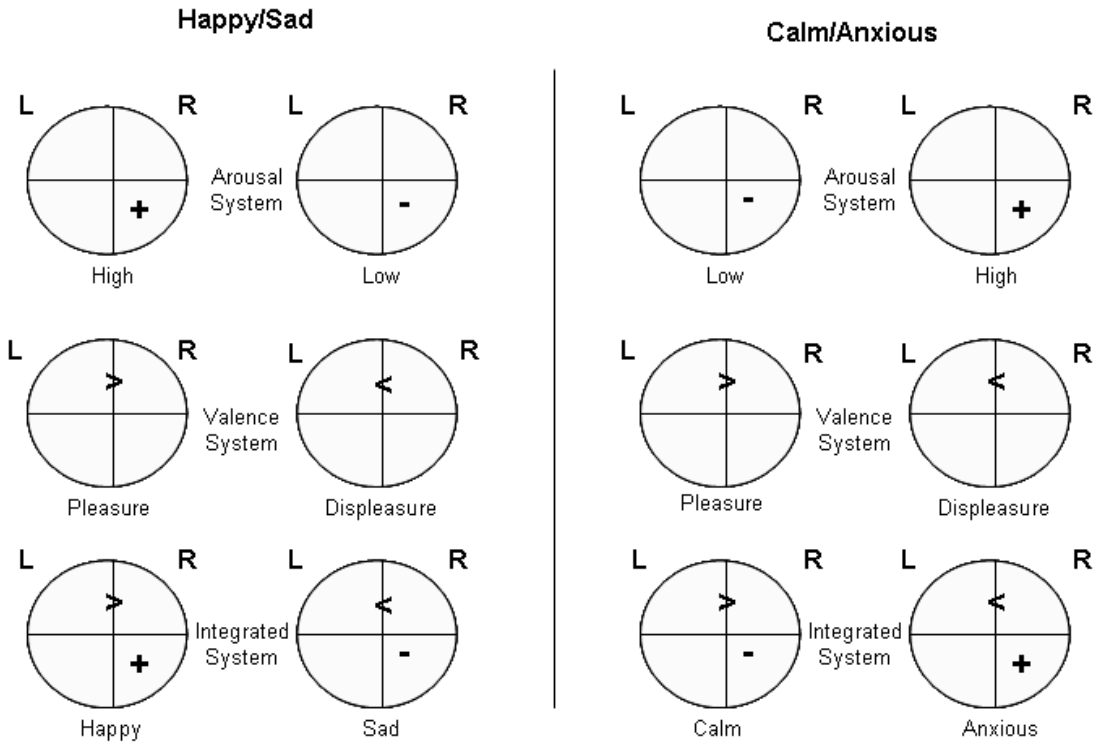


Figure 3. Heller's (1990) model of regional activation. (adapted from Heller, W. (1990). The neuropsychology of emotion: Developmental patterns and implications form psychopathology. In N. Stein, B. L. Leventhal & T. Trabasso (Eds.), *Psychological and Biological Approaches to Emotion* (pp. 167-211). Hillsdale. NJ: Erlbaum).

As can be seen in Figure 3, happy emotional states are associated with high activation in the right parietal and left frontal regions and sad emotional states are associated with high activation in the right frontal regions and low activation in the right parietal regions. Calm emotional states are associated with low activation in the right parietal regions in conjunction with increased activation in the left frontal regions, while anxious states are associated with increased activation in the right parietal and right frontal regions. Depressive states are also proposed to be associated with low frontal activation (for reviews see the diathesis-stress model: Davidson, 1993 a, b; Henriques & Davidson, 1990; 1991). The model therefore suggests a reciprocal relationship between the activation of the right parietal and frontal regions and can account for a wider range of affective phenomena than Davidson and colleague's (Davidson et al., 1990; Davidson, 1992; 1993 a, b) approach-withdrawal model.

Heller (1990; 1991) stresses that there are some methodological limitations that should be taken into consideration when interpreting the functional significance of the hemispheric lateralisation of frontal/parietal activation. She argues that tasks involving judgements about stimulus affect may involve more frontal regions than tasks that stress the importance of accuracy and performance; therefore asymmetries may be elicited by mood induction instructions rather than by the actual generation of mood states. The majority of research underpinning the aforementioned models has involved EEG frequency band measures and the presentation of long duration affective stimuli or video clips designed to evoke emotional states. Limited research has focused on the temporal nature of affective lateralisation, and those studies with a temporal focus have been limited by the choice of affective stimuli. Using ERP measures (a review of ERPs is presented in the subsequent sections), Kayser, Tenke, Nordby, Hammerborg, Hugdahl, and Erdmann (1997) presented neutral and unpleasant (dermatological illness) faces and

found the amplitude of the N2-P3 complex was enhanced in response to unpleasant images in the right hemisphere which was taken as support for the valence hypothesis. Further support for the valence hypothesis was derived by Simon-Thomas, Role, and Knight (2005) using a Stroop paradigm, whereby enhanced N2 component amplitudes were reported in response to Stroop trials presented to the left visual field (right hemisphere) that were preceded by unpleasant images compared to Stroop trials preceded by a neutral image and compared to right visual field presentations. As pleasant images were not presented in either of these ERP studies, support for the valence hypothesis or right hemisphere model using ERP measures has not been firmly established. The temporal nature of affective lateralisation therefore requires substantial experimental attention.

Sex Differences in Emotion

Males and females share the same survival risks, therefore it would be reasonable to assume that appetitive and aversive cues would activate the underlying motivational systems to the same degree for both sexes. Neuroimaging and electrophysiological studies have shown similar brain regions (e.g., Karama, Lecours, Leroux, Bourgoin, Beaudion, Joubert, & Beauregard, 2002; Kemp, Silberstein, Armstrong, & Nathan, 2004; Wrase, Klein, Grusser, Hermann, Flor, Braus, & Heinz, 2003) and physiological responses (Bradley, Codispoti, Sabatinelli, & Lang, 2001b) to be activated in males and females in response to pleasant and unpleasant stimuli, however these studies also showed differential responses to motivationally relevant stimuli as a function of sex, with the most consistent finding being that females are more defensively activated than males. Females have been shown to rate unpleasant stimuli as significantly more unpleasant and more arousing than males (Bradley et al.) and adolescent girls have been

shown to rate moderately arousing unpleasant stimuli as significantly more unpleasant than adolescent boys (McManis, Bradley, Berg, Cuthbert, & Lang, 2001). As mentioned previously, Bradley et al. (2001a) conducted a systematic investigation of the behavioural and physiological responses to specific picture contents, which was followed by a subsequent study of the sex differences in physiological and behavioural responses to specific picture contents (Bradley et al., 2001b). Females were deemed to be more defensively activated than males, demonstrating larger changes in corrugator EMG activity, greater fear bradycardia (sustained cardiac deceleration in the context of aversive stimuli), and rated unpleasant stimuli as significantly more arousing and more unpleasant compared to males. SCR is assumed to provide a measure of arousal (Bradley et al., 1990; Bradley et al., 2001a; Lang et al., 1992; 1995; 1997) and SCR responses were larger in response to images of mutilation and human/animal attack for both males and females in Bradley et al.'s (2001b) study, however females exhibited larger SCR changes in response to unpleasant compared to pleasant and neutral stimuli, while males exhibited similar responses for both pleasant and unpleasant stimuli. Hillman, Rosegren, and Smith (2003) found that postural movements in response to aversive stimuli also show differentiation as a function of sex, with females exhibiting greater postural movements away from unpleasant images compared to males who demonstrated only modest postural movements.

The startle reflex does not appear to be differentially modulated by sex, with both Bradley et al. (2001b) and Hillman et al. (2003) failing to show any sex differences in the startle reflex during appetitive or aversive contexts. The data pertaining to sex differences in regional brain activation appears to vary depending on the experimental procedure (e.g., mood induction versus emotional perception). Imaging studies that involved the presentation of symbolic picture stimuli demonstrated increased activation

in the visual cortical areas (see Bradley et al., 2003; Lane et al., 1999; Lang et al., 1998) in response to emotional (pleasant and unpleasant) compared to neutral stimuli, and Lang et al. (1998) showed evidence of increased defensive activation for females, with greater activation in the right hemisphere in response to unpleasant stimuli compared to males. Mood induction studies have shown greater activation (total number of voxels) in females compared to males during transient sadness and the activation of different brain regions during transient happiness and sadness as a function of sex (George, Terence, Ketter, Parekh, Herscovitch, & Post, 1996). However, in another mood induction study amygdala activation was associated with the subjective experience of sadness in males with no such response shown for females (Schieder, Habel, Kessler, Salloum, & Posse, 2000). The data from neuroimaging studies is therefore inconsistent with no robust evidence of increased defensive activation for females.

In contrast to neurophysiological studies, the shape of affective space as defined by behavioural ratings of valence and arousal does differ as a function of sex. As mentioned previously, motivational vectors can be inferred by the strength of the correlation between ratings of valence and arousal for individual pictures; and these motivational vectors reflect the degree to which stimuli engage the brain's underlying motivational systems (Bradley et al., 2001a). Correlations are performed on ratings of valence and arousal for pleasant and unpleasant picture stimuli separately in order to investigate the degree to which pleasant and unpleasant stimuli engage the brain's underlying appetitive and aversive systems. The shape of affective space as defined by Lang and colleagues, and discussed by Bradley et al.(2001a) takes the form of a boomerang, with two arms extending from a neutral centre to high arousing pleasant and unpleasant quadrants. For both pleasant and unpleasant stimuli, there is a strong linear relationship between ratings of valence and arousal, such that, pictures that are rated as

increasingly more pleasant or unpleasant are also rated as increasingly more arousing. The strength of the correlation between ratings of valence and arousal for individual pictures, or motivational vectors were shown to differ between males and females (Bradley et al., 2001b). Females showed a steeper and more linear motivational vector for aversive activation, demonstrated by a stronger positive correlation between ratings of unpleasantness and arousal compared to males. Males conversely showed a steeper and more linear appetitive vector, demonstrated by a stronger positive correlation between ratings of pleasantness and arousal compared to females (Bradley et al., 2001b). It has therefore been argued that males demonstrate greater appetitive activation than females in response to pleasant stimuli. Research by Bradley et al. (2001b), however suggest that this activation is specific to erotic stimuli. Males rated erotic material (both opposite sex nudes and erotic couples) as significantly more pleasant and arousing, and responded with significantly larger SCR changes while viewing erotic material than did females (Bradley et al.). These differential responses may result from different appraisal patterns for erotic material demonstrated by males and females. Both males and females reported feeling sexy and romantic while viewing erotic couples, however males reported feeling sexy and excited while viewing opposite sex erotica, and females reported feeling amused and embarrassed by opposite sex erotica and demonstrated more variability among endorsed feelings than males (Bradley et al.). Karama et al. (2002) investigated the neural correlates of sexual arousal in males and females and found that although erotic film excerpts evoked significant activation in a range of common cortical areas for males and females, males demonstrated significantly greater activation in the thalamus and hypothalamus than females in response to the erotic film. The hypothalamus is known to play a key role in the physiological arousal underlying sexual behaviours, and the magnitude of the hypothalamic response positively correlated

with reports of perceived sexual arousal in males only (Karama et al.), providing neurophysiological evidence that males are more appetitively activated than females.

Although males and females do show similar neurophysiological and physiological responses to motivationally relevant stimuli, there are important differences between the sexes regarding affective responses. The key differences that must be taken into consideration when conducting research into affective processing are that females appear to be more defensively activated than males, and males conversely appear more appetitively activated. A comprehensive study of the sex differences in appetitive and aversive activation has been conducted using physiological dependent measures (SCR, heart rate, startle reflex, EMG; see Bradley et al., 2001b); however sex differences in electrophysiological responses have received substantially less empirical attention.

Event-Related Potentials (ERPs)

ERPs provide valuable markers of a number of cognitive processes. In terms of elucidating the cognitive processing of affective pictures in the context of the current thesis, the utility of ERP measures is great. ERPs are the voltage fluctuations that are time locked to the presence of a definable event, be it internal or external to the subject. ERPs are extracted from ongoing EEG activity through processes of filtering and averaging and have excellent temporal resolution in the order of milliseconds (Empson, 1986; Fabiani, Gratton, & Coles, 2000; Picton, Bentin, Donchin, Hillyard, Johnson Jr et al., 2000). The ERP waveform is comprised of a series of components that are defined in terms of their latency and polarity, and their tendency to covary in response to experimental manipulations (Fabiani et al., 2000; Friedman, Cycowicz, & Gaeta, 2001). The ERP reflects the synchronistic activation of a large population of neurons from both cortical and subcortical regions, however multiple neural generators may be involved in

such activation, thus the spatial resolution of ERPs is quite poor (Fabiani et al., 2000; Friedman et al., 2001). Distortion of electric fields caused by the skull leads to further difficulties identifying the source of an ERP component without the use of dense electrode arrays and dipole analysis, or sophisticated imaging technologies such as fMRI or PET (Fabiani et al., 2000). The components of the ERP waveform are differentially affected by the physical properties of the eliciting stimulus and the psychological processes invoked by the stimulus.

According to Empson (1986), ERPs averaged from the first 80ms of the EEG response are controlled by the physical properties of the stimulus and are therefore modality specific. Components that are modulated by the physical properties of the stimulus and are obligatory are referred to as sensory or exogenous (Empson; Fabiani et al., 2000; Picton et al., 2000). Components referred to as endogenous reflect the activity associated with information processing operations such as stimulus evaluation (Empson; Fabiani et al.; Picton et al.). There are some ERP components evoked between 100 and 300ms post-stimulus onset that are sensitive to both the physical and psychological properties of the eliciting stimulus and these components are referred to as mesogenous (Fabiani et al.). For the purpose of the current thesis, the mesogenous components will be referred to as the early positive or early negative components.

P1 and N1Components

The series of components reflected in the ERP waveform differs depending on whether testing occurs in the visual or auditory modality. In the auditory modality, modulation of positive components as early as 50ms post-stimulus onset are reliably demonstrated (Crowley & Colrain, 2004), however as noted by Empson (1986), the first identifiable peak for visual evoked potentials (VEPs) occurs around 100ms, identified as

the P1 component. The P1 is a positive component that can peak as early as 70-80ms post-stimulus onset and typically manifests at occipital regions (Clark & Hillyard, 1996; Mangun & Hillyard, 1991; Hillyard, Luck, & Mangun, 1994; Hopfinger & Mangun, 1998; Müller & Rabbitt, 1989). This component is thought to represent the earliest stage of visual processing that is modulated by voluntary shifts of attention and the occipital maximum is consistent with a neural generator in the visual cortex (Mangun & Hillyard). As noted, exogenous components are sensitive to the physical features of the stimulus. Since the P1 component is sensitive to the direction of attention as well as the physical features of the stimulus, the P1 component is considered mesogenous and is assumed to reflect the stage of visual processing that precedes complete perceptual analysis (Müller & Rabbitt). While the P1 component is typically assumed to reflect processes associated with visual spatial attention, modulation of the P1 component is not based exclusively on spatial attentional factors. Taylor (2002) for example found enhanced P1 amplitudes in response to images of upright faces compared to inverted faces and natural scenes containing animals compared to natural scenes not containing animals. These results were taken as evidence that P1 amplitude is sensitive to stimulus saliency.

During visual tasks the P1 component is typically followed by a negative peaking component known as N1, and the amplitude of this component is also modulated by stimuli appearing at attended locations. The N1 component is however functionally distinct from the earlier P1 component as the N1 component is evoked when detailed perceptual analysis is required and is not evoked during simple RT tasks (Mangun & Hillyard 1991; Muller & Rabbitt, 1989). It has also been proposed that the P1 component provides an index of object discrimination while N1 provides an index of the encoding of visual spatial information (Clark & Hillyard, 1996; Mangun, 1995).

P2 Component

Research as to the functional significance of the P2 component is scarce, and the research that has been conducted has been almost exclusively within the auditory domain. The P2 component evoked during auditory paradigms is seen as functionally associated with the N1 component, referred to as the N1-P2 complex or vertex potential given the maximal amplitudes at central midline sites or the vertex (Crowley & Colrain, 2004). The P2 component peaks between 150 and 250ms during auditory paradigms, and while the latency and topography of the P2 components are similar within the auditory, visual, and somatosensory domains (for review see Crowley & Colrain), it is unclear whether a unitary neural generator underlies the P2 component and whether the functional significance of the P2 component is the same across stimulus modalities. The research underpinning the current thesis is conducted within the visual modality, and although little is known about the P2 component evoked within the visual domain, previous research has suggested that the component is sensitive to stimulus qualities related to feature detection and encoding (Dunn, Dunn, & Andrews, 1998). The P2 component is also proposed to provide an index of recognition potential or the electrical response of the brain occurring when a recognisable image is encountered (Rudell & Hua, 1995).

García-Larrea, Lukaszewicz, and Maugiére (1992) examined ERP responses to non-targets during an auditory oddball task where either a cognitive response (active and passive) or no response was required. A positive component peaking approximately 250ms (P250) post-stimulus onset, with a central maximum was evoked in response to non-targets only when a cognitive response was required. The authors concluded that P250 reflects the process of stimulus classification or target identification that must occur before the later endogenous components can be evoked. They also concluded that

the P250 component is a genuine mesogenous component that is not exclusively modulated in response to the physical qualities of the eliciting stimulus.

N2 Component

The N2 component has also been extensively studied within the auditory domain, with research suggesting that the early negativity between 100 and 300ms post-stimulus onset reflects processes of selective attention, elementary feature analysis, and auditory sensory memory (Fabiani et al., 2000). The topography of the N2 component differs depending of whether it is evoked within the auditory or visual domain, with an occipital maximum for the N2 component evoked within the visual modality and a central or frontal maximum for the N2 component evoked within the auditory modality (Fabiani et al.). However, when the experimental task involves aspects of both visual and auditory modalities, an N2 component with a central maximum is evoked (Gehring, Gratton, Coles, & Donchin, 1992). The topography of the N2 component also varies as a function of task type, with an N2 component evoked at both frontal and parietal regions during some go-nogo tasks (e.g., Lavric, Pizzagalli, & Forstmeier, 2004), and a fronto-central N2 component evoked during flanker or noise-compatibility tasks (e.g., Seifert, Naumann, Hewig, Hagemann, & Bartussek, 2006).

The N2 component is considered one ERP marker of stimulus identification for visually presented stimuli (Dien, Spencer, & Donchin, 2004), and the amplitude of the N2 component is enhanced in response to violations of expectancy arising from the presentation of low probability stimuli (Decon, Breton, Ritter, & Vaughan, 1991; Gehring et al., 1992). N2 amplitudes are enhanced in response to expectancy violations independent of stimulus factors such as spatial location and N2 amplitude also increases with the magnitude of the mismatch between the presented stimuli and expected target

(Gehring et al.). The N2 component is also sensitive to expectancy violation within the auditory domain, and has been associated with the miss match negativity (MMN) component (for reviews see Fabiani et al., 2000; Näätäen, Alho, & Schröger, 2002). The N2 component has also been proposed to reflect inhibition and conflict monitoring processes, typically studied in the context of go-nogo paradigms (Lavric et al., 2004).

Late Positive Complex (LPC)

For tasks that require decision making, target detection, deviance detection, stimulus evaluation, and other cognitive processes, a sustained positivity is typically evoked between 300 and 600ms post-stimulus onset. This ERP component has been defined as the late positive complex (LPC) however the functional significance of this component can not be unequivocally stated, as the LPC is comprised of a series of subcomponents that respond differently depending on the experimental manipulation. The subcomponents of the LPC have been identified as: P3a, novelty P3, no-go P3, P3b, and Positive Slow Wave (PSW) (Goldstien, Spencer, & Donchin, 2002; Rushby, Barry, & Doherty, 2005).

There is a lack of consensus in the literature as to whether the novelty P3 and P3a are distinct components and as such, P3a and novelty P3 are often referred to as one and the same (for the purpose of the current thesis, novelty P3 and P3a will be collectively referred to as novelty P3). Much of the research surrounding the novelty P3 component has been conducted within the auditory domain, however as components occurring after 300ms post-stimulus onset are considered endogenous, are sensitive to psychological variables, and are not modality specific, ERP data from the auditory domain is assumed to be applicable to the visual domain. Low probability, deviant stimuli elicit an orienting response, and the novelty P3 component is assumed to reflect

the evaluative aspects of novelty processing associated with the orienting response (Bledowski, Prvulovic, Goebel, Zanella, & Linden, 2004; Friedman et al., 2001; Goldstien, et al., 2002).

The novelty P3 component is frequently investigated in the context of an oddball paradigm, where infrequent target and distracter stimuli are presented within a train of frequent non-target stimuli. Both target and distracter stimuli occur with low probability, and Bledowski et al. (2002) established that although greater cerebral activity was associated with the processing of targets compared to distracters (evidence of target identification and preparation for a motor response), both target and distracter detection were associated with ventrolateral frontoparietal engagement, indicating that a common neural network is involved in both target and distracter detection. The topography of the novelty P3 component is typically restricted to frontal and fronto-central sites (Courchesne, Hillyard, & Galambos, 1975; Friedman et al., 2001) however there is evidence of a distributed network involved in the processing of novelty. Novel stimuli or distracters have been shown to evoke both a frontal and parietal P3 component in the same latency range, and the different topographies of the novelty P3 components are assumed to reflect different cognitive functions (Friedman et al., 2001; Katayama & Polich, 1998). As will be discussed below, P3b typically demonstrates a parietal maximum and is sensitive to psychological variables associated with information processing and memory. The novelty P3 elicited at parietal sites is also assumed to be sensitive to psychological variables such as task relevant information (Gaeta, Friedman, & Hunt, 2003) and although it is evoked earlier than P3b, novelty P3 evoked at parietal sites is assumed to reflect similar processes as P3b (Friedman et al.).

The novelty P3 manifested at anterior and frontal sites is sensitive to the physical characteristics of the stimulus (Gaeta et al., 2003) and has also been argued to reflect

inhibitory processes associated with task irrelevant, deviant stimuli (Goldstien et al., 2002). The novelty P3 component however is not taken simply to reflect a response to the physical complexity of the stimuli, as Courchesne et al. (1975) demonstrated that the novelty P3 evoked at frontal sites was dependent upon the recognisability of the distracter stimuli. Unrecognisable images (colourful abstract drawings) evoked a novelty P3 at frontal sites, while easily recognisable images (geometric shapes) evoked a posterior novelty P3 component (Courchesne et al.). The P3 component evoked in response to infrequent and easily recognisable non target stimuli has also been referred to as the no-go P3 (Comerchero & Polich, 1999). Similar to P3b, the novelty P3 component is also affected by task difficulty, with a linear relationship between task difficulty and novelty P3 amplitude observed over frontal/central sites (Comerchero & Polich; Polich & Comerchero, 2003).

The P3b (or P3) component was first identified in 1965 by Sutton, Braren, Zubin, and John. They found a sustained positivity peaking approximately 300ms post-stimulus onset that was enhanced in response to expectancy violations and low probability stimuli. In the decades since its identification, the P3b component has been recognised as a marker of a range of cognitive processes, and is typically evoked between 275 and 425ms post-stimulus onset, with maximal amplitudes at centro-parietal and parietal midline sites, intermediate amplitudes at the central midline, and minimal amplitudes at frontal midline sites (Picton, 1992; Pritchard, Brandt, & Barratt, 1986; Verleger, 1988) depending on the experimental manipulation. The latency of the P3b component has been taken to reflect stimulus evaluation time, and the dissociation between P3b latency and RT suggests that stimulus evaluation time is relatively independent of response selection and execution stages (Kutas, McCarthy, & Donchin, 1977). The amplitude of the P3b component has been proposed to reflect the allocation of perceptual and central

resources from a limited capacity pool (Kok, 1997; 2001), and is sensitive to probability and task relevant information (Donchin, 1981; Pritchard, 1981).

An inverse relationship between P3b amplitude and subjective probability has been widely established. Probability information is determined subjectively by the participant's expectancy as to event frequency and is therefore not directly determined by prior presentation of the stimulus (Donchin, 1981; Pritchard, 1981). P3b amplitude is enhanced in response to stimuli that are task relevant whether as a result of experimental instructions or personal relevance (Donchin; Pritchard). Stimulus probability and task relevance also interact; as Kok (2001) notes, the effects of stimulus probability on P3b amplitude are not observed when subjects actively ignore target stimuli. The triarchic model proposed by Johnson Jr (1986) recognises that subjective probability and task relevance are important conditions for P3b modulation and the model reduces the various constructs responsible for P3b elicitation into three dimensions of subjective probability, stimulus meaning, and information transmission, or the actual proportion of information that is transmitted by the stimulus accounting for information loss (for further reviews of the triarchic model see Johnson Jr, 1993).

P3b amplitude has also been identified as a marker for memory modification and learning processes as outlined in Donchin's (1981) context updating model. The model proposes that schemas representing all the available information about the environment are stored in long term memory and require updating when a novel stimulus is presented, and the process of updating is manifested by P3b amplitude. This is consistent with the inverse relationship between subjective probability and P3b amplitude as improbable events require integration into environmental schemata for accurate representations (Donchin & Coles, 1988). Verleger (1988) proposed an alternative to the context updating model and argued that P3b amplitude represents the excess activation that is

released from parietal areas once perceptual processes have been concluded and contexts have been closed. There is however much debate as to the viability of the context closure model (for review see Donchin & Coles).

As mentioned previously, P3b amplitude is proposed to reflect the allocation of perceptual and central resources from a hypothetical, limited capacity pool when evaluating the task relevance or significance of stimuli and events (Kok, 2001). Evidence for a limited capacity pool has been provided by dual-task studies that show performance improvements on a primary task to be associated with performance decrements on the secondary task, indicating that the two tasks tap into the same limited capacity pool (for a review of P3b and dual-task methodologies see Kok, 1997; 2001). Reductions in P3b amplitude for the secondary task indicate that greater effort or attentional resources were required to complete the primary task. Manipulation of task difficulty and priority have also been cited as evidence for a limited capacity pool, as increasing the effort required to perform a difficult task compared to an easy task results in P3b reductions and P3b reductions are associated with decreasing task priority (see Kok, 1997; 2001 for a review of the factors that determine capacity demands and the subsequent effects on P3b amplitude).

P3b amplitude has therefore been associated with a range of cognitive operations and is sensitive to task requirements. Evidence however suggests that P3b amplitude is also affected by a range of environmental and biological variables that are involved in fluctuations of arousal state. Polich and Kok (1995) reviewed a range of studies outlining the effect of arousal states on P3b amplitude, suggesting that P3b amplitude is reliably modulated by changes in circadian rhythms, ultradian rhythms, recency of food intake, seasonal variations, menstrual cycle, frequency of exercise, sleep deprivation, and common drugs such as caffeine, nicotine, and alcohol. Monitoring for such variables

is therefore particularly important for studies that involve P3b amplitude as a dependent measure.

The subcomponent of the LPC referred to as positive slow wave (PSW) reflects a broadly distributed positivity, typically peaking between 400 and 700ms post-stimulus onset (Pritchard et al., 1986). Like the P3b component, PSW activity is maximal at the parietal midline site and is reduced at the central midline site, however unlike the P3b component, negativity is demonstrated at frontal sites (Birbaumer, Elbert, Canavan, & Rockstroh, 1990; Pritchard et al.). The onset and topography of the PSW component often overlaps that of the P3b component, therefore it is not surprising that these two components respond in a similar fashion to certain experimental manipulations. PSW activity is evoked when perceptual demands are high and therefore PSW is assumed to provide an index of further processing that is beyond the capacity reflected by the P3b component. The nature of the PSW component and the conditions under which it is reliably evoked have not been firmly established (Dien et al., 2004), however PSW has been taken to reflect processes involved in memory (Rösler & Heil, 1991), learning, and perceptual operations (Ruchkin, Johnson, Mahaffey, & Sutton, 1988).

ERPs as a Measure of Affective Picture Processing

ERP measures have been widely implemented in the study of affective picture processing, with highly discrepant results reported between studies utilising different methodologies. Sustained picture viewing paradigms have been frequently employed in affective picture processing research and involve the random presentation of equal probability affective stimuli for durations of several seconds, and often involve long inter trial intervals (ITIs) (see Cuthbert et al., 2000; Keil et al., 2002; Loew et al., 2003; Palomba et al., 1997; Schupp et al., 1997). Such paradigms reliably elicit large late

positive shifts in the ERP waveform in response to affective stimuli, beginning as early as 200ms, which can be sustained for the entire picture viewing period (e.g., Cuthbert et al., 2000). Larger ERP amplitudes evoked in response to pleasant and unpleasant stimuli compared to neutral stimuli have been frequently shown for the positive ERP components peaking between 300 and 500ms (e.g., Keil et al., 2002; Loew et al., 2003; Meinhardt & Pekrun, 2003; Mini et al., 1996; Schupp et al., 2000; Schupp et al., 2003a) and PSW activity between 600 and 1000 ms (e.g., Amrhein et al., 2004; Cuthbert et al. 2000; Diedrich et al., 1997; Johnston et al., 1986; Keil et al., 2002; Palomba et al., 1997). Larger P3b amplitudes [also referred to as the late positive potential (LPP: Ito et al., 1998b) in the emotional ERP literature] evoked in response to both pleasant and unpleasant stimuli compared to neutral are assumed to reflect the processing of arousal information, as LPP amplitude has been shown to co-vary with rated arousal (Cuthbert et al.) and amplitudes are enhanced in response to highly arousing pleasant and unpleasant stimuli compared to respective low arousing stimuli (Cuthbert et al.; Schupp et al., 2000). A negative component identified at temporo-occipital sites between 280 and 320ms defined as early posterior negativity (EPN) also shows enhancements in response to pleasant and unpleasant stimuli compared to neutral stimuli, with the largest enhancement in response to the most highly arousing contents (Schupp et al., 2003a; 2003b; 2004b). Larger LPP and EPN amplitudes for highly arousing pleasant and unpleasant stimuli have also been interpreted as indexing greater attentional engagement with motivationally relevant appetitive and aversive cues (Lang et al., 1997; Schupp et al., 1997; 2000; 2003b; 2004a), as highly arousing picture categories typically depict images of mutilation, human/animal threat and erotica that have important relevance for survival. The effect that motivationally relevant information has on the process of attentional resource allocation has been investigated using startle probe (Schupp et al.,

1997) and dual task methodology (Meinhardt & Pekrun, 2003). Reduced P3b amplitude in response to startle probes (Schupp et al., 1997) and target tones (Meindhardt & Pekrun) presented in the context of unpleasant and pleasant pictures compared to neutral pictures was argued to reflect greater attentional engagement with motivationally relevant cues; as a reduction in P3b amplitude indicates that fewer resources were available for the processing of target tones and startle probes. The effect of motivational factors on ERP measures have been investigated within the context of drug dependence where drug associated cues are assumed to evoke strong activation of the approach system. Van de Larr, Licht, Franken, and Hendriks (2004) established that significant electrophysiological differences exist between people with a drug dependency and controls, with enhanced N300, late positive slow wave (200-1220ms), and sustained positive slow wave (2000-4000ms) amplitudes shown in response to cocaine cues compared to neutral cues for the cocaine dependent group only. This evidence adds support to the theory that the endogenous ERP components are sensitive to motivationally relevant stimuli rather than simply providing an index of affective arousal.

The slow cortical potentials are assumed to be sensitive to arousal and/or motivationally relevant information, however there is a body of literature to suggest that both early (P1: Carretié et al., 2004; Smith et al., 2003; P2; Carretié et al., 2001a; Delplanque et al., 2004) and late endogenous (P3a: Delplanque et al., 2006; P3b; Delplanque et al., 2005; Ito et al., 1998a) ERP activity are also more pronounced for unpleasant stimuli than pleasant and neutral stimuli which has been interpreted as a negativity bias. Among other discrepancies, enhanced P3b amplitudes have been shown in response to pleasant compared to unpleasant and neutral stimuli (Amrhein et al., 2004; Cuthbert et al., 2000; Diedrich et al., 1997) and the early endogenous ERP

components (e.g., P1, P2, N2) have not shown reliable modulations as a function of unpleasant valence (e.g., Carretié, Martín-Loeches, Hinojosa, & Mercardo, 2001b; Delplanque et al., 2005; Delplanque et al., 2006; Schupp et al., 1997). Amplitude enhancements have also been demonstrated for the N260 component in response to increasing levels of arousal independent of hedonic valence (Junghöfer, Bradley, Elbert, & Lang, 2001), highlighting the importance of systematic control of arousal variables.

Affective picture processing has been explored using paradigms other than sustained picture viewing. For example, the modified oddball (e.g., Delplanque et al., 2004; Delplanque et al., 2005; Delplanque et al., 2006; Ito et al., 1998a; Smith et al., 2003), passive oddball (e.g., Carretié et al., 2004), and pattern correspondence tasks (e.g., Carretié, Iglesias, García, & Ballesteros,1996; Carretié et al., 2001) have all been used to explore affective picture processing. Affective ERP modulations have been less consistent in studies using modified oddball tasks than sustained picture viewing, however the modified oddball task affords control over 'classic' or paradigm-specific ERP effects, making it a useful tool in emotional ERP research. Subjective probability and task relevance are two factors known to affect the amplitude of the P3b component (Donchin, 1981; Donchin & Coles, 1988), and these factors can be controlled through the use of a modified oddball paradigm by presenting emotional target stimuli with equal probability, and requiring simple responses to all emotive stimuli to reduce the impact of task related ERP effects. According to Carretié, Iglesias, and García (1997), paradigms such as the modified oddball and pattern correspondence tasks, which involve the presentation of images where one half is inverted and is either congruent or incongruent with the other half of the image, are preferred in affective picture processing research as the objective of investigating emotional responses can be disguised and the impact of classic ERP effects minimised. This is particularly important given that emotional

stimuli are more salient than neutral, which may especially affect ERP component modulations during sustained picture viewing. The importance of controlling for task relevant ERP effects was highlighted by Carretié et al. (1996; 1997) who showed that when the explicit affective nature of a task was disguised, no modulation of the P3b component was observed.

As mentioned previously, although the startle reflex and other physiological measures (e.g., SCR, heart rate, facial muscle activity, startle reflex) respond to overall valence more reliably than specific picture contents, these measures have shown consistent variations as a function of picture content (see Bradley et al., 2001a). A substantial number of studies investigating ERP responses to affective pictures have intermixed semantic pictures categories and/or arousal level (e.g., Amehein et al., 2004; Cuthbert et al., 2000; Delplanque et al., 2005; 2006; Keil et al., 2002; Mini et al., 1996; Palomba et al., 1997; Schupp et al., 2000; 2003b), or have used a very limited range of semantic pictures that also may not be adequately matched for arousal level (e.g., Carretié et al., 1996; 1997; 2001b; 2003; 2004; Ito et al., 1998a). It is therefore proposed that if ERP responses vary as a function of specific picture content in a manner similar to the startle reflex and a number of other physiological measures, the common practice of intermixing semantic contents in affective ERP studies presents a serious confound.

A study by Schupp et al. (2004a) showed that LPP and probe P3b amplitudes are modulated in response to specific picture contents. Pictures of erotic couples and opposite sex nudes evoked significantly larger positivity in the 400-700ms and 700-1000ms intervals compared to pictures of sport, and component amplitudes in both intervals were comparable in response to erotica (erotic couples and opposite sex nudes) and romantic couples. Similar results were shown for unpleasant images, with enhanced positivity in both time windows in response to mutilation and human/animal threat

compared to images of contamination and loss, and the largest amplitudes in response to the highly motivationally relevant images of mutilation. The probe P3b amplitude in Schupp et al.'s (2004a) study was significantly smaller in response to erotic stimuli compared to sporting images, suggesting greater attentional requirements for the processing of these stimuli. Unpleasant stimuli on the other hand required equal attentional resources for processing, evidenced by a general inhibition of probe P3b for all unpleasant picture contents. Schupp et al. (2004b) also reported significantly larger LPP and EPN amplitudes in response to erotic images compared to pleasant images of babies and families, and enhanced LPP and EPN amplitudes in response to mutilation compared to threatening images. The results of these studies indicate that LPP (P3b and PSW) and EPN amplitudes vary in a meaningful fashion in response to specific picture contents, and add support for the model of motivated attention and affective states (Bradley & Lang, 2000; Hamm et al., 2003; Lang, 1995; Lang et al., 1990; Lang et al., 1997), whereby attention is more deeply engaged more by motivationally relevant appetitive and aversive cues.

ERPs, Facial Recognition, and Emotion

The processes underlying facial recognition are separable from the processes involved in other forms of object recognition and this has been demonstrated by ERP responses to facial and non-facial stimuli. The N170 is a negative component peaking between 150 and 200ms post-stimulus onset, with an occipito-temporal maximum and is assumed to be modulated specifically by facial stimuli (Bousten, Humphreys, Praamstra, & Woods, 2006; Stekelenburg & de Gelder, 2004). The N170 component is thought to be face-specific as the amplitudes of this component are enhanced in response to face compared to non-face stimuli (Bousten et al.; Eimer, 2000) and object inversion impacts more

upon the ERP responses to face stimuli than non-face stimuli (Bousten et al.). Inversion disrupts the global configuration of stimulus features and as ERP responses, specifically the N170, are sensitive to inverted faces more so than inverted objects, Bousten et al. argue that face perception is based on global configuration features. Bousten et al. investigated the local and global configuration effects on face and object recognition during an oddball task. Local configuration was manipulated though the Thatcher illusion (Thompson, 1980), where the eyes and mouth of a face are inverted relative to the rest of the face so when viewed upside down the face looks relatively normal, however when viewed upright the face looks extremely abnormal. Global configuration was manipulated by presenting both Thatcherized and normal faces upside down and the same manipulations were performed for house stimuli. Thatcherization in upright faces distorts the local configuration by changing the relation between local features while preserving the global configuration (Bousten et al.). Bousten et al. reported increases in N170 latency and reductions in amplitudes in response to Thatcherized faces and enhanced latency effects for upright compared to inverted Thatcherized faces. The reduction in N170 amplitude in response to the Thatcherized faces was interpreted as reflecting the reduced availability of configural information and the latency effects for upright and inverted Thatcherized images indicates that face perception is based on both global and local features.

The N170 component remains unaffected by non-perceptual features such as familiarity (Eimer, 2000), and emotional expression (Holmes, Vuilleumier, & Eimer, 2003), and is suppressed when facial recognition is disrupted by high and low spatial filters (Pourtois, Dan, Grandjean, Sander, & Vuilleumier, 2005). The N170 component is therefore assumed to reflect the early structural encoding of faces prior to higher order cognitive evaluations. The longer latency ERP components are sensitive to non-

perceptual features of facial stimuli such as stimulus familiarity (e.g., N400, P600: Eimer) and are assumed to reflect processes associated with recognition memory and communication of affect. Facial expressions are central non-verbal markers of an individual's emotional and motivational state, and are therefore effective at communicating approach and avoidance signals. Facilitated processing of fearful and threatening faces has been reflected in the longer latency ERP components (e.g., N400: Nelson & Nugent, 1990; EPN, LPP: Schupp, Öhman, Junghöfer, Weike, Stockburger, & Hamm, 2004c), which is somewhat consistent with the negativity bias shown for non-facial stimuli (e.g., Delplanque et al., 2005; 2006; Ito et al., 1998a). The amplitudes of the earlier ERP components have also shown modulations that are consistent with a negativity bias. Upright fearful faces evoked larger P120 and P250 amplitudes compared to neutral faces (Eimer & Holmes, 2002), and fearful faces elicited larger P1 amplitudes compared to neutral stimuli for normal unfiltered faces and for faces with a low spatial filter (Poutrois et al.). The same results were not shown for facial stimuli with a high spatial filter. Enhanced P1 amplitudes in response to fearful expressions were shown for the unfiltered and low spatial filter images, thus Poutrois et al. concluded that P1 modulation was specific to fearful expression and was not a result of differences in low level visual features. The fear defense system is activated by environmental stimuli that convey threat, and thus ERP evidence indicates that facial expressions signalling threat are also effective at activating the fear defense system.

Summary

Electrophysiological (EEG, ERP) studies have shed some light on the mechanisms involved in affective picture processing. The motivational model of affect that provided a neat fit with the physiological data outlined in Chapter 1 was also highly applicable to

the interpretation of the electrophysiological data, with some noted discrepancies. The underlying appetitive and aversive systems are argued to be differentially lateralised within the left and right frontal regions, with the right parietal region involved in modulating affective states via an arousal control mechanism. As noted, there is scarce ERP research focusing on the hemispheric lateralisation of affect, however a large body of ERP research without a topographical focus surrounds the processing of affective pictorial information. A number of studies have shown enhanced ERP amplitudes in response to both pleasant and unpleasant stimuli compared to neutral, and this quadratic effect is assumed to reflect the greater attentional engagement with arousing and/or motivationally relevant stimuli. Conflicting evidence comes from studies that have shown enhanced ERP component amplitudes in response to unpleasant stimuli compared to pleasant and neutral stimuli, which has been interpreted as reflecting a negativity bias. The vast majority of emotional ERP research has involved some form of confound such as intermixed semantic and arousal qualities within general pleasant and unpleasant categories, or the use of limited and/or unrepresentative images. It is difficult then to conclude which model, the motivational model (quadratic effect) or negativity bias, is the most definitive as each are applicable to the data that has been reported and studies supporting the quadratic effect and negativity bias are similarly flawed. ERP responses also vary with specific picture content, highlighting the problem associated with intermixing semantic categories and the need to vary not only valence and arousal but semantic content systematically.

Previous reports of sex differences in physiological and neurophysiological responses are somewhat inconclusive and relatively little research has focused on sex differences in electrophysiological responses. Females are assumed to be more defensively activated than males, while males are assumed to be more appetitively

activated than females, based on behavioural ratings of valence and arousal that show a stronger aversive vector for females and a stronger appetitive vector for males. The sex differences illustrated by imaging studies (fMRI, PET) are also far from conclusive and differences in methodology cannot be ruled out as contributing factors to the observed sex differences in response to affective stimuli. It therefore remains to be established whether the sex differences observed at a behavioural and physiological level hold true for electrophysiological responses, and thus whether males and females perceive and evaluate affective information differently.

CHAPTER 4: VISUAL ATTENTION AND EMOTION

Covert Visual Attention

In order to function in a complex environment, individuals must be proficient at responding to both predictable and unpredictable events. The ability to shift attention from one location to another is a crucial component of selective attention (Perchet & García-Larrea, 2000) and efficient shifts of attention are fundamental to information processing and thus functioning within a dynamic environment. Visual-spatial attention involves processes of attentional engagement and attentional disengagement (Posner, 1980; Posner & Petersen, 1990) and attentional focus can be shifted overtly via head and eye movements or purely covertly via a central mechanism (Posner). Covert shifts of attention have been widely investigated using trial-by-trial cueing paradigms developed by Posner and colleagues (Posner; Posner & Cohen, 1984), where target stimuli are presented either in the same location as a preceding cue or as directed by the preceding cue (valid) or in the opposite location (invalid).

Posner (1980) proposed two modes of control for covert visual orienting: exogenous (reflexive) and endogenous (central). These two modes of control have traditionally been investigated with two types of cueing paradigms referred to as central symbolic and peripheral. Central symbolic cueing involves the presentation of a centrally located arrow that accurately predicts the location of a subsequent target on a certain proportion of trials (Posner; Maylor, 1985). The type of orienting initiated by symbolic cueing is argued to be voluntary and controlled, as the informational value of central symbolic cues such as arrow heads must be decoded before attention can be oriented. Peripheral cueing paradigms involve the presentation of a non-informative cue in the periphery for example, a change in luminance (Posner; Maylor; Müller & Rabbitt,

1989). The type of orienting initiated by peripheral cueing is argued to be reflexive and automatic in comparison to the voluntary, controlled orienting initiated by central symbolic cues (Müller & Rabbitt). Non-informative spatial cues summon attention reflexively and attention is oriented in response to the sensory features of the stimuli in a bottom-up fashion, independent of top-down mechanisms (Hopfinger & Ries, 2005; Müller & Rabbitt). Peripheral cues are argued to trigger both a highly transitory automatic mechanism and a persistent controlled mechanism, whereas central symbolic cueing initiates a controlled mechanism only (Müller & Rabbitt). The mechanisms by which attention is oriented to spatial locations in peripheral and central symbolic cueing paradigms are argued to be partly or wholly separate (Mangun, 1995), however Müller and Rabbitt suggest that the information derived by these separate mechanisms feeds into the same orienting mechanism, which is particularly evident for voluntary shifts of attention initiated by both types of cueing.

In both peripheral and central symbolic cueing paradigms, benefits for RT and accuracy follow valid trials and costs follow invalid trials, known as the cue validity effect (Posner, 1980; Maylor, 1985; Mangun, 1995; Mangun & Hillyard, 1991; Eimer, 1994; 1996; Perchet & García-Larrea, 2000). The magnitude of the cue validity effect does however differ depending on whether attention is oriented reflexively or voluntarily. Peripheral cues elicit a more powerful facilitation effect at the cued location compared to central symbolic cues when the interval between the cue and target, or SOA is short (100-175ms: Müller & Rabbitt, 1989). The slow acting, controlled mechanism initiated by peripheral cues at long SOAs between 275-400ms allows for sustained facilitation although at a lower level compared to facilitation effects that occur at short SOAs (Müller & Rabbitt). Central symbolic cues however initiate this slower-acting mechanism only. The maximum facilitation achieved by peripheral cues at shorter

intervals (<400ms) is greater than that of central symbolic cues Müller & Rabbitt), therefore these authors concluded that the reflexive mechanism triggered by peripheral cues is more effective at facilitating the processing of subsequent targets than the voluntary mechanisms initiated by central symbolic cues. For SOAs greater than 400ms peripheral and central symbolic cues produced equal facilitation suggesting that both types of orienting involve the same voluntary mechanisms (Müller & Rabbitt). An inhibitory mechanism is however initiated at long SOAs during peripheral cueing that is not initiated during symbolic cueing (Mangun, 1995; McDonald, Ward, & Kiehl, 1999), strengthening the argument that the mechanisms underlying reflexive and voluntary attention are separable.

Facilitation and Inhibitory Effects of Reflexive Attention

Improved processing of validly cued targets during peripheral cueing is thought to result from focusing of attention (Müller & Rabbitt, 1989) and this facilitation occurs at short SOAs (<300ms see Collie, Maruff, Yucel, Currie, & Dankert, 2000; Hopfinger & Mangun, 1998; Maylor, 1985; Mangun, 1995; Posner, 1980; Posner, Cohen, & Rafal, 1982). Perceptual facilitation mechanisms are thought to improve the representations of sensory events by reducing the time required to discriminate sensory features and thus increasing the rate of stimulus registration by the brain (Mangun). During peripheral cueing, attention is firstly reflexively oriented to the cued location where facilitation occurs on valid trials if a target is presented shortly after. If the target does not appear after a short period attention is then reoriented to the fixation and an inhibitory mechanism is activated that inhibits covert attention and eye movements from orienting back to the previously cued location (Prime & Ward, 2006). Responses to validly cued targets at long SOAs are slowed due to this inhibitory mechanism first identified by

Posner and Cohen (1984) as inhibition of return (IOR). The functional significance of this inhibitory mechanism has been argued to maximse sampling of novel areas within the visual fields (Posner, 1988) however there is little consensus regarding the sensory/perceptual or motor mechanisms underlying this inhibitory component. There are two dominant accounts of IOR: one that IOR occurs as a result of a motor bias against responding to the previously scanned location; or that IOR arises from changes in attentional or pre-motor perceptual processes. The attention account of IOR holds that inhibitory mechanisms are activated that bias attention from being oriented to previously scanned locations relative to novel locations (Posner; Prime & Ward). Alternatively, the motor bias account suggests that individuals respond more slowly to valid cues because they must overcome location-specific motor inhibition which is generated by the cue (Prime & Ward). The two opposing accounts thus propose that the IOR effect may reflect attenuation of sensory-perceptual processing of targets appearing at the cued location or may simply result from delayed motor responses (McDonald, Ward, & Kiehl, 1999).

ERP measures can provide valuable information as to the operation of both facilitatory and inhibitory processes that occur during shifts of attention and thus may help to disentangle the opposing theories of IOR. As mentioned, voluntary shifts of attention affect electrophysiological activity as early as 70-80ms post-stimulus onset, manifesting as the occipital P1 component (Mangun & Hillyard, 1991; Hillyard et al., 1994; Hopfinger & Mangun, 1998; Müller & Rabbitt, 1989). P1 amplitudes are enhanced for stimuli presented at attended locations (Clark & Hillyard, 1996) and thus facilitation, reflected by enhanced P1 amplitudes, is shown for validly cued targets (see Hillyard et al., 1994; Hopfinger & Ries, 2005; Mangun, 1995; Mangun & Hillyard, 1991; Perchet & García-Larrea, 2000). This facilitation effect is dependent on the type

of cueing involved and at long SOAs during peripheral cueing, the reverse pattern occurs and P1 amplitudes are reduced in response to validly cued targets (McDonald et al., 1999; Prime & Ward, 2004; 2006; Wascher & Tipper, 2004). This effect could be interpreted as facilitation or benefits on invalid trials (e.g., Eimer, 1994), however P1 suppression for validly cued targets has been more frequently interpreted as a cost or inhibition on valid trials (McDonald et al.; Prime & Ward; Wascher & Tipper). P1 reduction in response to validly cued targets has often been accompanied by behavioural IOR effects (e.g., increased RT, reduced accuracy), suggesting that P1 suppression might reflect a perceptual mechanism involved in IOR (Prime & Ward, 2006; Wascher & Tipper). The mechanisms underlying the electrophysiological IOR effect (P1 suppression) have been investigated using ERP measures by researchers such as Prime and Ward (2006). These researchers investigated response-locked and target-locked lateralised readiness potentials (LRPs), a motor-related ERP, in order to elucidate whether overt or behavioural IOR effects arise from changes in pre-motor or motor processes. Response locked LRPs were virtually identical on valid and invalid trials, therefore a motor bias account of IOR was not supported as for such an account to be viable, LRPs would be expected to have an earlier onset on valid trials reflecting the longer time required to overcome the motor inhibition created by valid cueing (Prime & Ward, 2006). The overt expression of the IOR effect was argued to arise due to changes in perceptual processes reflecting the inhibition of attentional reorientation to the cued location. It can not however be unequivocally stated that an attentional bias against responding to the cued location is responsible for the behavioural IOR effect, as there are sensory interactions such as sensory summation and refractoriness which occur during peripheral cueing that may present a possible confound.

Sensory interactions occur between the target and cue during peripheral cueing paradigms because, on valid trials, the cue and target stimulate the same sensory receptors and neurons in the visual pathways. The cue may therefore induce either excitatory or refractory states of the visual neurons that then influence subsequent target processing (Mangun, 1995). It is possible that the neurons that responded to the cue continue to respond above their baseline rate when the target appears resulting in more vigorous responding referred to as sensory summation, or alternatively, the neurons are responding below their baseline rate when the target appears resulting in less vigorous responding, referred to as sensory refractoriness (McDonald et al., 1999). P1 reductions on valid trials have been argued to reflect sensory refractoriness rather than inhibitory processes, as the ERP component generator is argued to be in a refractory state when the target appears, resulting in ERP component suppression (McDonald et al.). This proposition was investigated by McDonald et al. (Experiment 2) who reduced the impact of sensory interactions by presenting the cue and target dichoptically so that the cue and target were seen in different eyes, manipulating the location of the cue and target, and manipulating colour and shape variables of the cue and target. Despite these manipulations P1 amplitudes were reduced on valid trials, the authors concluding that P1 suppression did not arise from sensory interactions between the cue and target, and neither were changes in retinal sensitivity responsible for P1 suppression or the IOR effect observed at a behavioural level. P1 reductions also occurred at a long SOA (900-1100ms) in McDonald et al.'s study when sensory interactions were argued to be the smallest. Wascher and Tipper (2004) also provide evidence to suggest that P1 suppression does not arise from sensory refractoriness or any other sensory interaction, finding that although P1 suppression was greatest when the cue and target appeared in exactly the same location, a small but notable P1 suppression effect was observed when

the target appeared at an adjacent location. The IOR effect therefore appeared to be distributed around the cued location and decreased as a result of increasing distance between the target and the cued location. Wascher and Tipper interpreted the pattern of P1 amplitude suppression as reflecting an attentional gradient surrounding the cued location and evidence of perceptual suppression. Based on the results of the studies conducted by Washer and Tipper and Mc Donald et al. P1 suppression does not appear to be accounted for solely by sensory interactions and may therefore be considered a viable electrophysiological marker of IOR. However, a similar attentional gradient reported by Collie et al. (2000) utilising behavioural measures only, was not interpreted as reflecting perceptual suppression, rather the results were interpreted as reflecting a motor bias rather than an attentional bias against responding to the cued location. These researchers proposed that if behavioural IOR arises solely from an attentional bias then its effects should be observed for the cued location only. Because the IOR effect was observed for validly cued targets appearing at both 9° and 18° of visual angle, and responses were slowed across the entire visual field rather than at the cued location only, the IOR effect was considered to result from a motor bias against responding to the cued location rather than as a result of an attentional bias against (Collie et al.). These mutually exclusive interpretations of similar data highlight the inconsistencies between behavioural and electrophysiological studies of IOR and raise questions as to the relative independence of electrophysiological and overt responses. Hence, although the majority of studies support an attentional account of the IOR effect, there are still some inconsistent interpretations.

Overall, P1 suppression, when observed in peripheral cueing paradigms that involve a long SOA and thus behavioural IOR effects are expected, is frequently interpreted as reflecting an inhibitory mechanism. However, it is difficult to ascertain

whether P1 suppression reflects the same inhibitory processes as the IOR effect observed at a behavioural level, as P1 suppression has been shown in the presence and absence of overt IOR effects. Although the vast majority of studies have shown ipsilateral P1 reductions to be accompanied by behavioural IOR effects (for a review see Prime & Ward, 2006), there are noted examples where P1 reductions for validly cued targets have been observed at long SOAs when facilitation effects for RT were observed at a behavioural level (e.g., Eimer, 1994: Experiment 1; Stormark, Nordby, & Hugdahl, 1995) and when no significant difference between validly and invalidly cued targets was observed (e.g., Eimer, 1994: Experiment 2; Hopfinger & Mangun, 1998). Because behavioural IOR effects may be absent in the presence of P1 reduction, it could be suggested that inhibitory (P1) and excitatory (N1) effects compete and have a differential influence over time (see Mangun, 1995). Wascher and Tipper (2004) agree that the behavioural effects of IOR are inherently ambiguous because overlapping excitation can mask inhibition resulting in facilitation effects. It is possible then that inhibition, as reflected by P1 suppression, may be present in the neural systems but is not observed in overt behaviour. This proposal was based on findings of P1 suppression at the cued location independent of SOA (50, 100, 350, and 900ms) and the finding that IOR was evoked only with transient cues and not with sustained cues, as sustained cueing maintains neural excitation states (Wascher & Tipper). It is probable then that some dissociation exists between electrophysiological manifestations of inhibition (P1 suppression) and IOR defined in terms of overt responses, and that behavioural IOR effects are not a necessary precondition for P1 suppression.

There are other examples of ERP components evoked during peripheral cueing paradigms that show sensitivity to cue validity information. A negative difference (Nd) wave is evoked at various time intervals during peripheral cueing paradigms and the

functional significance of these Nd waves has been debated. The posterior Nd wave evoked in McDonald et al.'s (1999) study was argued to be related to sensory refractoriness and not IOR, while P1 reduction was argued to be related to the behavioural IOR effect. The posterior Nd310 wave identified in Wascher and Tipper's (2004) study was the only component that differentiated transient cues that produced IOR and sustained cues which did not (for a review on the effect of transient and sustained cues on IOR see Collie et al., 2000). The Nd310 wave in the aforementioned study was evoked when the target and cue were presented at the exact same location and only when IOR was demonstrated at a behavioural level. The Nd310 was therefore argued to reflect the need to increase attentional processing to overcome the perceptual deficit brought about by the valid cue (Wascher & Tipper).

Cue validity information also influences the amplitudes of the late positive ERP components such as the P3b component that are evoked during peripheral cueing. The amplitude of the P3b component has frequently shown enhancements in response to validly cued targets (e.g., Hopfinger & Mangun, 1998; Hopfinger & Ries, 2005; McDonald et al., 1999), however there are instances where P3b amplitudes were larger in response to invalidly cued targets (e.g., Eimer, 1994), and such inconsistencies could be argued to arise from differences in methodology. P3b amplitude is enhanced in response to task relevant information (Donchin, 1981; Pritchard, 1981) and in peripheral cueing paradigms where the cue provides task relevant information as to the likely spatial location of the target, enhanced P3b amplitudes for validly cued targets appears a logical result. Hopfinger and Mangun suggest that the visual location stimulated by the cue is briefly tagged as being more task relevant, influencing higher order processing of target stimuli appearing at the same location and this accounts for the enhanced P1 and P3b amplitudes for validly cued targets at short SOAs in their 1998 study. The spatial

information conveyed by peripheral cues would however appear to be more task relevant when responses are required to target location and less task relevant when responses are required to target identity. The aforementioned studies involved target discrimination tasks, with the exception of McDonald et al., and the influence of cue validity on the P3b component is further complicated by the fact that P3b amplitude is also enhanced in response to low probability stimuli (Donchin, 1981; Pritchard, 1981). Enhanced P3b amplitude in response to low probability invalid stimuli (e.g., Eimer) therefore is a logical result. P3b amplitude was however differentially affected by response requirements in Eimer's study, with enhanced amplitudes shown for invalidly cued targets when responses were made to target location (where task relevance effects should be maximal) but not when responses were based on target discrimination. Some uncertainties therefore surround the influence of cue validity on the P3b component, and it could be argued that an interaction between task relevant and subjective probability variables is responsible for P3b modulation, particularly for invalidly cued targets.

Covert Visual Attention and Emotion

The engagement and disengagement components of covert visual attention have been widely investigated using trial-by-trial or Posner cueing paradigms and recently, modified Posner paradigms have been applied to the study of attentional processes in both normal and anxious populations. Affectively charged picture and verbal stimuli replace traditional luminance or brightness stimuli as peripheral cues in modified Posner cueing paradigms as a means of investigating whether threatening stimuli attract attention and modulate the engagement component of covert attention (valid trials), or whether threatening stimuli hold attention and thus modulate the disengage component

(invalid trials). As outlined in Chapter 2, mammals evolved in an environment where dangerous events occurred at unpredictable locations in space and time and thus survival depended on the ability to locate potentially threatening stimuli in the environment rapidly. Fear-relevant targets are detected more rapidly among fear-irrelevant distracters than are fear-irrelevant targets among fear-relevant distracters during visual search tasks (see Öhman, Flykt, & Esteves, 2001a; Öhman, Lundqvist, & Esteves, 2001b), and fear-relevant stimuli prompt more rapid shifts of attention than do fear-irrelevant stimuli (Öhman et al., 2001a). Detection of fear-relevant and fear-irrelevant stimuli is argued to occur via different search patterns. Öhman et al. (2001a) reported increased RT with the number of distracters for fear-irrelevant targets, suggestive of a serial search, while RT for fear- relevant targets was not affected by the number of distracters, suggestive of a parallel search. From an evolutionary perspective it is highly adaptive for individuals to shift attention rapidly from threatening stimuli for efficient responses, and normal participants do appear to demonstrate rapid disengagement. Tipples and Sharma (2000) for example showed no significant difference in RT between validly and invalidly cued targets, only an overall slowing of RT for pleasant and unpleasant stimuli compared to neutral, and for high compared to low arousing stimuli. This research did however involve sustained cueing which is thought to maintain neuronal excitation states (Collie et al., 2000; Wascher & Tipper, 2004) and given the possible dissociation between electrophysiological and overt responses, the results of this study remain somewhat inconclusive. Stormark et al. (1995) investigated behavioural and electrophysiological responses to target stimuli which were validly or invalidly cued by emotional (pleasant, unpleasant) and neutral words. They reported significantly faster RTs for validly cued compared to invalidly cued targets when cued by emotion words, however the target-evoked P1 component was significantly reduced in response to validly cued targets

compared to invalidly cued targets that were cued by emotion words. The authors interpreted this result as reflecting a benefit on invalid trials suggesting that greater attentional resources were required to disengage attention from the cued location. As noted in the previous subsection, P1 suppression is typically interpreted as a cost on valid trials associated with inhibition, rather than a benefit on invalid trials. As the cue-target SOA was relatively long (600ms) it is possible that the P1 enhancements shown for invalidly cued targets may be attributed to electrophysiological inhibitory effects rather than an emotional effect. One study to date that has measured electrophysiological responses during a modified Posner paradigm where threatening and neutral faces served as cues only showed a cue validity effect for the clinical group and for target-evoked P3b rather than P1 amplitude. P3b target amplitudes were enhanced for the physically abused group in response to targets invalidly cued by angry faces (Pollak & Tolley-Schell, 2003). The effect that threatening stimuli have on processes of attentional orienting is therefore far from fully understood given the inconsistencies between behavioural and electrophysiological data for both normal and clinical populations.

In the case of clinical populations, the attentional orienting processes thought to operate in anxious populations have typically shown high anxious participants to respond more slowly to targets that are invalidly cued by threatening stimuli (Fox, Russo, Bowels, & Dutton, 2001; Georgiou, Bleakley, Hayward, Russo, Dutton, Eltiti, & Fox, 2005; Yiend & Mathews, 2001). Facilitation effects following the onset of threatening stimuli are not typically demonstrated on valid trials, indicating that the presence of threatening stimuli does not enhance target processing at the cued location; and furthermore, no deficit in the disengage component of covert visual attention has been demonstrated by low anxious participants in the aforementioned studies. It is argued then that threatening stimuli evoke an anxiety-specific deficit in the disengage

component of covert visual attention which may result from the reduced threshold for preferential threat processing demonstrated by high anxious individuals (Yiend & Mathews). Stimuli that are weakly associated with threat receive preferential processing by high anxious individuals while low anxious individuals can efficiently ignore these same stimuli in order to complete task requirements. This anxiety-related deficit in the disengage component is thought to be specific to fear-relevant stimuli rather than to negative stimuli in general as Georgiou et al. reported that high anxious individuals took longer to categorise a target letter in the periphery following a fearful face whereas no anxiety-specific effects followed the presentation of a sad facial expression.

The differences in threat processing between high and low anxious participants may arise from the use of cue stimuli that are only weakly associated with threat, such as facial expressions (e.g., Fox et al., 2001; Pollak & Tolley-Schell, 2003) and emotional words (e.g., Amir, Elias, Klumpp, & Przeworski, 2003; Stormark et al., 1995). These stimuli may only be effective at activating an attentional bias in high anxious individuals while stimuli that are strongly associated with threat, (e.g., images of human attack or injury) should activate the defense system regardless of anxiety level. This seems particularly likely as highly arousing unpleasant images of human mutilation and human/animal threat are more effective at activating the fear defense system, evidenced by larger and stronger neural activity evoked in response to these stimuli compared to images of facial threat (Bradley et al., 2003).

Summary

The data from peripheral cueing paradigms are notoriously inconsistent and the ERP effects are difficult to isolate and interpret. Heated debate concerns the functional significance of P1 amplitude suppression in the face of behavioural IOR effects and it

remains to be decided whether P1 suppression can be considered an electrophysiological correlate of IOR especially since a number of studies have reported P1 suppression in the absence of behavioural IOR effects (e.g., Eimer, 1994; Hopfinger & Mangun, 1998; Stormark et al., 1995). Although the majority of studies do show P1 suppression in conjunction with slowed responses to validly cued targets, studies that report P1 suppression in the absence of behavioural IOR effects raise further questions concerning the relative independence of behavioural and electrophysiological responses during covert shifts of attention and the necessary preconditions for inhibitory effects.

The inherent difficulties associated with interpreting the data from peripheral cueing paradigms become increasingly more complex when considering modified cueing paradigms. The lack of consensus as to the effect of emotional stimuli on covert shifts of attention is hindered by the limited number of studies into this area, and while little is known as to the effect of threatening stimuli on the attentional orienting processes of normal participants, it is assumed that natural selection has favoured an attentional system that allows for rapid disengagement from threatening stimuli. There is some consensus that high anxious individuals demonstrate difficulty disengaging attention from threatening stimuli rapidly, and this failure to disengage attention serves to maintain anxiety at an elevated level. The covert attentional processes involved in the detection of, and response to, motivationally relevant stimuli for normal participants is an important line of enquiry and attempts must be made to uncover these processes in light of the methodological issues discussed previously.

CHAPTER 5: RATIONALE AND GENERAL AIMS

Emotions can be classified on the basis of behavioural states (approach/avoidance), motivational or drive states (reward, punishment, thirst, hunger, pain, craving), mood states (depression, anxiety, mania, cheerfulness, contentment, worry), emotion systems (seeking, panic, rage, fear) basic or discrete emotions (happiness, fear, anger, disgust, sadness, surprise, contempt) and social emotions (pride, embarrassment, guilt, shame, maternal love, sexual love, infatuation, admiration, jealousy) (Adolphs, 2002). The current thesis is concerned with the biphasic structure of emotion, or more specifically, affective states that are considered to be intrinsically tied to underlying appetitive and aversive motivational systems. As previously mentioned, affective states and responses can be viewed as either strategic or tactical, with the strategic dimension defined solely in terms of hedonic valence and level of arousal. Hedonic valence determines the direction of the motivational response (pleasant states activate the appetitive system and unpleasant states activate the aversive system) and arousal determines the level of activation within either system (Lang et al., 1990; Lang et al., 1992; Lang et al., 1997). Tactical emotions are far more diverse and context dependent than strategic emotions. The focus of the current thesis is on the strategic nature of affect as only the biphasic variables of valence and arousal are investigated. Bradley (2000) suggests that emotional research can be sorted into four categories of task contents: perception, anticipation, imagination, and action. As the current thesis is aimed at investigating the processing of affective information organised according to a simple biphasic structure, the following experiments involve a purely perceptual task of responding to symbolic pictorial stimuli that vary systematically on levels of hedonic valence and arousal.

The motivational states elicited by affective pictures are assumed to be fundamentally similar to those that occur when an organism responds to environmental cues (Lang et al., 1997), therefore presenting symbolic pictures designed to activate the brain's motivational systems is of great ecological validity. Furthermore, during a picture viewing paradigm participants are involved in the passive intake of sensory information which has the advantage of reducing motor interference (Hamm et al., 2003; Lang et al., 1997). Over the past two decades Lang and colleagues have created a set of pictorial stimuli that can be utilised to systematically investigate emotion and attentional processes. The most recent compilation of IAPS stimuli (see Lang et al., 1999) comprises over 700 affective pictorial stimuli that vary on levels of rated valence, arousal, and dominance, and are relatively culture free. The boomerang shaped structure of affective space as defined by the normative IAPS data has remained stable over several years of picture research and is similar for both pictorial, auditory, and verbal stimuli (for reviews see Bradley, 2000; Bradley et al., 2001a; Bradley & Lang, 2000; Hamm et al., 2003; Lang et al., 1993; Lang, 1995; Lang et al., 1997). The experimental use of IAPS stimuli allows systematic control of valence and arousal dimensions and also semantic qualities. Stimulus durations, presentation rates, stimulus size, intensity, and a range of other stimulus parameters can be carefully controlled through the use of IAPS stimuli and consistency can be maintained between experimental paradigms. Due to these advantages and a focus on the biphasic structure of emotion and motivation, IAPS stimuli were selected for presentation in the following series of empirical studies.

Our understanding of the behavioural and physiological correlates of valence, arousal, and specific picture contents has been aided by a large body of experimental research. It is widely agreed that facial muscle activity, heart rate, startle reflex, and ratings of pleasantness correlate with a valence dimension, while SCR, interest ratings,

viewing time, and arousal ratings correlate with an arousal dimension (see Bradley, 2000; Bradley & Lang, 2000; Hamm et al., 2003; Lang et al., 1997). The slow cortical wave is also assumed to covary with rated arousal (Lang et al., 1997; Hamm et al., 2003, Cuthbert et al., 2000), as is the functional activity in the visual cortex (Lang et al., 1998; Bradley et al., 2003). A variety of ERP component amplitudes have shown enhancements in response to both pleasant and unpleasant stimuli compared to neutral (see Amrhein et al., 2004; Cuthbert et al., 2000; Diedrich et al., 1997; Johnston et al., 1986; Keil et al., 2002; Loew et al., 2003; Meinhardt & Pekrun, 2003; Mini et al., 1996; Palomba et al., 1997; Schupp et al., 1997; 2003a; 2004a; 2004b), however another body of research has demonstrated enhanced ERP component amplitudes in response to unpleasant stimuli relative to pleasant stimuli (see Carretié et al., 2001a; 2004; Delplanque et al., 2004; 2005; 2006; Ito et al., 1998a; Smith et al., 2003). As discussed in Chapter 3, there are some important methodological issues surrounding the interpretation of electrophysiological responses to affective stimuli and a definitive model of affective picture processing has yet to be established.

ERP evidence of affective picture processing generally agrees with to one of two dominant theories. The first is that enhanced ERP responses to pleasant and unpleasant stimuli reflect the processing of motivationally relevant stimuli, and the second is that enhanced ERP responses to unpleasant compared to pleasant and neutral stimuli reflects a negativity bias. As mentioned previously, larger ERP responses to pleasant and unpleasant stimuli compared to neutral is typically taken as evidence that attention is more deeply engaged by motivationally relevant stimuli and this interpretation is based on the model of motivated attention and affective states proposed by Lang and colleagues (Bradley & Lang, 2000; Hamm et al., 2003; Lang, 1995; Lang et al., 1990; Lang et al., 1997). Throughout the course of the current thesis, reports of enhanced ERP

component amplitudes evoked in response to pleasant and unpleasant stimuli compared to neutral will be referred to as the quadratic effect, reflecting the U-shape structure of ERP responses plotted along a continuum from unpleasant through neutral to pleasant valence. Although the quadratic effect shown for ERP responses closely resembles the model of motivated attention and affective states, alternative interpretations have been presented whereby enhanced ERP responses to pleasant and unpleasant stimuli relative to neutral stimuli are assumed to reflect the emotional value of the stimulus rather than variables associated with motivational relevance (e.g, Diedrich et al., 1997; Johnston et al., 1986; Mini et al., 1996; Palomba et al., 1997). The data from affective ERP research therefore has not been consistently interpreted in light of motivational models of affective states, and the appropriateness of a motivational interpretation for affective ERP responses will be addressed in the current thesis.

The current thesis is divided into two phases. Phase 1 involves a series of three empirical studies aimed at elucidating the cognitive mechanisms involved in affective information processing by investigating the effects of hedonic valence, arousal, and semantic content on ERP responses. Previous research efforts in the area have been hampered by intermixing the arousal and semantic contents of the experimental stimuli, therefore the general aim of Phase 1 is to address these methodological concerns by systematically varying the dimensions of valence, arousal, and motivational relevance (or semantic content) and presenting stimuli in a modified oddball task that controls for paradigm specific ERP effects. Providing a systematic investigation of these variables should allow for a definitive model of affective picture processing to be identified.

Phase 2 involves of a series of three empirical studies utilising peripheral cueing paradigms. The general aim of these studies is to investigate the effect that motivationally relevant stimuli may have on processes of attentional orienting. To our

knowledge, this is the first series of empirical studies using a peripheral cueing paradigm where affective pictures serve as peripheral cues. A secondary aim therefore is to determine whether standard peripheral cueing effects are observed in this modified cueing paradigm. The attentional mechanisms involved in the processing of threat-related stimuli in anxious populations are quite well understood, however few research efforts have been concerned with the processing of threat related information in normal participants using electrophysiological measures, and even less is known about the processing of motivationally relevant appetitive information in normal participants. The primary aim of Phase 2 therefore is to investigate whether motivationally relevant stimuli influence attentional processes in a more global fashion in normal participants or whether attentional engagement and disengagement mechanisms are differentially influenced by motivationally relevant stimuli.

CHAPTER 6: PHASE 1- THE QUADRATIC EFFECT AND THE NEGATIVITY BIAS

Experiment 1: The Negativity Bias

The results of ERP studies of affective picture processing generally agree with two dominant theories: the quadratic effect, defined by enhanced ERP component amplitudes in response to pleasant and unpleasant stimuli relative to neutral stimuli, and the negativity bias or larger ERP component amplitudes evoked in response to unpleasant, relative to pleasant and neutral stimuli. This Phase of the empirical studies aims to identify the most appropriate model of affective picture processing by addressing the methodological limitations identified in previous research, namely the intermixing of semantic and arousal contents. High and low arousing neutral, unpleasant, and non-sexual pleasant stimuli are presented in Experiment 1. Comparisons between highly arousing and motivationally relevant sexual and unpleasant stimuli are made in Experiment 2 following the preliminary investigation of Experiment 1 in which potential confounds associated with sexual arousal are avoided.

Previous research using sustained picture viewing paradigms reliably show larger LPP (P3b and PSW) amplitudes in response to both pleasant and unpleasant stimuli compared to neutral, which is assumed to reflect the high level of visual processing resulting from the allocation of sustained attention toward motivationally relevant information (Keil et al., 2002). Research evidence from studies utilising modified oddball paradigms, however have shown enhanced early endogenous (P1, P2) and LPP amplitudes in response to unpleasant stimuli compared to pleasant and neutral stimuli, assumed to reflect the negativity bias. As sustained picture viewing paradigms typically involve longer stimulus durations and inter trial intervals (ITIs) than modified oddball

paradigms and do not involve the manipulation of target context (e.g., Crites, Cacioppo, Gardner, & Berntson, 1995; Ito et al., 1998a; Smith et al., 2003) or stimulus probability (Delplanque et al., 2004; 2005), it could be argued that the quadratic relationship frequently reported is a paradigm-specific effect and that only with sufficiently long stimulus durations and ITIs can the quadratic relationship in slow cortical activity be detected. However, Schupp et al. (2000) tested this assumption by presenting affective stimuli at shorter durations, typical of modified oddball paradigms but without an oddball manipulation and replicated the quadratic relationship. The quadratic effect therefore does not appear to be paradigm specific to sustained picture viewing, nor is it conclusive that the negativity bias is paradigm specific to the modified oddball paradigm given the added control over 'classic' ERP effects provided by oddball paradigms (for example control of subjective probability and task relevance effects on P3b amplitude). If the discrepancies cannot be explained in terms of differences in experimental paradigms, then perhaps they can be explained by the differences in experimental stimuli.

As noted previously, IAPS stimuli vary on levels of valence, arousal, and semantic characteristics. For example, high arousing unpleasant stimuli typically depict images of human mutilation, death, and human/animal threat, whereas low arousing unpleasant stimuli depict images of pollution, contamination, human illness, or deceased animals. High arousing pleasant stimuli typically depict images of sport/adventure and erotica, and low arousing pleasant stimuli typically depict images of nature, animals, romance, families, or food. Both physiological and electrophysiological responses have been shown to vary as a function of specific picture content, with enhanced SCR (Bradley et al., 2001a), P3b amplitude, and PSW activity (Schupp et al., 2004a, b) shown in response to pictures depicting human/animal threat and mutilation compared to

other unpleasant picture stimuli. Similarly pleasant pictures of erotic couples and opposite sex nudes elicit the largest changes in SCR (Bradley et al., 2001a), P3b amplitude, and PSW activity (Schupp et al., 2004a, b) compared to all other pleasant picture stimuli. These stimuli were not only rated as more arousing, but were of greater motivational relevance, which is consistent with the model of motivated attention and affective states (Lang et al., 1997). A possible confound is associated with the intermixing of arousal level and semantic qualities, as highlighted by Schupp et al.'s (2004 a) study. Schupp et al. showed the quadratic effect to be replicated when ERP data was averaged across picture categories, however when ERP data was averaged for specific picture categories (e.g., erotic couples, happy families, dangerous animals, human mutilation), ERP waveforms were shown to be differentially modulated by specific arousal and semantic characteristics.

The primary aim of Experiment 1 is to investigate the effects of valence, arousal, and motivational relevance (or semantic content) on cognitive processes such as the allocation of attentional resources. A modified oddball paradigm is used to present the affective stimuli to control for 'classic' ERP effects, specifically the effect of subjective probability and task relevance on P3b amplitude. In Experiment 1, high and low arousing stimuli are not intermixed within general pleasant, unpleasant, and neutral categories, and a sustained picture viewing paradigm is not employed, the quadratic effect previously reported is not expected to be replicated. The separability of arousal and motivational relevance as factors influencing cognitive processing is investigated by comparing high and low arousing unpleasant stimuli in Experiment 1. While it is acknowledged that the arousal level of sport/adventure and sexual stimuli can be matched, and differences in motivational relevance therefore can be reliably investigated, the inclusion of sexual stimuli in Experiment 1 was not deemed to be

desirable. Because sexual arousal may influence cognitive processing differently to other forms of affective arousal that are tightly associated with motivational relevance, comparing highly arousing and motivationally relevant unpleasant stimuli with equally arousing and less motivationally relevant, non-sexual pleasant stimuli was considered most appropriate for the initial investigation of the effects of valence, arousal, and semantic content in Experiment 1.

Following the major assumption of the negativity bias, that the consequences of not attending or responding to an aversive event are more catastrophic than not attending to a similarly intense positive event (Rozin & Royzman, 2001), the primary prediction for Experiment 1 is that greater attentional resources, as indexed by increased P3b amplitude, will be allocated toward the processing of highly arousing and motivationally relevant unpleasant stimuli compared to equally arousing but less motivationally relevant pleasant sporting images and compared to neutral images. Following the findings of Smith et al. (2003), Carretié et al. (2001a; 2004), and Delplanque et al. (2004) who showed a negativity bias for the early ERP components (e.g., P1, P2) it is anticipated that the modulation of the early positive ERP components will also reflect a negativity bias. The inherent motivational relevance of the affective stimuli is hypothesised to be the primary factor to account for affective ERP modulations. The amplitudes of the early and late positive ERP components are therefore predicted to be similar for high and low arousing neutral and high and low arousing pleasant stimuli that differ on arousal level but share similarly low motivational qualities. For the unpleasant stimuli that differ on both arousal level and motivational qualities, ERP amplitudes are expected to be enhanced in response to high arousing compared to low arousing unpleasant stimuli as a result of differences in motivational characteristics rather than as a result of arousal differences.

Sex differences have been reliably reported in both behavioural and physiological responses, however, sex differences in neurophysiological responses are less consistent. Females demonstrate heightened activation of the aversive system as measured by both behavioural ratings of valence and arousal (Bradley et al., 2001b; McManis et al., 2001) and physiological responses (Bradley et al., 2001b), whereas males demonstrate heightened activation of the appetitive system (Bradley et al., 2001b). These sex differences have been identified via analysis of variance performed on the ratings of valence and arousal for pleasant and unpleasant pictures, and correlational analyses that were performed on the ratings of valence and arousal for individual picture stimuli to investigate the motivational vectors for males and females (Bradley et al., 2001b). Overall, males and females are expected to rate pleasant, unpleasant, and neutral stimuli in a similar fashion. It is predicted that males and females will rate high arousing pleasant, neutral, and unpleasant stimuli as significantly more arousing than respective low arousing stimuli, and will rate high arousing unpleasant stimuli as significantly more unpleasant than low arousing unpleasant stimuli given the stronger correlation between valence and arousal for unpleasant stimuli compared to pleasant stimuli (Bradley et al., 2001a). No significant differences in valence ratings are predicted between high and low arousing pleasant, or high and low arousing neutral stimuli. Following from Bradley et al. (2001b) who showed females to be more reactive to unpleasant stimuli, rating these pictures as more unpleasant and more arousing than males, it is predicted that females will rate unpleasant stimuli as significantly more unpleasant than males and respond with larger ERP component amplitudes for unpleasant stimuli, with the greatest difference between males and females shown for the highly arousing and motivationally relevant unpleasant stimuli. Heightened activation of the appetitive system demonstrated by males was shown to be specific to erotic stimuli (Bradley et al., 2001b) and as erotic

stimuli will not be presented in Experiment 1, no sex differences in behavioural or ERP responses are expected for pleasant stimuli. Correlational analyses will be performed separately for male's and female's ratings of valence and arousal for individual picture stimuli. The purpose of these analyses is to identify potential sex differences in the strength of the underlying motivational vectors. Following from Bradley et al. (2001b) who showed females to demonstrate stronger defensive activation, it is predicted that females will show a stronger positive correlation between ratings of valence and arousal for unpleasant stimuli. Again, as sexual stimuli are not presented in Experiment 1, no significant sex differences in the correlation between valence and arousal ratings for pleasant pictures are predicted.

According to the valence hypothesis, positive affect is lateralised toward the left cerebral hemisphere and negative affect is lateralised toward the right cerebral hemisphere (Demaree et al., 2005). Davidson and colleagues (Davidson, 1992; 1993a, b; Davidson et al., 1990) and Heller (1990; 1991) propose that the approach and withdrawal systems that are activated by pleasant and unpleasant stimuli are localised within the left and right frontal regions respectively. It is therefore predicted that the hemispheric lateralisation of pleasant and unpleasant stimuli will be most pronounced in the left and right frontal regions. As the P3b component typically shows a parietal maximum, it is expected that the lateralisation of affect in the frontal regions will be restricted to the early positive components. Davidson (1993a) proposed that the right parietal region is specialised for the perception of emotional information independent of hedonic valence, and Heller's (1990; 1991) regional activation hypothesis proposes that the right parietal region plays an important role in the mediation of both cortical and autonomic arousal. The prediction that P3b amplitude will be enhanced in response to highly arousing and motivationally relevant unpleasant stimuli is expected to be

observed in both the left and right parietal regions, however due to the proposed specialisation of the right parietal region in the processing of valence and arousal information, it is predicted that the magnitude of this difference will be greater in the right parietal electrode site compared to the left parietal electrode site.

Method

Participants

Participants were 19 male (*M* age=21.58 years, *SD*=4.56, *Age Range:*18-33) and 19 female (*M* age=22.16 years, *SD*=4.88, *Age Range:*18-33) first year psychology students at the University of Tasmania who were right-handed, with normal or corrected to normal vision. Participants were excluded if they had taken illicit substances, were heavy smokers or binge drinkers, were suffering or had previously suffered from any psychological or neurological illness, had suffered a severe head injury, or were on prescription medication. Participants were also excluded if they had a history of phobic responses. Informed consent was obtained from all participants and all participants were given course credit for their time. Ethical approval was granted by the Human Research Ethics Committee (Tasmania).

Apparatus, Stimuli, and EEG Recording

EEG activity was recorded from 32 sites using SynAmps 1 amplifiers according to the international 10-20 system of electrode placement (Jasper, 1958). A Quik-cap with sintered Ag/Ag Cl electrodes was used to collect the EEG data using Neuroscan 4.3.1 software. All electrode sites were referenced to the mastoids, horizontal electro-oculargraphic (EOG) activity was recorded from electrodes placed at the outer canthi of both eyes, and vertical EOG activity was recorded from electrodes above and below the

left eye. Pictorial stimuli were presented on a computer using Neuroscan STIM 4.1 software. Electrode impedance was kept below 5KΩ. EEG activity was sampled continuously at 1000Hz, and amplified with a high pass filter of 0.15, and low pass filter of 100Hz. Reaction time and accuracy data were recorded for each target trial. EEG data was merged with behavioural files following which ocular artifact reduction was conducted. Continuous data files were then low pass filtered at 30Hz, epoched offline for a 1000ms epoch commencing 100ms before stimulus onset and baseline corrected. High and low voltage cut-offs for artifact rejections were set at 100µV and -100µV respectively. EEG activity corresponding to correct responses for each target category was averaged and then band-pass filtered at 48dB per octave, with a high band pass of 0.15Hz and a low pass of 30Hz. Averages including more than 15 trials were accepted for analyses. Grand mean average waveforms were calculated separately for each picture category for each electrode site, and ERP waveforms for each target stimulus were scored for peak amplitude, the window of measurement determined by visual inspection of the grand means. Individual peak detection was then conducted.

Two hundred stimuli were selected from the IAPS (Lang et al., 1999) based on the valence and arousal normative data set. The IAPS normative data was scored on a nine-point Likert scale, thus neutral stimuli were selected from the IAPS that had mean valence ratings of approximately five, while pleasant stimuli had mean valence ratings of six and above, and unpleasant stimuli had mean valence ratings of three and below (see Appendix A). High arousing stimuli had arousal scores greater than five and low arousing stimuli were selected that had arousal scores of five or less. Forty high arousing neutral stimuli were selected from various surreal images following Mourão-Miranda et al.'s (2003) methodology in which surreal images were rated as neutral on valence, but were rated as arousing due to the visual complexity of the images (see Appendix A).

These 240 emotional stimuli were then independently rated by 21 first year psychology students for level of valence and arousal on a nine-point Likert scale: valence (1=highly unpleasant, 5=neutral, 9=highly pleasant); arousal (1=not at all exciting/arousing, 5=moderately arousing, 9=highly exciting/arousing). The stimuli were independently rated in order to create a set of stimuli appropriate for an Australian sample. As the scores were not normally distributed the median was used to select the experimental slides. The independent ratings resulted in only a limited number of slides being available for experimental use for the Australian sample, as only 20 slides per picture category were within the IAPS bipolar criteria for valence and arousal ratings. High and low arousing neutral stimuli had a median valence score of five, high arousing neutral stimuli had a median arousal score of four and above, and low arousing neutral stimuli had a median valence score of one. High and low arousing pleasant stimuli had median valence scores of six and above, high arousing pleasant stimuli had median arousal scores of six and above, low arousing pleasant stimuli had median arousal scored less than five. High and low arousing unpleasant stimuli differed on both median scores of valence (high=1, low=3) and arousal (high=7, low=1). As noted previously, Bradley et al. (2001a) showed a positive correlation between measures of valence and arousal for both pleasant and unpleasant stimuli. As can be seen in Figure 4, valence and arousal scores increased in a linear fashion, with a stronger relationship observed between ratings of valence and arousal for unpleasant stimuli, consistent with Bradley et al. It is therefore difficult to match high and low arousing stimuli on level of valence, especially unpleasant stimuli given the stronger correlation between unpleasantness and arousal. Also it is extremely difficult if not impossible to match the arousal level of high arousing neutral stimuli with that of high arousing pleasant and unpleasant stimuli given the boomerang shape of affective space defined by Lang and colleagues (see Bradley, 2000;

Bradley et al.; Bradley & Lang, 2000 Hamm et al., 2003; Lang, 1995; Lang et al., 1997; Lang et al., 1993).

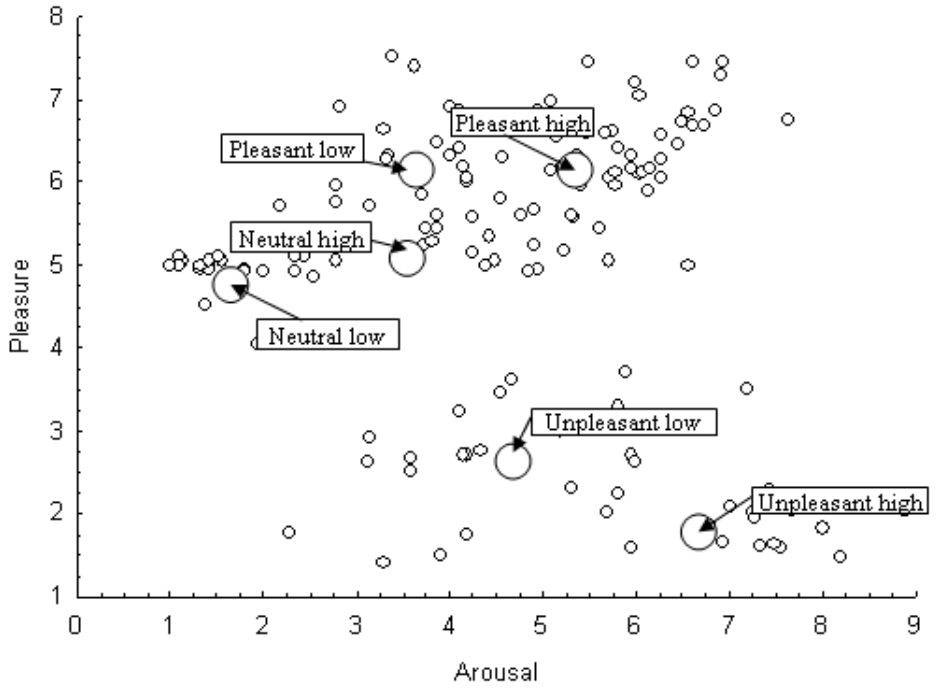


Figure 4. Distribution of valence and arousal scores for the stimuli in Experiment 1.

ANOVAs conducted on the independent valence rating data showed significant main effects of Picture Category, $F(1.64, 31.11)=528.89$, $MSE=.30$, $p<.001$ and Arousal Category, $F(1,19)=11.81$, $MSE=.18$, $p<.01$, and a significant two-way interaction between these variables, $F(1.74, 33.03)=27.25$, $MSE=.17$, $p<.001$. Tukey HSD post hoc tests indicated that high ($M=5.31$, $SEM=.10$) and low arousing neutral stimuli ($M=4.97$, $SEM=.03$) were matched on level of valence, as were high ($M=6.27$, $SEM=.15$) and low arousing pleasant stimuli ($M=6.39$, $SEM=.13$). High and low arousing unpleasant stimuli however were not matched on valence level, as high arousing unpleasant stimuli ($M=1.91$, $SEM=.08$) were rated as significantly more unpleasant than low arousing

unpleasant stimuli (*M*=2.93, *SEM*=.13) (*p*s <.05). All picture categories differed significantly from each other on levels of valence (*p*s<.05).

ANOVAs conducted on the independent arousal rating data indicated that arousal ratings differed as a function of arousal category, $F(1,19)=90.54$, $MSE=.91$, $p<.001$, and picture category, $F(1.76, 33.46)=49.56$, $MSE=1.55$, $p<.001$. Tukey post hoc tests indicated that high arousing stimuli were rated as significantly more arousing than low arousing stimuli, ($p<.05$), and that unpleasant stimuli (*M*=5.59, *SEM*=.31) were rated as significantly more arousing than pleasant (*M*=4.69, *SEM*=.21) and neutral stimuli (*M*=2.80, *SEM*=.34) ($p<.05$), which also differed significantly. Although the two-way interaction between Picture Category and Arousal was not significant, $F(1.96, 37.34)=.67$, $MSE=.59$, $p=.52$, inspection of the means showed that all high arousing picture stimuli were rated as more arousing than respective low arousing picture stimuli (neutral high *M*=3.69, *SEM*=.30; neutral low *M*=1.90, *SEM*=.24; pleasant high *M*=5.34, *SEM*=.26; pleasant low *M*=3.91, *SEM*=.24; unpleasant high *M*=6.34, *SEM*=.33; unpleasant low *M*=4.65, *SEM*=.32).

IAPS pictorial stimuli were converted from JPEG to PCX form for compatibility with STIM 4.1 software and all picture sizes were set at 384 x 256 pixels. The experimental task involved four blocks, consisting of 20 of each of high and low arousing unpleasant, pleasant, neutral, and distracter stimuli (a large blue and a large grey square: 6.50cm x 9.75cm). Three hundred and twelve trials were presented in each block, with 39 presentations for each picture category, each block lasting approximately 10 minutes. As there were 20 stimuli for each picture category, in order for 39 presentations to be made, 19 of each of high and low arousing picture stimuli were presented twice, and one picture stimulus per block was presented only once. A modified three stimulus oddball paradigm was use to present the stimuli, each with a

probability of .25, which was further broken down into high and low arousal, with a probability of .125 respectively. The probability level was set at .125 for each affective target stimulus (the affective target was different for each experimental block) in order that valid comparisons could be made between experimental blocks. Although the paradigm involved the presentation of mixed affective standard stimuli, the target probability for each affective stimulus was still lower than the overall probability of the unattended affective stimuli (.75). As mentioned previously, distracter stimuli included a large blue (high arousing) and a large grey (low arousing) rectangle in order for the experiment to be fully factorial, however the EEG data for high and low arousing distracter targets was collapsed for averaging purposes. Each slide was presented centrally for 200ms, with an inter stimulus interval (ISI) that varied randomly between 1000 and 2000ms. Spielberger, Gorsuch, Lushene, Vagg, and Jacobs' (1983) State-Trait Anxiety Inventory (STAI) was used to measure levels of state and trait anxiety. The pictorial stimuli that were rated after the experiment was complete were presented for a duration of 2000ms and were presented so that the image approximately filled the available space on the 13 inch computer monitor.

Procedure

Participants were informed as to the purpose of the study and after reading the information sheet, completed the participant consent form and a brief medical questionnaire. The State and Trait versions of the STAI were then administered. Participants then had electrodes attached and were seated in a sound attenuated room. Four oddball conditions (or blocks) were presented to the participant in a counterbalanced order, with the stimuli presented randomly within each block. Depending on the condition, participants were instructed to respond to either the

distracter, pleasant, unpleasant, or neutral target by pressing a button on two separate response pads with the index fingers of each hand to equalise motor activity. The pictorial stimuli were then re-presented and participants rated each slide for levels of valence and arousal on a nine-point Likert scale via a computer monitor. The state version of the STAI was then re-administered.

Design

The experiment followed a 2[Sex: male, female] x 3(Picture Category: neutral, pleasant, unpleasant) x 2(Arousal: high, low) mixed factorial design. The electrode sites led to two further repeated measures variables of Sagittal and Coronal site. Inspection of the grand mean waveforms (see Figures 11a & b) indicated that no early positive components were evoked. An N2 component was evoked over fronto-central sites and a late positive component identified as P3b was evoked over central, centro-parietal, and parietal sites. The dependent variables for the ERP data were P3b amplitude and latency, and preliminary analyses were performed on the N2 amplitude and latency data which were not expected to show significant effects as a function of affect. The dependent measures for the behavioural data were reaction time (RT), accuracy, ratings of valence and arousal, and scores on the state and trait versions of the STAI.

Data Analysis

Means and standard errors were calculated for the valence and arousal rating data for each high and low arousing neutral, pleasant, and unpleasant stimulus. Means and standard errors were calculated for the RT data for correct responses and for the accuracy data. Behavioural data were analysed using three-way mixed ANOVAs with Sex as the between subjects factor and Picture Category (neutral, pleasant, and

unpleasant) and Arousal (high, low) as the within subjects factors. Means and standard errors were calculated for scores on both the Trait and two State versions of the STAI. The STAI data was analysed using two-way mixed ANOVAs with Sex as the between subjects factor and State (pre, post-experiment) as the within subjects factors. The trait anxiety data was analysed using an independent samples t-test. Correlations between ratings of valence and arousal for males and females were performed using Pearson's product-moment coefficients (Pearson's *r*).

ERP waveforms for each high and low arousing neutral, pleasant, and unpleasant target stimulus category were scored for peak amplitude. Standard stimuli were not subjected to statistical analysis as the interest lies with stimuli that were actively evaluated. The grand mean waveforms (see Figures 11a & b) show a distinct peak between 300 and 500ms post-stimulus onset, maximal at centro-parietal and parietal sites that was identified as the P3b component. Distracter stimuli elicited a novelty P3 (or P3a) component (see Figures11a & b), however as the interest lies with the affective stimuli, novelty P3 for distracter stimuli were not subjected to statistical analysis. The means for the N2 and P3b amplitude and latency data were assessed using five-way mixed ANOVAs, with Sex [male, female] as the between subjects factor, and Picture Category (neutral, pleasant, and unpleasant), Arousal (high, low), Sagittal site (centro-parietal and parietal) and Coronal site (far left, left, midline, and right, far right) as the within subjects factors. Significant main effects and interactions involving Sagittal and Coronal sites will not be reported unless they are of theoretical significance. As it was predicted that the magnitude of the valence and arousal effects would be greatest in the right parietal region as a result of a regional specialisation for valence and arousal information processing (see Davidson, 1993a; Heller, 1990; 1991), three-way ANOVAs

were conducted on the P3b amplitude data with repeated measures variables of Picture Category, Arousal, and Hemisphere (left electrode site, right electrode site).

Behavioural data was available for all participants; however two participants' data were excluded from ERP data analysis due to post experimental indication of a previous head injury in one case and of current medication use in the other. The data from a further eight participants were excluded due to a pattern of missing data for the high arousing neutral category, due to these participants evaluating the high arousing neutral stimuli as pleasant. Analysis of the data for the remaining 28 participants (15 female) were conducted using Statistica 7.0 using repeated measures ANOVAs with Greenhouse-Geisser corrections where appropriate. The alpha level was set at .05 and Tukey HSD post hoc tests were used to test for significant differences between individual means where necessary.

Results and Discussion

Behavioural Data

STAI

The two-way mixed ANOVA conducted on the state anxiety data showed a significant main effect of State Anxiety, $F(1,36)=4.36$, $MSE=30.02$, $p<.05$. Ratings of state anxiety increased significantly post experiment ($M=35.98$, $SEM=1.39$) compared to pre experimental measures ($M=33.35$, $SEM=1.41$) ($p<.05$). Males and females did not differ in their ratings of state anxiety, $F(1,36)=1.87$, $MSE=119.00$, $p=.18$, and the interaction between Sex and State Anxiety was not significant, $F(1,36)=1.35$, $MSE=40.58$, $p=.25$. The independent samples *t*-test conducted on the trait anxiety data indicated that males and females did not differ significantly on levels of rated trait anxiety, $t(36)=1.42$, $p=.16$. The significant increase in state anxiety from pre to post experimental measures

is assumed to be attributed to the presentation of the highly arousing unpleasant stimuli, both during the experimental task, and during the post experimental rating period. The post experimental rating period however is assumed to be more highly associated with the significant increase in state anxiety, as the pictorial stimuli were viewed for a longer period and at a greater stimulus size than the images presented in the experimental task.

Accuracy

The three-way mixed ANOVA conducted on the accuracy data indicated that the main effect of Sex was significant, $F(1,35)=459.8$, $MSE=106.4$, $p<.001$, with females demonstrating significantly higher accuracy levels ($M=31.76$, $SEM=.99$) than males ($M=28.98$, $SEM=.96$). A significant two-way interaction was shown between Picture Category and Arousal, $F(1.39, 48.75)=48.12$, $p<.001$. As shown in Figure 5, and confirmed by Tukey post hoc tests, accuracy levels did not differ significantly between high and low arousing pleasant stimuli, however accuracy levels were significantly higher for low arousing neutral compared to high arousing neutral stimuli, and for high arousing unpleasant compared to low arousing unpleasant stimuli (ps$<.05$). High arousing unpleasant stimuli were responded to with significantly greater accuracy than high arousing pleasant and neutral stimuli and high arousing pleasant stimuli were responded to with significantly greater accuracy than high arousing neutral stimuli (ps$<.05$). For low arousing stimuli, accuracy levels were significantly greater for neutral and pleasant compared to unpleasant stimuli ($p<.05$), with no significant difference in accuracy levels between low arousing pleasant and neutral stimuli ($p>.05$).

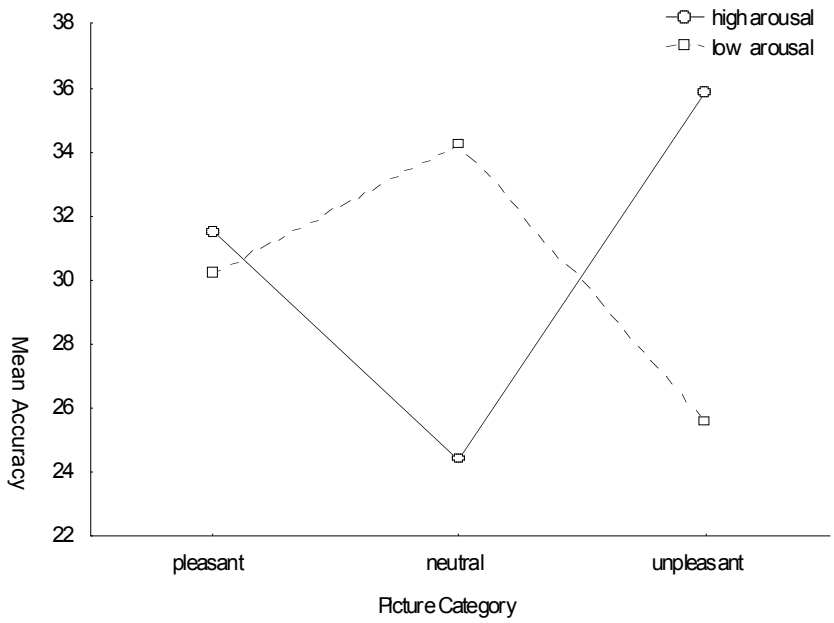


Figure 5. Mean accuracy scores in response to high and low arousing picture categories.

The differences observed in the accuracy data are argued to be a result of stimulus salience and complexity. High arousing neutral stimuli were selected from surreal images and were therefore more visually complex than all other affective stimuli. There was noted difficulty associated with the affective evaluation of the neutral high arousing stimuli, and a number of participants classified these stimuli as pleasant. As a result the accuracy levels for high arousing neutral stimuli were significantly lower than for all other affective stimuli. A negativity bias was demonstrated for the accuracy data, with high arousing unpleasant stimuli evaluated with significantly greater accuracy, and this result is assumed to arise from the increased salience of these stimuli.

Reaction Time

ANOVAs conducted on the reaction time data indicated that RT differed as a function of Picture Category, $F(1.42, 49.65)=3.73$, $MSE=.008$, $p<.05$. Tukey post hoc tests showed

significantly faster RT in response to unpleasant (*M*=.53ms, *SEM*=.01) compared to pleasant stimuli (*M*=.57ms, *SEM*=.01) ($p<.05$), however no significant differences between neutral (*M*=.59ms, *SEM*=.02) and pleasant, or neutral and unpleasant stimuli were reported. The main effects of Arousal, $F(1,35)=2.34$, *MSE*=.011, $p=.13$, and Sex, $F(1,35)=.09$, *MSE*=.028, $p=.76$, were not significant, and no significant higher order interactions were revealed. The RT and accuracy data provide only partial support for the negativity bias, as although high arousing unpleasant stimuli were evaluated with greater accuracy, these stimuli were not responded to more rapidly.

Valence Ratings

Valence ratings differed as a function of Picture Category, $F(1.88, 67.88)=791.83$, *MSE*=.51, $p<.001$, and Arousal level, $F(1,36)=9.65$, *MSE*=.39, $p<.05$, but not as a function of Sex, $F(1,36)=.74$, $p=.39$. These significant main effects were qualified by a significant two-way interaction between Picture Category and Arousal, $F(1.59, 57.14)=41.21$, *MSE*=.34, $p<.05$ as shown in Figure 6. Tukey post hoc tests indicated that high and low arousing pleasant stimuli were matched on rated valence. High arousing neutral stimuli were rated as significantly more pleasant than low arousing neutral stimuli ($p<.05$), and as previously mentioned, this is assumed to result from a number of participants classifying these stimuli as pleasant. High arousing unpleasant stimuli were rated as significantly more unpleasant than low arousing unpleasant stimuli ($p<.05$) and this is consistent with the stronger correlation between ratings of valence and arousal for unpleasant stimuli outlined by Bradley et al. (2001a). For both high and low arousing stimuli, pleasant, neutral, and unpleasant stimuli differed significantly from each other on level of rated valence (*p*s<.05).

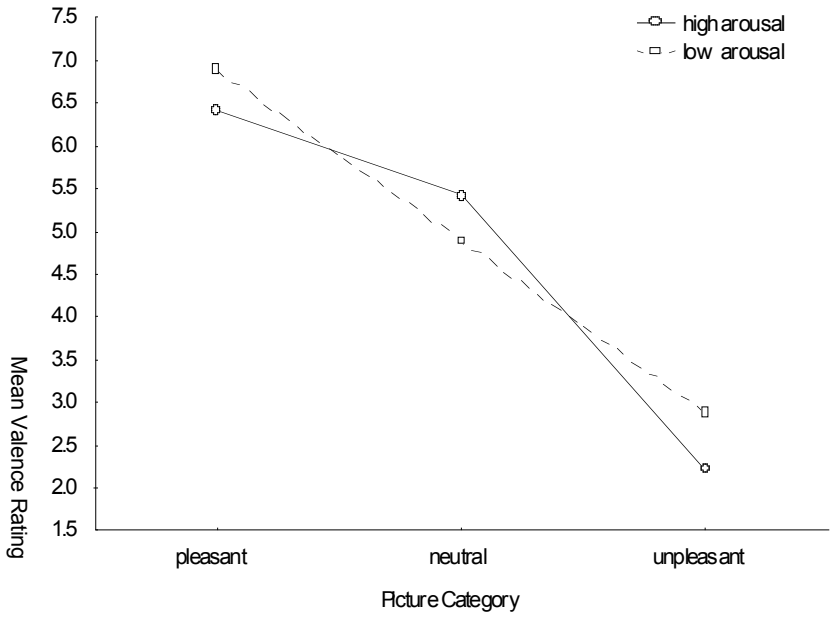


Figure 6. Mean valence ratings for high and low arousing neutral, pleasant, and unpleasant stimuli.

A significant two-way interaction between Picture Category and Sex was also revealed, $F(1.88, 67.88)=5.33$, $MSE=.39$, $p<.01$. As can be seen in Figure 7, and confirmed by Tukey post hoc tests, both males and females rated pleasant, unpleasant, and neutral stimuli as significantly different from each other (ps<.05). Females also rated unpleasant stimuli as significantly more unpleasant than males ($p<.05$). The hypothesis that females would show greater defensive activation as measured by valence ratings was partially supported as females did rate unpleasant stimuli significantly more unpleasant than males. However, the level of defensive activation in response to the most highly arousing contents did not differ between males and females as had been predicted.

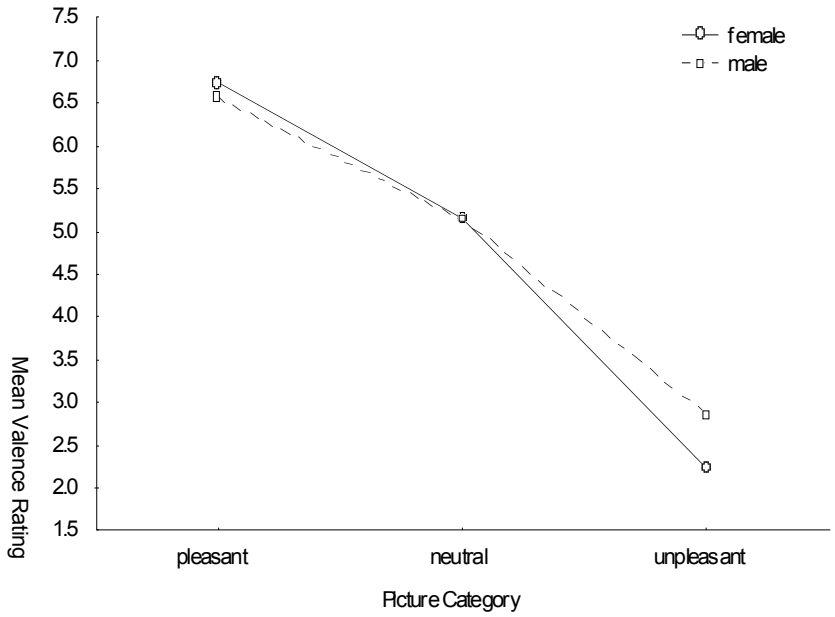


Figure 7. Mean valence ratings for males and females for neutral, pleasant, and unpleasant stimuli.

Arousal Ratings

Ratings of arousal also differed as a function of Picture Category, $F(1.34, 48.30)=25.47$, $MSE=4.09$, $p<.001$ and Arousal level, $F(1,36)=77.33$, $MSE=2.00$, $p<.001$, but not as a function of Sex, $F(1,36)=.28$, $MSE=6.78$, $p=.60$. These significant main effects were qualified by a significant two-way interaction between Picture Category and Arousal, $F(1.74, 62.73)=4.47$, $MSE=1.28$, $p<.05$. As shown in Figure 8 and confirmed by Tukey post hoc tests, all high arousing stimuli were rated as significantly more arousing than respective low arousing stimuli, and for both high and low arousing picture categories, pleasant and unpleasant stimuli were rated as significantly more arousing than respective neutral stimuli (*p*s<.05).

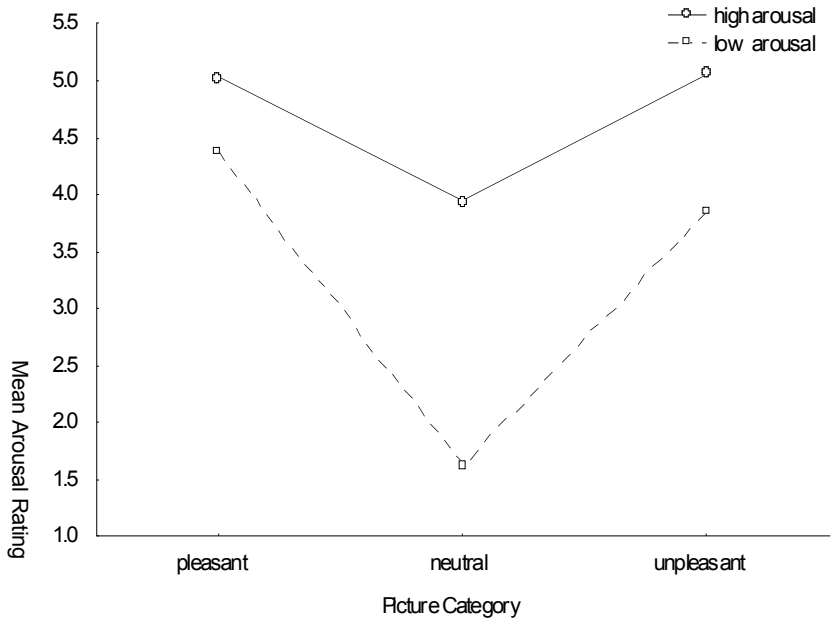


Figure 8. Mean arousal ratings for high and low arousing neutral, pleasant, and unpleasant stimuli.

Ensuring that the arousal levels of affective picture categories are matched is particularly important given that the early ERP components (e.g., N260: Junghöfer et al., 2001) and the P3b or LPP components vary as a function of arousal (Cuthbert et al., 2000; Schupp et al., 2000; Schupp et al., 2004a, b). As the high arousing pleasant and unpleasant picture categories, and the low arousing pleasant and unpleasant picture categories are matched on rated arousal in Experiment 1, it will be possible to draw valid conclusions from the ERP data as to the effect of motivational relevance as each high, and each low arousing pleasant and unpleasant picture category differ on this dimension only. The independent effect of arousal can be validly examined through comparisons of the non-affective neutral stimuli that differ significantly on arousal level, and also between pleasant stimuli which are matched for valence but differ significantly in arousal. The interactive effects of arousal and motivational relevance can be further

investigated through comparisons of high and low arousing unpleasant stimuli that differ on both motivational relevance and arousal.

Valence and Arousal Correlations for Males and Females

Correlational analyses were performed on the valence and arousal rating data for males and females separately, revealing some sex differences in appetitive and aversive activation. As can be seen in Figures 9 and 10, the correlation between ratings of valence and arousal for high and low arousing unpleasant stimuli are stronger for females than for males. Females also appear to rate a larger number of high arousing unpleasant stimuli as more highly arousing and more highly unpleasant than do males. The correlation between ratings of valence and arousal for high and low arousing pleasant stimuli appear fairly similar for males and females, however ratings of high arousing pleasant stimuli appear to project further into the high arousal quadrant for males compared to females.

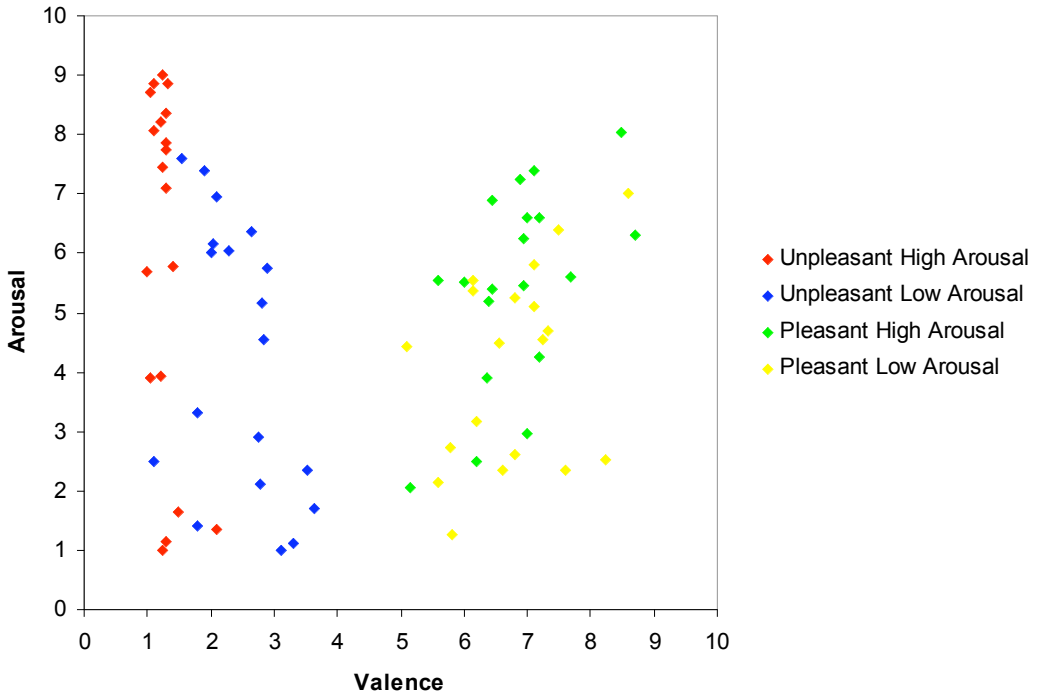


Figure 9. Correlation between ratings of valence and arousal for high and low arousing stimuli for female participants.

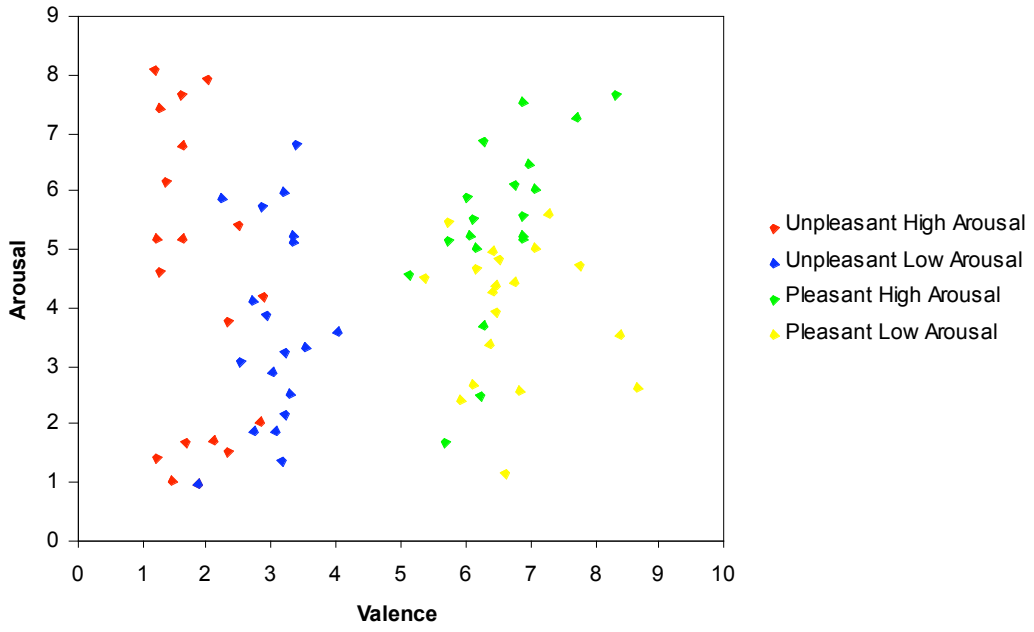


Figure 10. Correlation between ratings of valence and arousal for high and low arousing picture stimuli for male participants.

Correlational analyses were performed separately for male's and female's ratings of valence and arousal for each picture category. Pearson's *r* correlation coefficients and the significance level are shown in Table 1. As can be seen, both males and females show a moderate positive correlation between ratings of valence and arousal for high arousing pleasant stimuli, significant at the .05 level, with the correlation slightly stronger for males. No other significant correlations are shown between ratings of valence and arousal for males. Females in contrast show a moderate positive correlation between valence and arousal ratings for high arousing neutral stimuli and a moderate to strong negative correlation between ratings of valence and arousal for low arousing neutral stimuli, significant at the .01 level. There was a strong trend toward a significant negative correlation between female's ratings of valence and arousal for high arousing unpleasant stimuli, and a trend toward a significant negative correlation shown for low arousing unpleasant stimuli.

Table 1

Pearson's Correlation Coefficients for Correlations Between Valence and Arousal Ratings for Males (N=19) and Females (N=19.)

	Female		**Male**	
Picture Category	*r*	*p*	*r*	*p*
Pleasant High: valence/arousal	.55	* .016	.64	** .003
Pleasant Low: valence/arousal	.35	.14	-.12	.63
Neutral High: valence/arousal	.61	** .005	-.71	.77
Neutral Low: valence/arousal	-.71	** .001	-.28	.25
Unpleasant High: valence/arousal	-.45	.055	-.29	.23
Unpleasant Low: valence/arousal	-.42	.07	-.18	.46

p<.05, ** *p*<.01

It is acknowledged that the sample size is not sufficiently large enough to allow adequate power in a correlational analysis, however the data do provide some interesting insights as to the activation of the appetitive and aversive systems and provide some support for the experimental hypotheses. The appetitive vector as inferred by the correlation between valence and arousal ratings for pleasant stimuli, was activated in both males and females in response to high arousing, non-sexual pleasant stimuli, and it appears that the strength of the correlation between valence and arousal ratings was somewhat stronger for males. The greater activation of the appetitive system inferred from the stronger positive correlation between ratings of valence and arousal for pleasant stimuli shown for males relative to females, is not consistent with the experimental hypotheses, as no significant sex differences in the correlation of valence and arousal ratings were predicted for pleasant stimuli. However, given the small sample size, this conclusion must be interpreted tentatively. The prediction that females are more defensively activated than males was given some credit, as females did show a trend toward a significant negative correlation between ratings of valence and arousal for high and low arousing unpleasant stimuli, while no such results were shown for males. Again, increasing the sample size would allow for more conclusive results, however the data do point towards stronger activation of the aversive system in females, which is consistent with the IAPS normative data (Lang et al., 1999) and Bradley et al. (2001b).

ERP Data

Grand mean averages for correct responses to high and low arousing affective targets, and for distracter stimuli were computed for the 30 electrode sites. Figure 11a shows the grand mean averages for high arousing picture stimuli and distracters. An N2 component

can be observed with maximal amplitudes at fronto-central, midline sites decreasing from frontal to centro-parietal sites. There is little consensus as to the functional significance of the N2 component, cited as an index of stimulus identification in the visual domain (Dien et al., 2004) and an index of inhibition and conflict monitoring (Lavric et al., 2004). The N2 component is also enhanced in response to low probability stimuli (Decon et al., 1991; Gehring et al., 1992) and the functional significance and topography of the N2 component varies depending on whether testing occurs in the auditory or visual domain (Fabiani et al., 2000). The N2 component has not shown sensitivity to affective variables (e.g., Delplanque et al., 2006; Schupp et al., 1997) or incentive value (e.g., Seifert et al., 2006) and preliminary analysis of the N2 component in the current experiment confirms these findings. The N2 component was therefore not subjected to further statistical analysis or interpretation (analyses of the N2 component are reported in Appendix I and T).

An early positive component (P1, P2) was expected to be evoked but was not observed. The P3b component, maximal over centro-parietal and parietal sites can be observed in Figures 11a and b. P3b amplitude was larger in response to high arousing unpleasant stimuli compared to high arousing pleasant and neutral stimuli (see Figure 11a), however P3b amplitude does not appear to be differentially affected by low arousing stimuli (see Figure 11b). Distracter stimuli elicited a novelty P3 component, which was also maximal over centro-parietal and parietal regions and the amplitude of the novelty P3 component was larger than that of the P3b component evoked in response to the affective targets. The novelty P3 or P3a is typically elicited in response to low probability, distracter stimuli with maximal amplitudes at fronto-central sites. The novelty P3 component has, however, been observed at centro-parietal and parietal sites and the novelty P3 component evoked at these regions is assumed to reflect similar

processes as P3b (Friedman et al., 2003). Courchesne et al. (1975) reported that when distracter stimuli were unrecognisable images, a frontal novelty P3 was evoked however when the distracter stimuli were easily recognisable images, a posterior novelty P3 component was evoked. The topography of the novelty P3 evoked in response to a simple geometric shape in Experiment 1 is therefore consistent with Courchesne et al.'s account of novelty P3, and it is argued that the novelty P3 component evoked in the current experiment reflects processes associated with novelty evaluation and that the topography of the component was determined by the recognisability of the stimuli. As the interest lies with the evaluation of the affective stimuli, the novelty P3 component was not subject to statistical analysis.

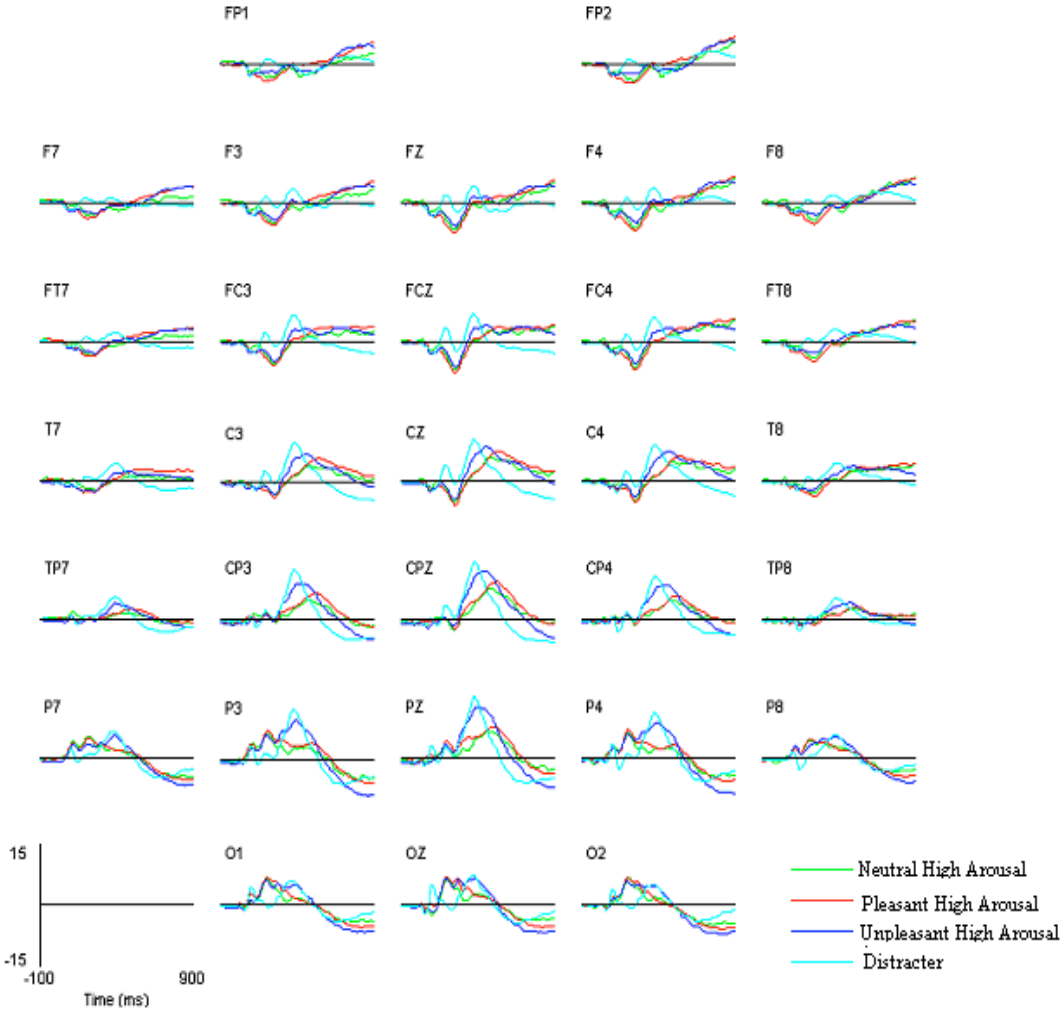


Figure 11a. Grand mean averages for high arousing picture stimuli and distracters.

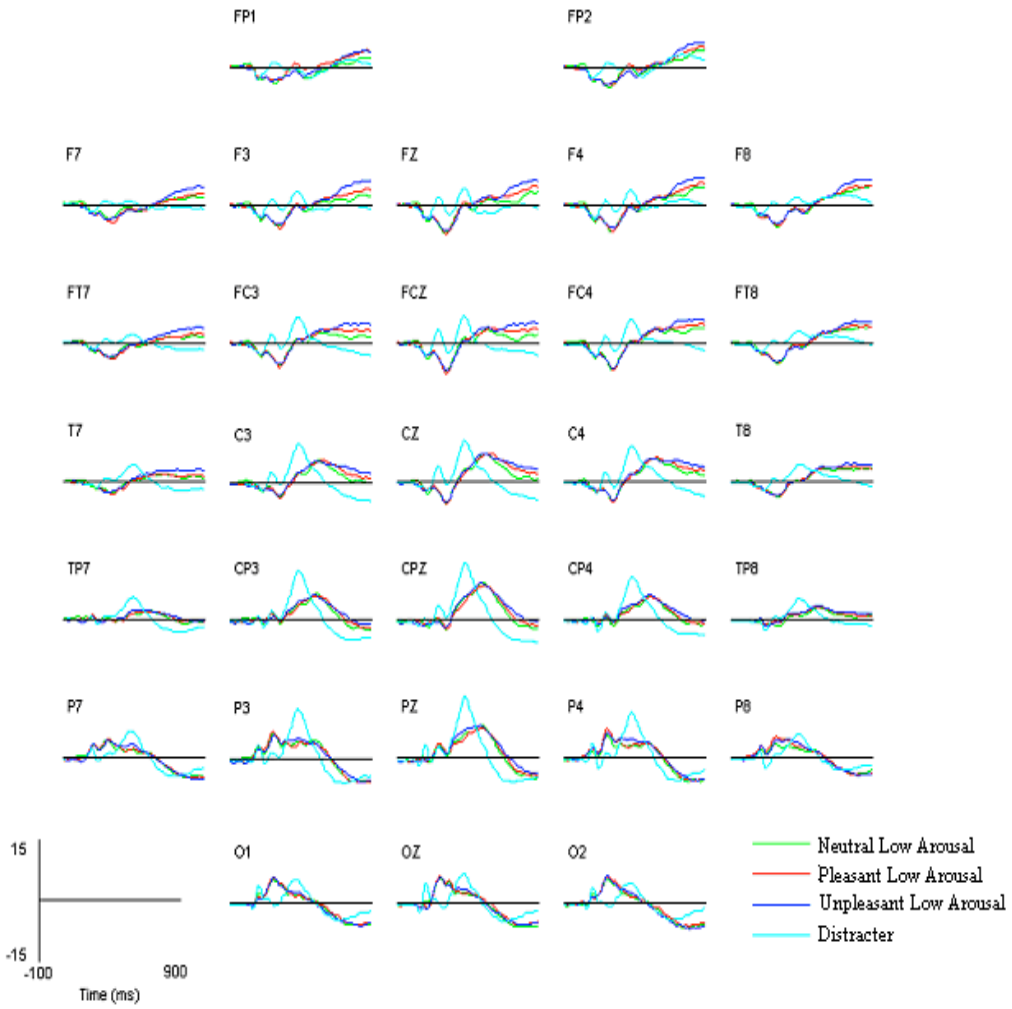


Figure 11b. Grand mean averages for low arousing picture stimuli and distracters.

P3b Amplitude

The five-way mixed ANOVA conducted on the P3b amplitude data indicated that P3b amplitude differed significantly as a function of Picture Category, $F(1.77, 46.05)=7.90$, $MSE=10.49$, $p<.001$, and differed significantly between Coronal sites, (1.80, 46.91)=72.66, $MSE=49.4$, $p<.001$. Trends toward significant main effects were shown for Sagittal site, $F(1.15, 30.00)=3.13$, $MSE=17.9$, $p=.05$, and Arousal, $F(1,26)=3.62$, $MSE=37.1$, $p=.07$, and the main effect of Sex was not significant, $F(1,26)=.08$,

MSE=.08, *p*=.78. These effects were qualified by a significant two-way interaction between Picture Category and Arousal, *F*(1.94, 50.46)=6.68, *MSE*=53.8, *p*<.01, as shown in Figure 12.

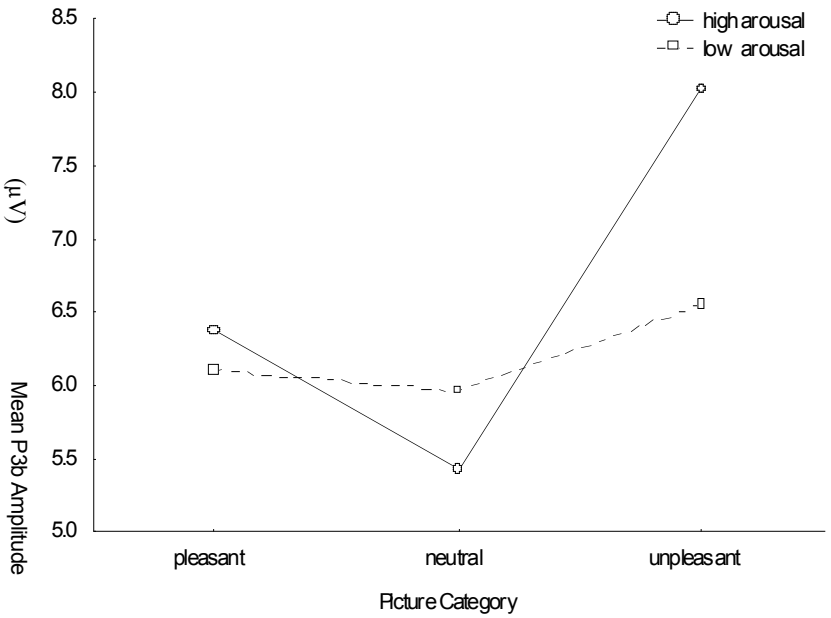


Figure 12. Mean P3b amplitude in response to high and low arousing neutral, pleasant, and unpleasant stimuli.

Tukey post hoc tests indicated that P3b amplitude was significantly larger in response to high compared to low arousing unpleasant stimuli (*p*<.05), with no significant difference between high and low arousing pleasant or high and low arousing neutral stimuli (*p*s>.05). P3b amplitude was also significantly larger in response to high arousing unpleasant compared high arousing pleasant and neutral stimuli (*p*s<.05) which did not differ significantly, and no significant differences were shown between low arousing picture stimuli (*p*s>.05). The current results add support for the negativity bias for LPP amplitude shown in previous research (Ito et al., 1998a; Delplanque et al., 2005;

2006), and it can be assumed with a degree of confidence that the differences shown in the ERP data are a result of differences in motivational relevance. High arousing pleasant images of sport/adventure and high arousing unpleasant images of human mutilation and attack were matched for affective arousal and differed in motivational characteristics; therefore it is assumed that P3b amplitude is reliably modulated by the inherent motivational relevance of the stimuli. No significant differences were shown between high and low arousing neutral or between high and low arousing pleasant stimuli, therefore it is assumed that the motivational relevance of the unpleasant stimuli in particular, had a more profound effect on P3b amplitude modulation than level of arousal.

P3b Latency

The ANOVA conducted on the latency data indicated that the main effects of Sagittal site, $F(1.31, 33.99)=99.10$, $MSE=12752$, $p<.001$, Coronal site, $F(2.46, 63.99)=2.97$, $p<.05$, and Arousal, $F(1,26)=6.13$ $MSE=12752$, $p<.05$, were significant and a trend toward a significant main effect of Picture Category was also shown, $F(1.81, 47.21)=2.96$, $MSE=18.37$, $p=.06$. P3b latency was significantly longer in response to low arousing ($M=45.27$ms, $SEM=8.41$) compared to high arousing stimuli ($M=444.39$ms, $SEM=8.06$) (ps$<.05$). No significant higher order interactions were revealed.

Hemispheric Lateralisation and P3b Amplitude

As no early components were evoked at frontal sites in Experiment 1, no support can be provided for the hemispheric lateralisation of approach and withdrawal systems within the left and right frontal regions (see Davidson, 1992; 1993a; Davidson et al., 1990;

Heller, 1990; 1991). The data supporting the regional activation hypothesis proposed by the aforementioned researchers was obtained using EEG frequency band measures and not ERP measures and thus the current results can not bear much weight in terms of the validity of this model. While it is acknowledged that EEG averaging could have been performed in the frequency domain, it was beyond the scope of the current thesis to do so. Analyses were performed by comparing the left (P3) and right (P4) parietal electrode sites in order to test the hypothesis that the magnitude of the valence and arousal effects would be larger in the right parietal region due to the proposed regional specialization of this area for valence and arousal information processing (Davidson, 1993a; Heller, 1990; 1991).

Analysis of variance conducted on the P3b amplitude data showed no significant main effect of Hemisphere, $F(1,27)=.01$, $MSE=9.52$, $p=.91$, and no significant higher order interactions were found. Given the absence of a significant higher order interaction between picture category, arousal level, and hemispheric region, no evidence was provided for the specialisation of the right parietal region for the processing of valence and arousal information. It is likely that event-related EEG measures are not sufficiently sensitive enough to detect the possible lateralisation effects of affective information processing due to the poor spatial resolution of ERP measures, and as such, conclusions based on the current results must be made tentatively.

Summary

A negativity bias was demonstrated for the ERP data with enhanced P3b amplitudes for highly arousing unpleasant compared to highly arousing pleasant and neutral stimuli. These results are assumed to reflect enhanced attentional engagement with motivationally relevant stimuli rather than an arousal modulation, as high arousing

pleasant sporting images and high arousing unpleasant images were matched for arousal level but differed in motivational qualities. Little support for a negativity bias was demonstrated at a behavioural level, however the behavioural data did provide some evidence of sex differences in affective responses. The correlation analysis provided some evidence that females are more defensively activated than males and males alternately were more appetitively activated in response to non-sexual pleasant stimuli. No significant differences between the sexes were revealed at an electrophysiological level, which suggests that males and females utilise similar cognitive processes and resources for the processing of motivationally relevant stimuli. The absence of sex differences at an electrophysiological level also points towards a possible dissociation between cognitive and overt responses to affective stimuli.

Experiment 2: Appetitive and Aversive Cues

Highly arousing unpleasant images prompted P3b amplitude enhancements in Experiment 1, suggesting that greater attentional resources were required to process motivationally relevant aversive cues compared to all other affective stimuli. A negativity bias was therefore demonstrated for the ERP data, however in order to fully investigate the best fitting model of affective picture processing, be it the quadratic effect or the negativity bias, and to draw valid inferences as to the independent effects of motivational relevance and arousal, comparisons need to be made between motivationally relevant pleasant and unpleasant stimuli that are matched on affective arousal. A highly arousing and motivationally relevant sexual category of slides is therefore included in Experiment 2. A low arousing sexual or romantic category of slides is also included in order for the experiment to be fully factorial, although no significant differences are predicted between low arousing stimuli based on the results of

Experiment 1. Highly arousing images of human mutilation, death, and sex have important implications for survival however as previously noted, the implications for aversive events are more immediate than for equally intense pleasant events. Following this assumption, it is predicted that P3b amplitude will be significantly larger in response to both highly arousing sexual and unpleasant stimuli compared to highly arousing pleasant (sport/adventure) and neutral stimuli, and compared to low arousing stimuli which do not share the same survival value. P3b amplitude is, however, predicted to be larger in response to highly arousing unpleasant compared to highly arousing sexual stimuli due to the differences in immediate survival value conveyed by these stimuli and based on evidence of a negativity bias demonstrated in Experiment 1.

Previously, it was speculated that the intermixing of arousal level and hence semantic contents may create a possible confound that is responsible for the quadratic effect frequently observed in affective picture processing research. This speculation follows from Schupp et al.'s (2004a) study that showed ERP component measures (P3b and PSW) to be differentially modulated by specific picture contents, however when analyses were performed by averaging ERPs across picture contents, no significant difference in P3b or PSW amplitudes were observed between pleasant and unpleasant stimuli. In order to investigate the possible confounding influence of intermixing arousal and semantic contents, ERPs will be averaged across high and low arousing picture contents for each valence category in Experiment 2. It is therefore predicted that under these conditions, the quadratic effect will be replicated, with significantly larger P3b amplitudes observed in response to both pleasant and unpleasant stimuli compared to neutral, and no significant difference observed between pleasant and unpleasant stimuli.

The early positive components that have shown enhancements in response to unpleasant stimuli in previous research (e.g., P2: Delplanque et al., 2004; P1: Smith et

al., 2003) were not elicited in Experiment 1. It is speculated that the absence of an early positive component in Experiment 1 resulted from the use of mixed affective stimuli as standard non-target stimuli and thus the repeated exposure of pictorial stimuli. Ito et al. (1998a), Loew et al. (2003), and Schupp et al. (2000) repeatedly exposed participants to a limited set of pictorial stimuli and showed reliable modulation of LPP amplitude however no early endogenous components were elicited. Delplanque et al. (2004) however showed P2 amplitude modulations as a function of valence using a modified oddball paradigm where a non-affective red and white checker-board served as the standard stimuli. Following these considerations, a non-affective standard stimulus will be presented in the modified oddball paradigm for Experiment 2 with the aim of eliciting an early positive component. Assuming that the early positive components are also sensitive to the motivational characteristics of the eliciting stimuli, the hypotheses for P3b amplitude are also applied to the early positive components.

The behavioural data of Experiment 1 provided some evidence that females are behaviourally more defensively activated than males which is consistent with the previous research of Bradley et al. (2001b). Bradley et al. also indicated that males demonstrate heightened appetitive activation compared to females which is specific for erotic stimuli. Based on the inclusion of highly arousing sexual stimuli in Experiment 2, it is predicted that at a behavioural level, males will show heightened appetitive activation, rating the sexual stimuli as significantly more pleasant and significantly more arousing than females. Given that females demonstrated heightened defensive activation compared to males, it is expected that females a will rate the unpleasant stimuli as significantly more unpleasant and significantly more arousing compared to males. In terms of the strength of the motivational vectors for males and females, it is expected that the positive correlation between the ratings of valence and arousal for sexual stimuli

will be significantly stronger for males than for females, and conversely, the negative correlation predicted between the ratings of valence and arousal for unpleasant pictures will be significantly stronger for females compared to males.

No significant sex differences in affective picture processing were demonstrated at an electrophysiological level in Experiment 1 and as such, no significant sex differences are expected for the ERP data in response to high and low arousing pleasant, unpleasant, and neutral stimuli in Experiment 2. However, although no significant sex differences were shown for the ERP data in Experiment 1, the inclusion of highly arousing sexual stimuli in Experiment 2 is expected to highlight potential sex differences in response to appetitive information. Males have been shown to demonstrate heightened physiological (e.g., Bradley et al., 2001b) and cortical activation (e.g., Karama et al., 2001) in response to erotic stimuli compared to females, therefore it is predicted that males will demonstrate enhanced appetitive activation in response to the highly arousing sexual stimuli compared to females, reflected by significantly larger ERP component amplitudes (P2 and P3b) in response to these stimuli.

Experiment 1 failed to show any evidence of hemispheric lateralisation, although the early positive components that may have been sensitive to hemispheric lateralisation were not evoked. It is therefore predicted that if an early positive component is evoked at frontal regions, then the processing of unpleasant affect will be lateralised to the right frontal region and the processing of pleasant affect will be lateralised to the left frontal regions, with the largest lateralisation effects demonstrated for high arousing and motivationally relevant stimuli. P3b amplitude did not show lateralisation effects in Experiment 1 therefore no significant differences are expected between the left and right hemispheres for P3b amplitude.

Method

Participants

Participants were 17 male (*M* age=21.06 years, *SD*=5.73; *Age Range*: 18-36) and 17 female (*M* age=22.06 years, *SD*=4.76, *Age Range*: 18-33) first year psychology students at the University of Tasmania who were right handed, with normal or corrected to normal vision. Participants were excluded following the criteria outlined in Experiment 1, and were all heterosexual to maximise the motivational relevance of mixed couple pictorial erotic stimuli.

Apparatus, stimuli, and EEG recording

Data acquisition procedures and EEG recording equipment were the same as that outlined in Experiment 1. Averages were also calculated for overall pleasant, neutral, and unpleasant picture categories by collapsing ERPs for high and low arousing picture categories. Averages with greater than 25 trials were accepted for analyses. Fifteen of each of high and low arousing pleasant, unpleasant, and neutral stimuli were selected from the picture set used in Experiment 1 based on the median score criteria outlined in Experiment 1. Fifteen highly arousing erotic stimuli with mean valence and arousal ratings of six and above (see Appendix B) were selected from the IAPS. Erotic couple stimuli were presented in the high arousing sexual category in order to reduce the variability associated with the use of opposite sex nudes as opposite sex nudes appear to be more effective at eliciting heightened appetitive activation in males compared to females as inferred by behavioural and physiological responses (Bradley et al., 2001b). Although Schupp et al. (2004a) showed no significant difference in ERP component measures (P3b, Probe P3, and PSW) between males and females in response to opposite sex erotica or in response to erotic couple stimuli, erotic couple stimuli were preferred

over opposite sex erotica in the current study as the images depicted sexual interaction that are relevant for both heterosexual males and females. Schupp et al. also showed no significant difference in ERP component measures between erotic couple stimuli and opposite sex erotica, therefore the use of erotic couple stimuli in Experiment 2 was considered to be appropriate. The low arousing sexual category of slides consisted of IAPS stimuli depicting romantic couples, which had mean valence ratings of six and above and mean arousal ratings less than five (see Appendix B). The distribution of valence and arousal ratings of the stimuli presented in Experiment 2 is illustrated in Figure 13. A red and white checker board was also selected from the IAPS for use as the standard stimulus (IAPS number: 7182).

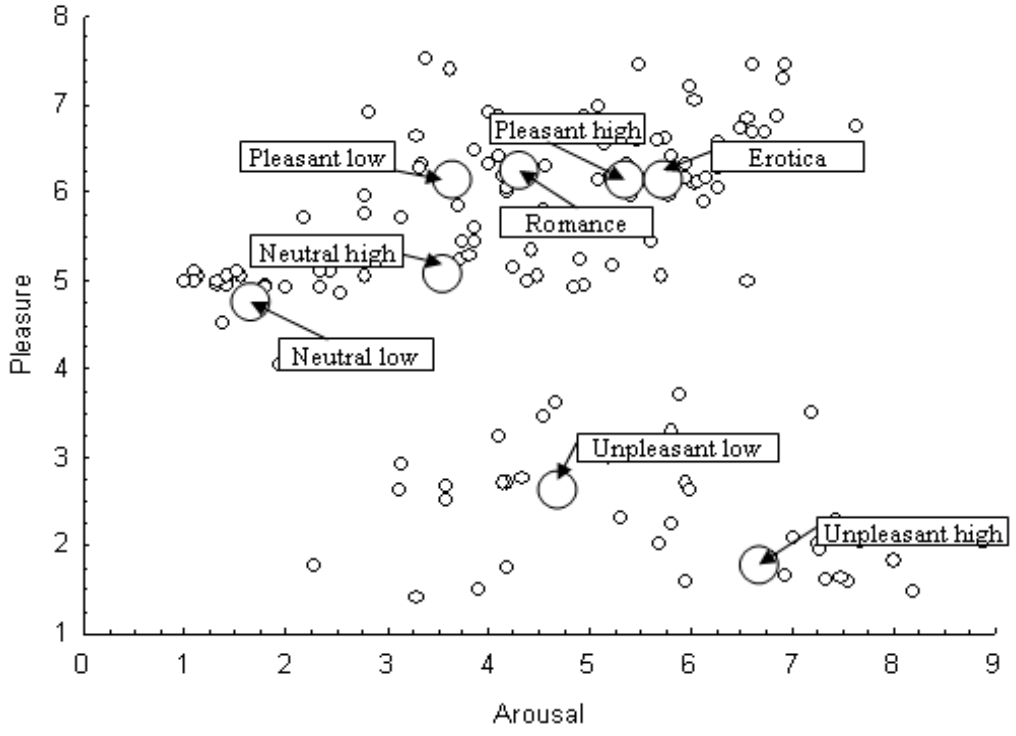


Figure 13. Distribution of valence and arousal measures for stimuli in Experiment 2.

IAPS stimuli were converted to PCX form and standardised in size in the same manner as Experiment 1. A modified two stimulus oddball paradigm was used to present the stimuli in Experiment 2. For ERP averaging purposes, each affective stimulus was presented twice. The affective target stimuli (neutral, pleasant, sexual, and unpleasant) were presented with a probability of .30 and standard stimuli with a probability of .70. The oddball condition contained 800 trials overall, 240 affective and 560 standard stimuli, and lasted approximately 20 minutes. Each slide was presented centrally for 200ms, with an ISI that varied randomly between 1000 and 2000ms. Spielberger et al.'s (1983) STAI was used to measure levels of state and trait anxiety. Again, the pictorial stimuli were presented for 2000ms at a size approximating the 13 inch computer monitor for the post experimental ratings.

Procedure

Participants were informed as to the purpose of the study and after reading the information sheet, completed the participant consent form and a brief medical questionnaire. The state and trait versions of the STAI were then completed. Participants had electrodes attached and were seated in a sound attenuated room. The oddball task was then presented and participants were instructed to respond to any picture that was not the standard red and white checkerboard by pressing a button on a response pad with their right index finger. Requiring a response to all target stimuli was intended to reduce the pattern of missing data seen in Experiment 1. The participants were instructed to pay attention to the content of each slide and were told that they would have to answer some questions about the stimuli after the experiment. Instructing participants to actively attend to the content of each image was intended to ensure that affective evaluation of the stimuli occurred. After the experimental task was complete, participants were

required to group the stimuli into as many common categories as they could think of. The pictorial stimuli were then re-presented and participants were required to rate each slide on level of valence, arousal, and approach/avoidance tendency, on a nine-point Likert scale via a computer monitor. For the approach/avoidance scale, participants were instructed to think of themselves in relation to each image and to rate the degree to which they would desire to be the person in the image or be involved in the situation depicted in the image and the degree to which they would avoid the depicted person and/or situation. The state version of the STAI was then re-administered.

Design

The experiment followed a 2[Sex: male, female] x 4(Picture Category: neutral, pleasant, sexual, unpleasant) x 2(Arousal: high, low) mixed factorial design, with electrode site leading to two further repeated measures variables of Sagittal and Coronal sites. Inspection of the grand mean waveforms (see Figures 22a, b, & c) indicated the presence of two positive components identified as P2 and P3b. The P2 component was elicited over centro-parietal and parietal sites, while the P3b component was again elicited over central, centro-parietal, and parietal sites. An N2 component was also elicited at fronto-central sites, however the N2 component was not included as a dependent measure for the ERP data based on the considerations outlined in Experiment 1. The dependent variables for the ERP data therefore were P2 and P3b amplitude and latency, and reaction time, accuracy, ratings of valence, arousal, and approach/avoidance tendencies, and scores on the state and trait versions of the STAI were the dependent measures for the behavioural data.

Data Analysis

Means and standard errors were calculated for the valence, arousal, and approach/avoidance ratings for each high and low arousing affective target. Means and standard errors were also calculated for the reaction time data for each correct response, and for the accuracy data. Three-way ANOVAs with Sex as the between subjects factor and Picture Category (neutral, pleasant, sexual, and unpleasant) and Arousal (high, low) as the within subjects factors were used to analyse the behavioural data. Means and standard errors were also calculated for scores on the pre- and post- STAI measures. Two-way ANOVAs with Sex as the between subjects factor and State (pre, post-experiment) as the within subjects factor were used to analyse the state anxiety data and an independent samples *t*-test was used to analyse the trait anxiety data. Pearson's correlations were again performed on the valence and arousal ratings for males and females separately as outlined in Experiment 1.

ERP waveforms for each high and low arousing neutral, pleasant, sexual, and unpleasant target stimulus were scored for peak amplitude. The P2 component was measured for peak amplitude between 150 and 250ms post-stimulus onset and the P3b component between 300 and 500ms post-stimulus onset. Standard stimuli were not subjected to statistical analysis as the interest lies with the affective stimuli that were actively evaluated. The means for each ERP component amplitude and latency were assessed using five-way mixed ANOVAs, with Sex [male, female] as the between subjects factor, and Picture Category (neutral, pleasant, sexual and unpleasant), Arousal (high, low), Sagittal site (central, centro-parietal, and parietal sites, depending on component topography) and Coronal site (far left, left, midline, right, far right) as the within subjects factors. Again, significant main effects and interactions involving sagittal and coronal sites will not be discussed unless they are of theoretical significance.

As mentioned previously, ERP averages were combined for high and low arousing picture contents in order to investigate whether intermixing arousal level (therefore semantic contents) may be responsible for the quadratic effect frequently reported in affective picture processing research. P3b amplitude and latency data for the combined data was analysed using three-way repeated measures ANOVAs with Picture Content (neutral, pleasant, unpleasant), Sagittal site, and Coronal sites as the within subjects variables. As noted previously, the P2 component was evoked at centro-parietal and parietal sites and since the hypotheses regarding hemispheric lateralisation pertained to the frontal regions, statistical analysis regarding hemispheric lateralisation effects were not performed on the P2 data. P3b amplitude was however analysed for hemispheric effects, with factors of Picture Category, Arousal, and Hemisphere Site (left parietal electrode, right parietal electrode) as the repeated measures factors. Statistical procedures were the same as that outlined in Experiment 1.

Results and Discussion

Behavioural Data

STAI

The two-way mixed ANOVA conducted on the state anxiety data failed to show a significant increase in state anxiety from pre to post experimental periods, $F(1,33)=2.54$, $MSE=41.85$, $p=.12$. State anxiety did not differ significantly between males and females, $F(1,33)=.54$, $MSE=196.61$, $p=.82$, and no higher order interactions were revealed. Trait anxiety also did not differ significantly between males and females, $t(33)=.26$, $p=.79$.

Accuracy

For the accuracy data, the main effects of Picture Category, $F(2.38, 76.18)=.74$, $MSE=.70$, $p=.53$, Arousal, $F(1,32)=.94$, $MSE=.50$, $p=.34$, and Sex, $F(1,32)=1.51$, $MSE=4.5$, $p=.23$, were not significant and no interactions reached significance.

Reaction Time

ANOVAs conducted on the reaction time data indicated that RT differed as a function of Picture Category, $F(2.31, 73.80)=19.23$, $MSE=.009$, $p<.001$, but did not differ overall as a function of Arousal, $F(1,32)=.47$, $MSE=.0002$, $p=.50$ or Sex, $F(1,32)=.024$, $MSE=.023$ $p=.88$. A significant two-way interaction was shown between Picture Category and Arousal, $F(2.79, 89.35)=11.37$, $MSE=.0003$, $p<.001$, as shown in Figure 14.

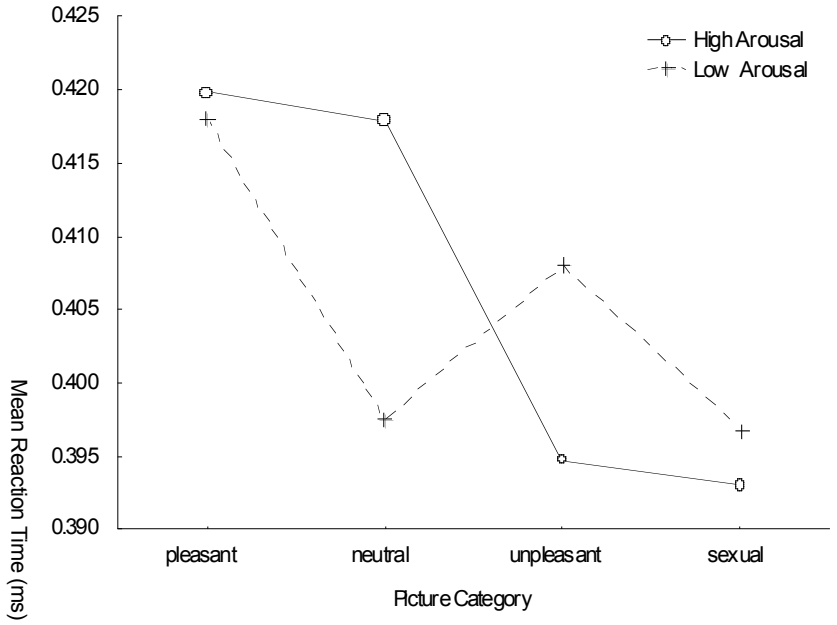


Figure 14. Mean reaction time in response to high and low arousing picture categories.

Tukey post hoc tests indicated that RT was significantly faster in response to low arousing neutral compared to high arousing neutral stimuli ($p<.05$), with no significant

difference in RT between high and low arousing pleasant, high and low arousing unpleasant, or high and low arousing sexual stimuli (*p*s>.05). Differences in visual complexity are assumed to account for the differences in response times observed between high and low arousing neutral stimuli, with greater time taken to respond to the more visually complex high arousing neutral stimuli (surreal images). There were no significant differences in RT between the high arousing sexual and unpleasant stimuli, and both categories of slides were responded to significantly faster than high arousing pleasant and neutral stimuli, indicating that the motivationally relevant stimuli were evaluated more rapidly, reminiscent of the quadratic effect at a behavioural level. RT was not shown to differ meaningfully as a function of picture content for the low arousing stimuli, as RT was significantly faster in response to low arousing neutral and sexual stimuli compared to pleasant and unpleasant stimuli (*p*s <.05).

Valence Ratings

Valence ratings differed as a function of Picture Category, $F(2.08, 64.43)=213.08$, $MSE=1.40$, $p<.001$, but did not differ as a function of Arousal, $F(1,31)=.74$, $MSE=.70$, $p=.79$, or Sex, $F(1,31)=.45$, $MSE=2.60$, $p=.50$. A significant two-way interaction was revealed between Picture Category and Arousal as shown in Figure 15.

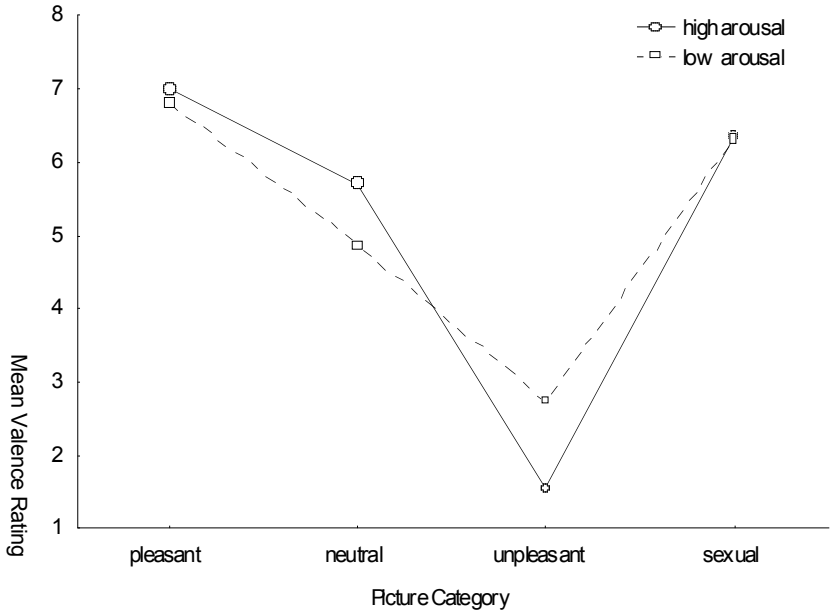


Figure 15. Mean valence ratings for high and low arousing neutral, pleasant, sexual, and unpleasant stimuli.

Tukey post hoc tests showed no significant difference in valence ratings between high and low arousing pleasant or between high and low arousing sexual stimuli. Consistent with Experiment 1, high arousing neutral stimuli were rated as significantly more pleasant than low arousing neutral stimuli and high arousing unpleasant stimuli were rated as significantly more unpleasant than low arousing unpleasant stimuli ($ps<.05$). High arousing pleasant stimuli were rated as significantly more pleasant than high arousing sexual stimuli ($p<.05$), with no significant difference between the valence ratings for low arousing pleasant and sexual stimuli. For both high and low arousing picture categories, pleasant and sexual stimuli were rated as significantly more pleasant than neutral and unpleasant stimuli, and neutral stimuli were rated as significantly more pleasant than unpleasant stimuli ($ps<.05$).

A significant three-way interaction was revealed between Picture Category, Arousal, and Sex, $F(2.45, 76.06)=2.74$, $MSE=.40$, $p<.05$, however as shown in Figure 16, and confirmed by Tukey post hoc tests, males and females did not differ significantly in their ratings of valence for high or low arousing stimuli. Although no individual mean comparisons reached significance, the graph does suggests that females generally rated pleasant stimuli higher and high arousing sexual stimuli lower than their male counterparts. Some partial support is therefore provided for the hypothesis that males would demonstrate greater appetitive activation, reflected by increased ratings of pleasantness for high arousing sexual stimuli compared to females. No evidence however was provided to support the hypothesis that females would demonstrate heightened defensive activation compared to males in terms of valence ratings.

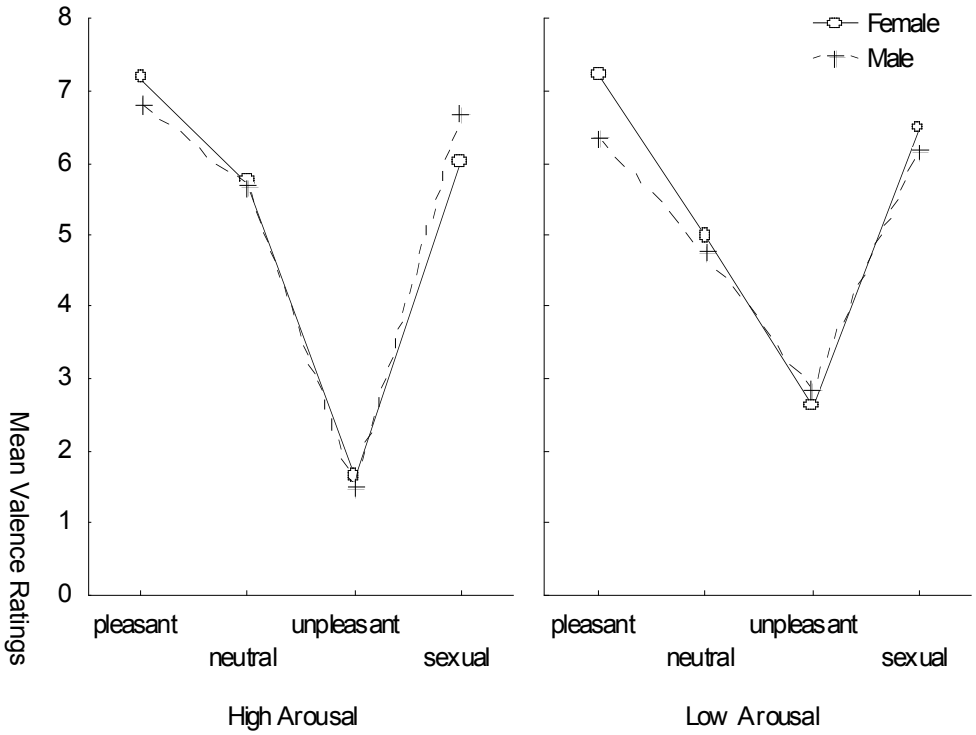


Figure 16. Mean valence ratings for each picture category for males and females.

Arousal Rating Data

Arousal ratings differed as a function of Picture Category, $F(2.18, 67.75)=28.62$, $MSE=3.20$, $p<.001$, and Arousal, $(1,31)=125.36$, $MSE=1.93$, $p<.001$, but did not differ as a function of Sex, $F(1,31)=.37$, $MSE=11.25$, $p=.55$. A significant two-way interaction was revealed between Picture Category and Arousal, $F(2.39, 74.22)=3.47$, $MSE=1.07$, $p<.05$, as shown in Figure 17.

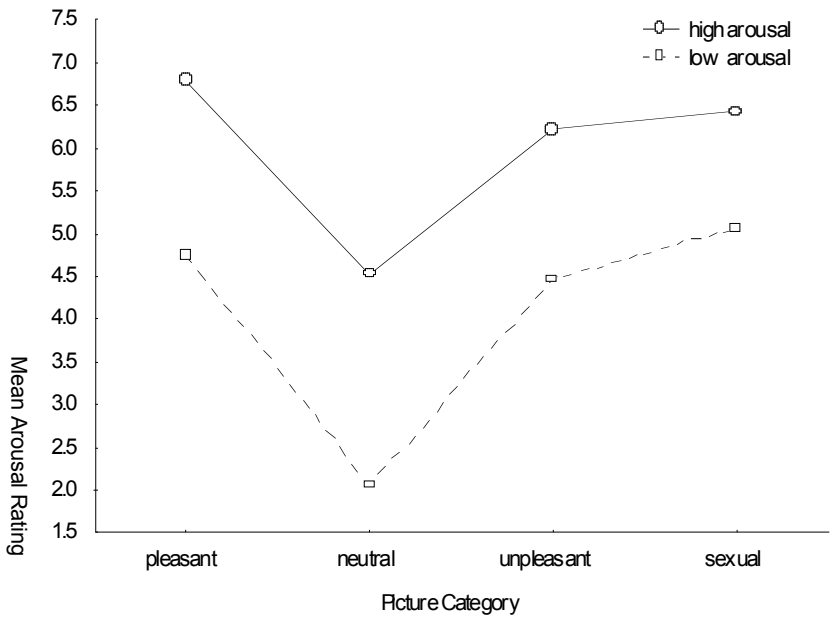


Figure 17. Mean arousal ratings for high and low arousing neutral, pleasant, sexual, and unpleasant stimuli.

Tukey post hoc tests indicated that all high arousing stimuli were rated as significantly more arousing than respective low arousing stimuli, and for both high and low arousing picture categories, pleasant, sexual, and unpleasant stimuli were matched on rated arousal and were rated as significantly more arousing than respective neutral stimuli (ps<.05). Affective stimuli (pleasant, sexual, and unpleasant) were matched for level of

arousal within both high and low arousing picture categories therefore valid comparisons can be made between affective stimuli differing in valence and semantic content.

A significant two-way interaction was identified between Picture Category and Sex, $F(2.18, 67.75)=3.75$, $MSE=3.29$, $p=.01$ (see Figure 18), and although Tukey post hoc tests failed to reveal any significant difference between male's and female's ratings of arousal for each picture category, the graph suggests that females rated unpleasant stimuli as more arousing than males. Females were shown to rate unpleasant stimuli as significantly more unpleasant than males in Experiment 1 but not in Experiment 2. The arousal rating data for Experiment 2 add some support for the theory that females are more defensively activated than males, as outlined by Bradley et al. (2001a). No evidence of increased appetitive activation was shown for male participants in arousal ratings.

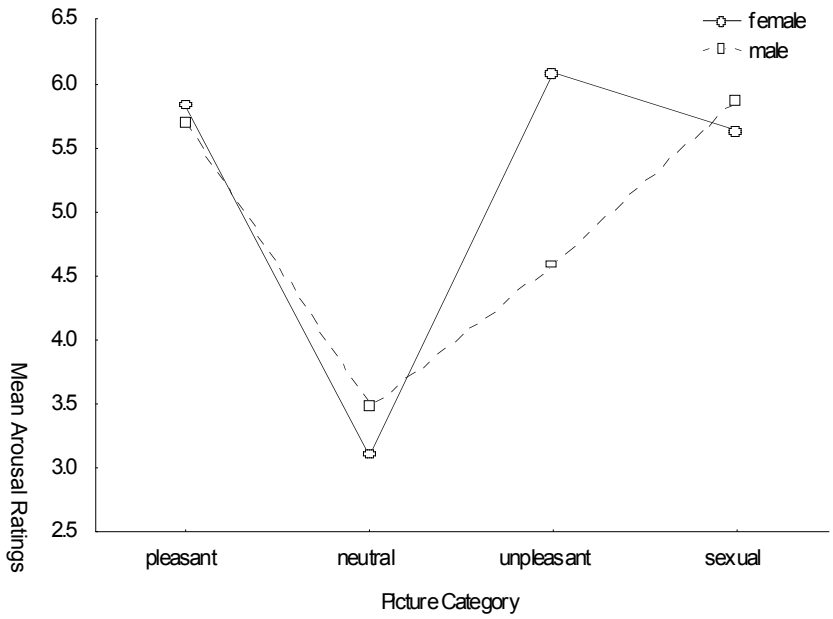


Figure 18. Mean arousal ratings for neutral, pleasant, sexual, and unpleasant stimuli for males and females.

Valence and Arousal Correlations for Males and Females

Correlational analyses were performed on the valence and arousal rating data for males and females separately, again revealing some sex differences in appetitive and aversive activation. As can be seen in Figures 19 and 20, males appear show a stronger coupling between ratings of valence and arousal for high arousing unpleasant stimuli, however female's ratings of the high arousing unpleasant stimuli tended to cluster more toward the extreme end of the arousal quadrant compared to males. A few notable outliers can be observed for both males and females in response to the high arousing unpleasant stimuli. Low arousing unpleasant stimuli appear to have received greater arousal ratings by females compared to males, and the spread of scores appears to be larger for males. The ratings of the high arousing pleasant stimuli appear to cluster in the high arousal quadrant more so for females than males, with little difference in the pattern of scores for the valence and arousal ratings of low arousing pleasant or low arousing sexual stimuli between males and females. In regard to the high arousing sexual stimuli, the spread of scores appears fairly similar for males and females, however there are a few notable outliers shown in the female data, where high arousing sexual stimuli have been rated as both low arousing and unpleasant in one case, and high arousing and unpleasant in the other case.

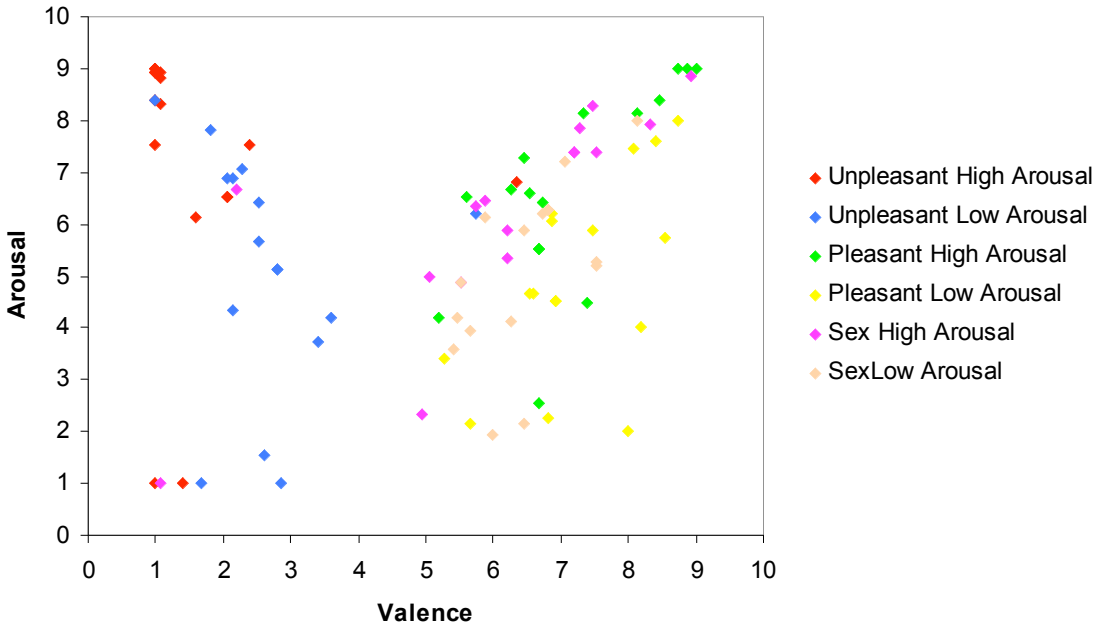


Figure 19. Correlation between ratings of valence and arousal for high and low arousing picture categories for female participants.

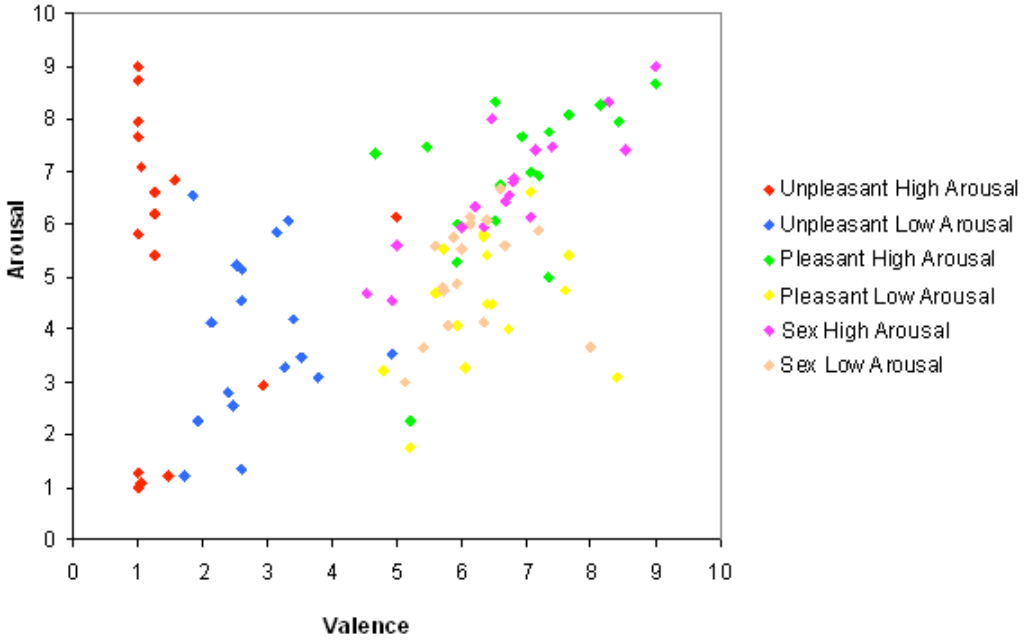


Figure 20. Correlation between ratings of valence and arousal for high and low arousing picture categories for male participants.

Pearson's *r* correlation coefficients and the significance level are illustrated in Table 2. In line with Experiment 1, both males and females showed a moderate to strong positive correlation between valence and arousal for high arousing pleasant stimuli, significant at the .05 level. Unlike Experiment 1, the correlation appears to be stronger for females, reinforcing the need to interpret the results of the correlational analyses of Experiments 1 and 2 with caution given the small sample size. A moderate positive correlation was shown between female's ratings of valence and arousal for low arousing pleasant stimuli, significant at the .05 level and, in line with the results of Experiment 1, a moderate positive correlation was shown between female's ratings of valence and arousal for high arousing neutral stimuli and a moderate negative correlation was shown between ratings of valence and arousal for low arousing neutral stimuli, significant at the .05 level. Males did not show any significant correlations between valence and arousal ratings for high and low arousing neutral stimuli, and no significant correlations were shown between ratings of valence and arousal for high and low arousing unpleasant stimuli for males or females. Moderate to strong positive correlations were shown between ratings of valence and arousal for high arousing sexual stimuli for both males and females, significant at the .001 level. A moderate positive correlation was shown between ratings of valence and arousal for low arousing sexual stimuli, significant at the .05 level for females only.

Table 2

Pearson's Correlation Coefficients for Correlations between Valence and Arousal Ratings for Males (N=17) and Females (N=17).

	Female		**Male**	
Picture Category	*r*	*p*	*r*	*p*
Pleasant High: valence/arousal	.69	* .003	.54	* .026
Pleasant Low: valence/arousal	.56	* .025	.26	.32
Neutral High: valence/arousal	.69	* .003	.39	.12
Neutral Low: valence/arousal	-.51	* .041	-.09	.73
Unpleasant High: valence/arousal	-.09	.73	-.04	.86
Unpleasant Low: valence/arousal	-.15	.58	-.1	.69
Sexual High: valence/arousal	.77	** .001	.88	** .001
Sexual Low: valence/arousal	.59	* .016	.22	.4

* $p<.05$, ** $p<.01$

It is unclear why no significant correlations were reported between ratings of valence and arousal for unpleasant stimuli in Experiment 2. Possible reasons could be attributed to the small sample size, however a trend toward a significant correlation for females was demonstrated in Experiment 1 with a similarly small sample. The most pertinent finding from the correlational analysis shown in Experiment 2 concerns the high arousing sexual stimuli. The hypothesis that males would demonstrate greater appetitive activation in response to sexual stimuli was not supported, as both males and females showed moderate to strong positive correlations between ratings of valence and arousal for high arousing sexual stimuli.

Approach/Avoidance ratings

Ratings of approach and avoidance tendencies differed as a function of Picture Category, $F(2.27, 70.24)=137.38$, $MSE=1.83$, $p<.001$, and did not differ as a function of Arousal, $F(1,31)=.34$, $MSE=1.20$, $p=.63$, or Sex, $F(1,31)=.73$, $MSE=3.74$, $p=.40$. A significant

two-way interaction was revealed between Picture Category and Arousal, $F(2.68, 83.08)=15.09$, $MSE=.62$, $p<.001$, as shown in Figure 21.

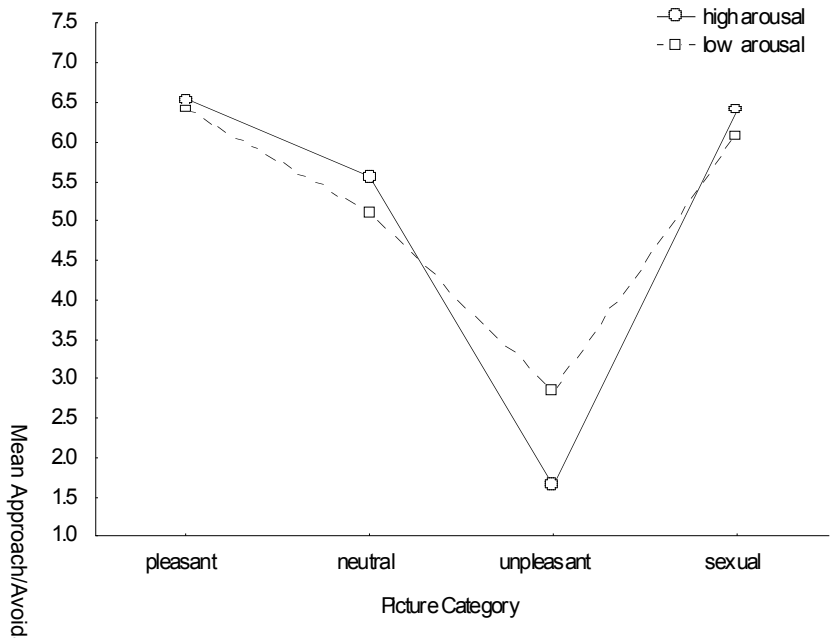


Figure 21. Mean approach and avoidance ratings for high and low arousing picture categories (Note: high scores indicate approach and low scores indicate avoidance).

Tukey post hoc tests showed no significant difference in approach/avoidance ratings between high arousing pleasant and sexual stimuli and both picture categories were rated significantly higher on level of approach than neutral stimuli, and unpleasant stimuli were rated significantly higher than all picture categories on level of avoidance (ps<.05). The same results were shown for low arousing pictures. The only significant difference between high and low arousing picture stimuli was shown for unpleasant stimuli, with significantly greater avoidance ratings for high arousing unpleasant stimuli than for low arousing unpleasant stimuli ($p<.05$). The difference between high and low arousing unpleasant stimuli is consistent with the stronger correlation between

unpleasantness and arousal outlined by Bradley et al. (2001a), and the results of Experiments 1 and 2 whereby high arousing unpleasant stimuli were rated as significantly more unpleasant than low arousing unpleasant stimuli. The high arousing unpleasant stimuli are also more motivationally relevant than the respective low arousing stimuli, thus it follows that these stimuli would elicit stronger avoidance tendencies. There was no difference in approach ratings between high arousing pleasant and sexual stimuli, low arousing sexual and pleasant stimuli, high and low arousing pleasant stimuli, or high and low arousing sexual stimuli. These results suggest that the sexual stimuli may not be perceived as more motivationally relevant than the other pleasant picture categories.

ERP Data

Grand mean averages for correct responses to high and low arousing target stimuli were computed for 30 electrode sites. Grand mean averages were also computed for combined high and low arousing pleasant, neutral, and unpleasant stimuli. Figures 22a, b, and c show the presence of an early negative component at frontal, fronto-central, and central sites, identified as N2 which is consistent with Experiment 1. Preliminary analysis of the N2 component did not show any theoretically relevant effects and therefore the analysis is excluded from the current discussion (see Appendix K and T for details). A small amplitude P2 component was elicited over frontal and fronto-central sites in response to sexual stimuli only, and a more robust P2 component was elicited in response to all affective stimuli over centro-parietal and parietal regions (see Figure 22a). P2 amplitudes were larger in response to high arousing sexual and unpleasant stimuli compared to pleasant and neutral stimuli, with no observable difference in P2 amplitude between low arousing stimuli (see Figure 22b). The P3b component had a centro-parietal

maximum and was larger in response to high arousing sexual stimuli compared to all other affective stimuli. P3b amplitudes were also larger in response to high arousing unpleasant compared to high arousing pleasant and neutral stimuli.

High and low arousing picture categories were combined into general pleasant, unpleasant, and neutral categories and the grand mean waveforms are illustrated in Figure 22c. As can be seen there is little difference in P3b amplitude between pleasant and unpleasant stimuli, however both these picture categories evoked larger P3b amplitudes than neutral stimuli. The P2 component for combined high and low arousing contents is only reliably elicited over parietal sites and does not appear to be differentially modulated by affective content.

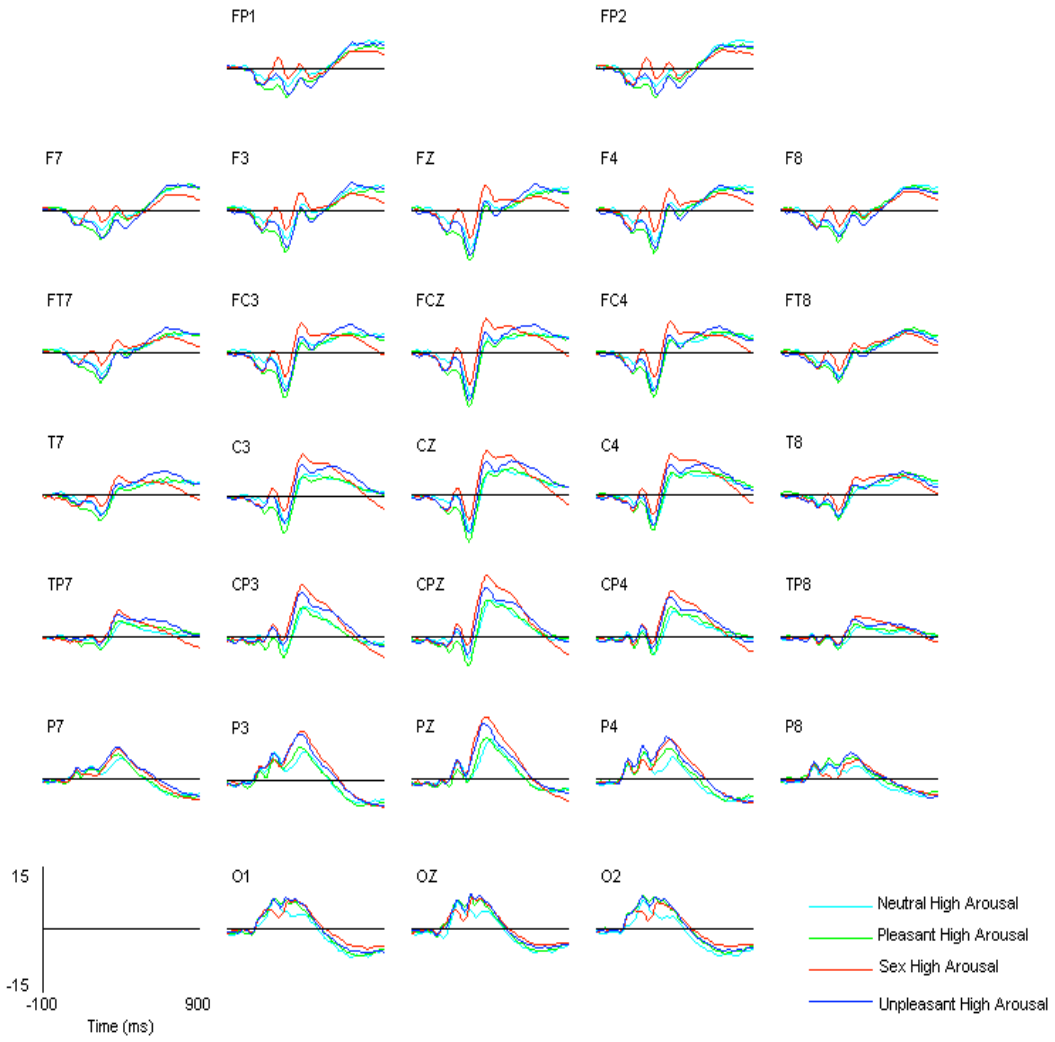


Figure 22a. Grand mean waveforms for high arousing picture categories.

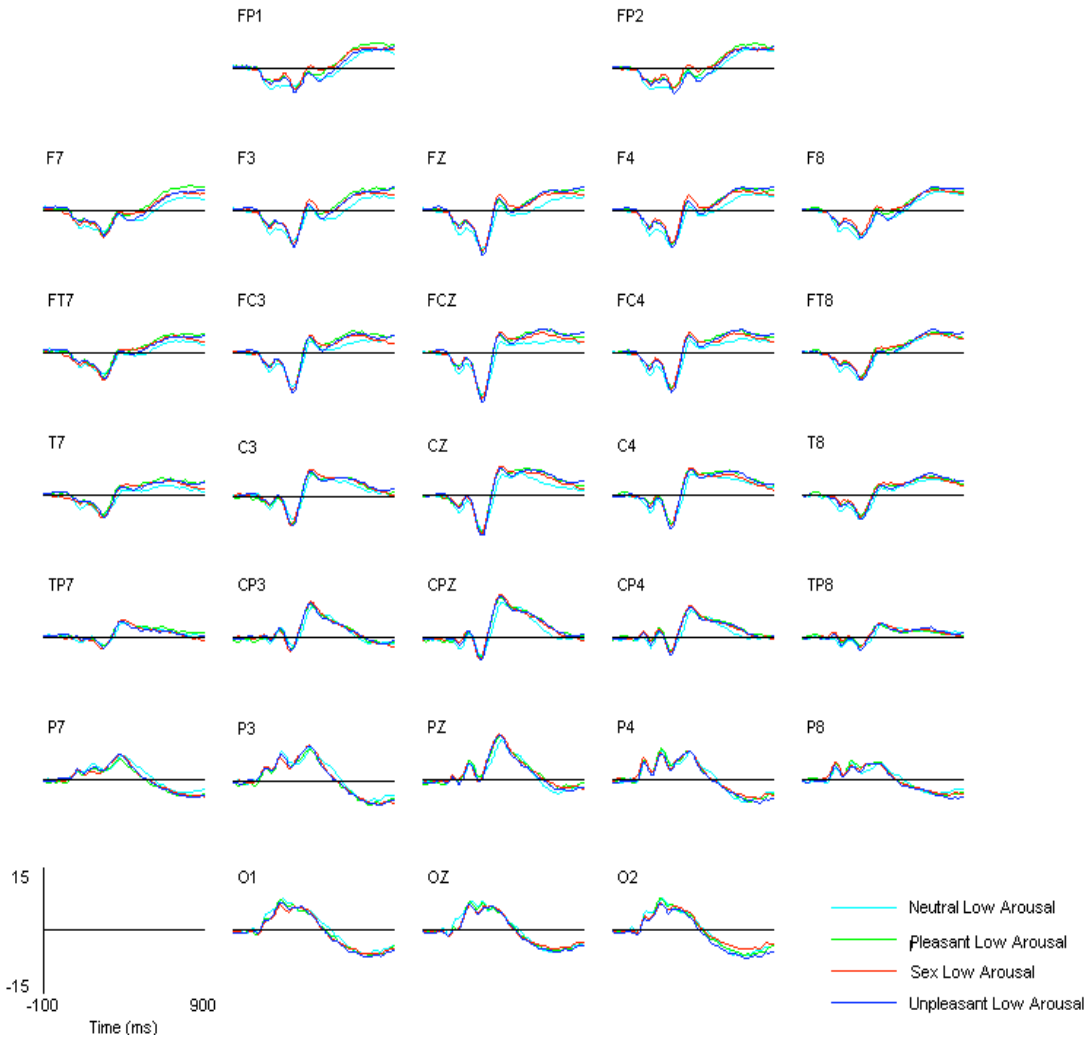


Figure 22b. Grand mean waveforms for low arousing picture categories.

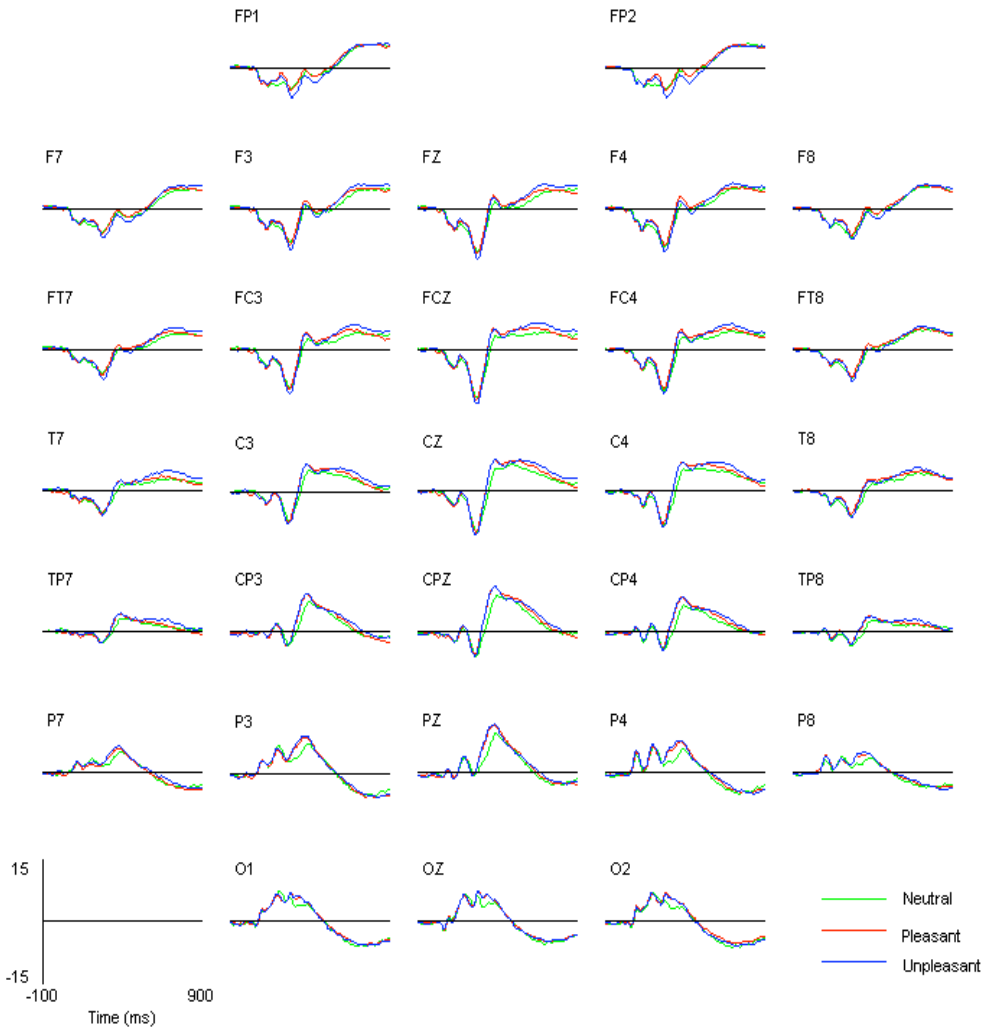


Figure 22c. Grand mean waveforms for neutral, pleasant, and unpleasant stimuli averaged across high and low arousing picture categories.

P2 Amplitude

The five-way mixed ANOVA conducted on the P2 amplitude data indicated that P2 amplitude differed as a function of Sagittal site, $F(1,32)=43.05$, $MSE=179.73$, $p<.001$, Coronal site, $F(2.61, 83.45)=12.62$, $MSE=69.69$, $p<.001$, and Sex, $F(1,32)=9.92$, $MSE=4776.44$, $p<.05$, with significantly larger P2 amplitudes for females ($M=5.62\mu V$, $SEM=.59$) compared to males ($M=2.97\mu V$, $SEM=.59$). There was also a trend towards a

significant main effect of Picture Category, $F(2.92, 93.53)=2.57$, $MSE=35.73$, $p=.059$, and a significant two-way interaction was revealed between Picture Category and Arousal, $F(2.69, 86.16)=3.86$, $MSE=25.86$, $p<.05$, as shown in Figure 23.

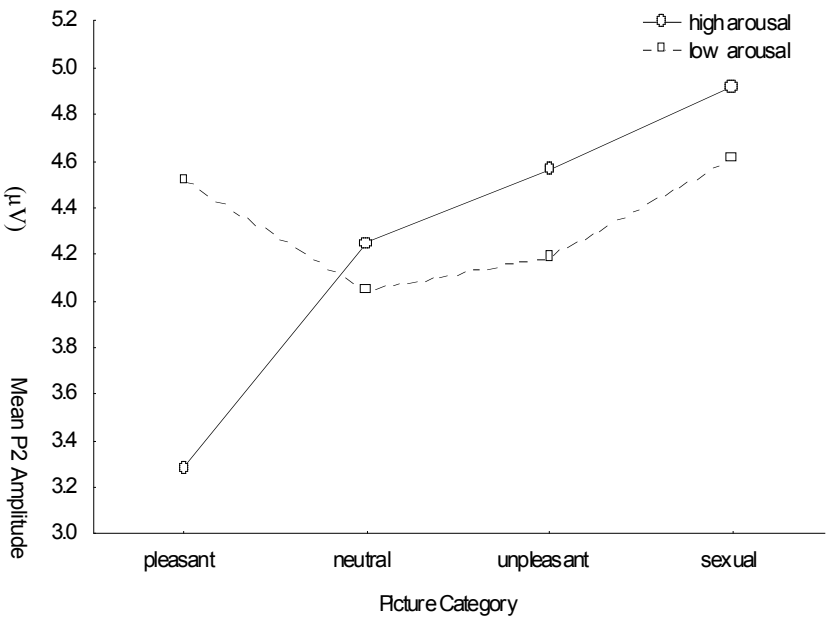


Figure 23. Mean P2 amplitude in response to high and low arousing picture categories.

Tukey post hoc tests showed no significant difference in P2 amplitude between high and low arousing neutral stimuli, high and low arousing sexual stimuli, or between high and low arousing unpleasant stimuli ($p<.05$). P2 amplitude was however significantly larger in response to low arousing pleasant compared to high arousing pleasant stimuli ($p<.05$). P2 amplitude was significantly larger in response to high arousing neutral, unpleasant, and sexual stimuli compared to high arousing pleasant stimuli (ps$<.05$) and there were no significant differences in P2 amplitude between low arousing stimuli ($p<.05$). The elicitation of the P2 component in Experiment 2 suggests that the use of mixed standards in Experiment 1 may have lead to a more rapid

habituation of the early positive components to target picture stimuli. The hypothesis that the early positive components would reflect a negativity bias however was not supported, as P2 amplitude was not significantly enhanced in response to unpleasant stimuli in Experiment 2. The P2 component does not appear to be sensitive to the motivational relevance of the stimuli, as the data do not fit with the model of motivated attention and affective states (Lang et al., 1997), nor does the data support a negativity bias. The data is more consistent with that of Schupp et al. (1997) and Delplanque et al. (2006) who showed no significant effects involving affect for the P2 component. However, as the P2 component was significantly reduced in response to high arousing pleasant stimuli, it is hard to say absolutely that the P2 component is not sensitive to affect.

The finding that P2 amplitude was significantly reduced in response to high arousing pleasant stimuli indicates that it may be somewhat sensitive to affective content, however not in a manner that conforms to either of the dominant theories of affective picture processing. It is argued that the observed P2 reductions for high arousing pleasant stimuli may reflect the fact that these images are less visually complex and/or less salient than the high arousing neutral, sexual, or unpleasant stimuli. This is difficult to state conclusively given that there is a lack of consensus as to the functional significance of the P2 component. It is also unclear whether the P2 amplitude data reported here is truly reflective of stimulus complexity or salience, especially as high arousing neutral stimuli were selected on the basis of high visual complexity, yet there was no significant difference in P2 amplitude between high and low arousing neutral stimuli. High arousing sexual and unpleasant stimuli are also more salient than the respective low arousing stimuli and, although P2 amplitude was larger in response to high arousing sexual and unpleasant stimuli compared to respective low arousing

stimuli, these differences were not significant. It is therefore unclear why P2 amplitude was significantly reduced in response to high arousing pleasant stimuli only, and the interpretation of these findings are further complicated by the lack of consensus regarding the functional significance of the P2 component.

P2 Latency

ANOVAs conducted on the P2 latency data failed to show significant main effects of Picture Category, $F(2.82, 90.14)=1.36$, $MSE=1666$, $p=.26$, Arousal, $F(1,32)=.32$, $MSE=1045$, $p=.32$, or Sex, $F(1,32)=1.79$, $MSE=11306$, $p=.19$. No theoretically relevant interactions were significant.

P3b Amplitude

P3b amplitude differed significantly as a function of Picture Category, $F(2.77, 88.58)=21.37$ $MSE=75$, $p<.001$, level of Arousal, $F(1,32)=24.13$, $MSE=53.88$, $p<.001$, and Coronal site, $F(2.44, 78.06)=113.15$, $MSE=48.5$, $p<.001$, and there was a trend toward a significant main effect of Sagittal site, $F(1.16, 37.03)=2.86$, $MSE=97.9$, $p=.06$. P3b amplitude did not differ significantly as a function of Sex, $F(1,32)=2.37$, $MSE=8871.7$, $p=.11$. A significant two-way interaction was revealed between Picture Category and Arousal, $F(2.91, 93.16)=10.36$, $MSE=445.20$, $p<.001$, as shown in Figure 24. Tukey post hoc tests showed no significant difference in P3b amplitude between high and low arousing neutral stimuli, or between high and low arousing pleasant stimuli. P3b amplitude was however significantly larger in response to high arousing sexual and unpleasant stimuli compared to respective low arousing stimuli (ps$<.05$). P3b amplitude was significantly larger in response to high arousing sexual compared to all other stimuli, and was significantly larger in response to high arousing unpleasant

compared to high arousing pleasant and neutral stimuli (*p*s<.05). The only significant difference shown for low arousing stimuli were the significantly larger amplitudes shown in response to low arousing sexual compared to low arousing neutral stimuli (*p*<.05).

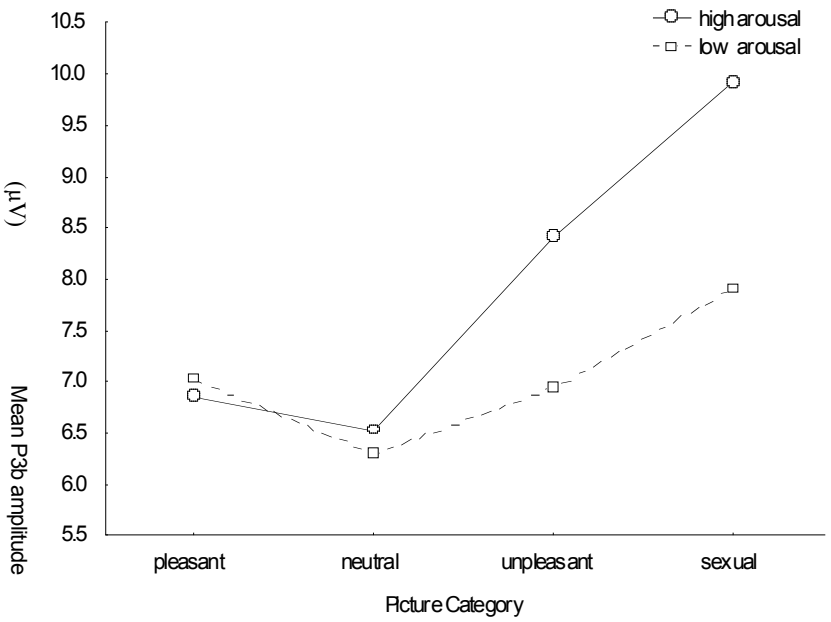


Figure 24. Mean P3b amplitude in response to high and low arousing picture categories.

The inherent motivational relevance of the stimuli was again assumed to account for variations in P3b amplitude, especially for pleasant stimuli, as P3b amplitude was significantly larger in response to sexually explicit stimuli compared to equally arousing sporting images, (despite these images being rated as significantly more pleasant), and compared to equally pleasant romantic images. Consistent with Experiment 1, P3b amplitude was significantly larger in response to high arousing unpleasant compared to high arousing pleasant and neutral stimuli, and in response to high arousing unpleasant compared to low arousing unpleasant stimuli. Contrary to the primary prediction of

Experiment 2, enhanced P3b amplitude was shown in response to sexually explicit stimuli compared to highly arousing unpleasant images of human mutilation and death, which is not consistent with a negativity bias or the quadratic effect. Similar results were illustrated in the grand mean average waveforms depicted in Schupp et al.'s (2004a) study, where ERP positivity between 500 and 1000ms at Pz appeared to be larger in response to opposite sex nudes and erotic couples than categories of unpleasant stimuli. However, no analyses however were performed to compare the ERP responses to the erotic and unpleasant stimuli in Schupp et al.'s study.

Again there was no ERP evidence to suggest heightened defensive activation for females, and the hypothesis that males would be more appetitively activated than females in response to sexual stimuli also was not supported. There were no significant differences between males and females in behavioural ratings of valence, arousal or approach/avoidance tendencies for the highly arousing sexual stimuli. The lack of a significant sex difference in the P3b amplitude data suggests that males and females process motivationally relevant information in a highly similar fashion, and allocate similar amounts of attentional resources to appetitive and aversive cues as indexed by P3b amplitude. This would appear a logical result as males and females share the same survival risks. It is plausible then that the mobilisation of energy for the preparation of, and response to, motivationally relevant stimuli as indexed by physiological measures does differ as a function of sex (Bradley et al., 2001b) and may be related to tactical responses which are highly variable. However, the actual allocation of attentional resources for the processing and evaluation of motivationally relevant stimuli does not appear to differ as a function of sex, and it is argued further that the cognitive processing of affective stimuli observed here reflects the strategic dimensions of valence and arousal along which emotional responses are organised.

P3b Latency

ANOVAs conducted on the P3b latency data indicated that P3b latency differed as a function of Picture Category, $F(2.24, 69.57)=5.94$, $MSE=8154.0$, $p<.001$, Sagittal site, $F(1.31, 40.60)=9.90$, $MSE=115522$, $p<.001$, and Coronal site, $F(2.44, 75.67)=5.09$, $MSE=1650$, $p<.001$, with a trend towards a significant main effect of Sex, $F(1, 31)=3.72$, $MSE=214204$, $p=.052$. Males demonstrated significantly shorter P3b latencies (M=400.13ms, SEM=10.09) compared to females (M=428.93ms, SEM=10.09). Tukey post hoc tests for Picture Category showed significantly longer latency in response to neutral (M=424.22ms, SEM=7.97) compared to sexual (M=408.10ms, SEM=7.98) and unpleasant stimuli only (M=411.14ms, SEM=7.92) (ps<.05). The allocation of attentional resources as indexed by P3b amplitude was larger in response to the most highly arousing and motivationally relevant stimuli however stimulus evaluation times as indexed by P3b latency (Kutas et al., 1977) were not so strongly influenced by the motivational relevance of the eliciting stimulus. Although the shorter P3b latencies observed in response to pleasant and unpleasant stimuli compared to neutral is somewhat reminiscent of the quadratic effect, a motivational interpretation of the data is excluded based on the non significant differences between pleasant (M=413.87ms, SEM=7.40), sexual, and unpleasant stimuli.

P3b Amplitude for High and Low Arousing Picture Stimuli Combined

As mentioned previously, analyses were conducted on the P3b amplitude data that was averaged across picture categories in order to investigate whether intermixing arousal and semantic contents contributes to the quadratic effect. ANOVAs conducted on the P3b amplitude data averaged across high and low arousing picture stimuli indicated that

P3b amplitude differed as a function of Picture Category, $F(1.92, 59.59)=8.28$, $MSE=34.44$, $p<.001$, Coronal site, $F(2.48, 36.22)=3.10$, $MSE=37.61$, $p<.001$, and there was a strong trend toward a significant main effect of Sagittal site, $F(1.17, 76.91)=94.80$, $MSE=19.56$, $p=.05$. Tukey post hoc tests showed no significant difference in P3b amplitude between pleasant ($M=8.23\mu V$, $SEM=.57$) and unpleasant stimuli ($M=8.50\mu V$, $MSE=.50$), however both pleasant and unpleasant stimuli evoked significantly larger P3b amplitudes than neutral stimuli ($M=7.50\mu V$, $MSE=.50$) (ps$<.05$). The quadratic effect or larger ERP component amplitudes for pleasant and unpleasant stimuli compared to neutral stimuli was therefore replicated for P3b amplitude when EEG activity was averaged across high and low arousing picture contents. This is consistent with the results of Schupp et al. (2004a) who showed P3 and PSW amplitudes to differ as a function of specific picture content however when high and low arousing picture contents were combined in Schupp et al.'s study, no significant differences in ERP component amplitudes were observed between pleasant and unpleasant stimuli. The results of Schupp et al. and the current study highlight the importance of systematically varying both the arousal level and the semantic qualities of the affective stimuli and to assess the separable effects of specific picture contents. It is therefore conceivable that the quadratic relationship reported in previous research arises when arousal level and hence semantic content is confounded.

P3b Latency for High and Low Arousing Picture Stimuli Combined

P3b latency differed as a function of Picture Category, $F(1.77, 54.97)=4.92$, $MSE=81.71$, $p<.05$, Sagittal site, $F(1.37, 42.60)=54.40$, $MSE=20233$, $p<.001$, and Coronal site, $F(2.48, 76.91)=94.80$, $MSE=19.56$, $p<.001$. Tukey post hoc tests indicated that P3b latency was significantly longer in response to pleasant ($M=421.91$ms,

SEM=7.12) compared to neutral stimuli (*M*=440.18ms, *SEM*=8.16) ($p<.05$), with no significant differences between pleasant and unpleasant stimuli (*M*=430.13ms, *SEM*=8.13) or between neutral and unpleasant stimuli.

P3b Amplitude and Hemispheric Lateralisation

Analysis of variance conducted on the P3b amplitude data for left parietal and the right parietal electrode sites showed a significant main effect of Hemisphere, $F(1, 33)=6.17$, *MSE*=30.85, $p<.001$. P3b amplitude was larger at the left (*M*=10.33µV, *SEM*=.79) than the right parietal site (*M*=9.14µV, *SEM*=.73). However, no higher order interactions involving hemisphere however were revealed. No support for the specialisation of the right parietal region for the processing of valence and arousal information was provided in Experiment 2 for the same reasons outlined in Experiment 1. Again no frontal components were available for analysis and as such there was no evidence of lateralisation of the approach and withdrawal systems within the left and right frontal regions.

Summary

Greater attentional resource allocation as indexed by P3b amplitude was required for the processing of sexually explicit stimuli compared to all other affective stimuli which is not consistent with either a negativity bias or quadratic effect. P3b amplitudes were however significantly enhanced in response to high arousing unpleasant compared to high arousing pleasant and neutral stimuli which is consistent with the results of Experiment 1. It is speculated that sexual arousal may influence cognitive processing differently to other forms of affective arousal and thus a possible confound is present in studies that have intermixed sexual and non-sexual stimuli within a general pleasant

category (e.g., Cuthbert et al., 2000; Delplanque et al., 2005; 2006; Keil et al., 2002; Mini et al., 1996; Schupp et al., 2000). The issues associated with intermixing semantic contents were highlighted further by the analysis in Experiment 2 in which high and low arousing stimulus categories were combined and the quadratic effect was shown to be replicated. It is therefore conceivable that the quadratic effect revealed in previous research in which arousal contents were intermixed results from a stimulus confound rather than accurately reflecting motivational engagement.

Again there was no electrophysiological evidence to suggest that males and females process affective or motivationally relevant stimuli differently to each other, although some more general sex differences were apparent in the ERP data, most notably that females demonstrated larger P2 amplitudes than males. The cognitive processing of affective and/or motivationally relevant stimuli as indexed by P3b amplitude in particular, did not differ between the sexes and this non significant difference is argued to stem from the shared survival risks of males and females. The sex differences observed at a behavioural level in Experiment 2 are not highly consistent with Experiment 1, as greater defensive activation for female participants demonstrated in the correlational analysis and valence rating data for Experiment 1 were not demonstrated in Experiment 2. Females did however rate the high arousing unpleasant stimuli as significantly more arousing than males in Experiment 2, and the collective results of Experiments 1 and 2 point toward a possible dissociation between behavioural and electrophysiological responses to affective stimuli in terms of sex differences.

Experiment 3: Social Content

The results of Experiments 1 and 2 indicate that valence (underlying the activation of the appetitive and aversive systems) and arousal information interact to influence ERP modulations, and most importantly ERP component amplitudes vary as a function of specific picture content. Given the finding that specific semantic contents, namely sexual content, have different effects on cognitive processing than other affective contents, Experiment 3 was designed to further investigate the effect of semantic picture qualities on ERP modulations by comparing pleasant, unpleasant, and neutral stimuli depicting social and non-social contents. Elucidating the effects of social content on ERP responses will determine whether social content was a potential confound associated with the sexual stimuli presented in Experiment 2.

Only low arousing stimuli are used in Experiment 3 as the IAPS does not include images that are representative of a high arousing pleasant or high arousing unpleasant non-social category. The neutral social stimuli depict images of neutral faces, and as outlined in Chapter 3, an N170 component maximal at occipito-temporal sites is expected to be elicited in response to these stimuli only. The N170 is face-specific and is not affected by non-perceptual features, however the early positive and longer latency ERP components are sensitive to emotional expression and a negativity bias has been demonstrated in response to both facial (Eimer & Holmes, 2002; Nelson & Nugent; 1990; Poutrois et al., 2005; Schupp et al., 2004c) and non-facial stimuli (Carretié, et al., 2001a; 2004; Delplanque et al., 2004; 2005; 2006; Ito et al., 1998a; Smith et al., 2003). Following the assumption that both facial and non-facial stimuli are effective communicators of appetitive and aversive events, it is expected that social and non-social stimuli should also be equally effective at activating the underlying motivational systems. No significant differences are therefore predicted between social and non-social

pleasant, social and non-social unpleasant, or social and non-social neutral stimuli. A negativity bias is however expected for both the behavioural and ERP data as highly arousing erotic images are not presented.

Method

Participants

The participants were the same group as participated in Experiment 2.

Apparatus, Stimuli, and EEG recording

Data acquisition procedures and EEG recording equipment were the same as those outlined in Experiments 1 and 2. Thirty pleasant, neutral, and unpleasant stimuli were selected from the IAPS based on low ratings of arousal. Pleasant stimuli had mean valence ratings of six, neutral stimuli had mean valence ratings less than five, and unpleasant stimuli had mean valence ratings less than three. All pictorial stimuli had arousal ratings less than five. These stimuli were further broken down into 15 of each of social and non-social stimuli (see Appendix C). Pleasant social stimuli depicted images of romantic couples, family interactions, and babies, while non-social pleasant stimuli mainly depicted images of animals and landscapes. Unpleasant social stimuli depicted images of human illness, poverty, mild injury, and non-social unpleasant stimuli depicted images of deceased animals and pollution. Neutral non-social stimuli depicted mostly household objects, and neutral social stimuli depicted neutral faces. Two neutral social stimuli were selected from the IAPS (2200, 2210), with the other 13 stimuli selected from Ekman and Friesen's (1976) Pictures of Facial Affect (see Appendix C). As per Experiment 2, a red and white checker board was presented as the standard stimulus (IAPS number: 7182).

The modified two stimulus oddball paradigm used to present the stimuli was the same as that outlined in Experiment 2. The oddball condition contained 600 trials overall, 180 affective, and 420 standard stimuli, and lasted approximately 15 minutes. The data from the STAI administered in Experiment 2 applied to Experiment 3 also. The pictorial stimuli were re-presented and rated on levels of valence, arousal, approach/avoidance and social content using the same parameters outlined in the previous experiments.

Procedure

The procedure for Experiment 3 was the same as that outlined in Experiment 2. However, at the conclusion of the experiment stimuli were rated on an additional scale of social content. For this scale participants were instructed to identify whether there were people depicted in the image and to rate the level of social content which varied depending on the level of interaction shown in the image.

Design

The experiment followed a 3(Affective Content: pleasant, neutral, unpleasant) x 2(Social Content: social, non-social) repeated measures design. The electrode sites lead to two further repeated measures variables of Sagittal site and Coronal site for the ERP data. The results of Experiments 1 and 2 failed to show any theoretically significant sex differences for the ERP data, thus the analyses for Experiment 3 were performed on combined male and female data. Inspection of the grand mean waveforms (see Figures 29a & b) showed the appearance of an early and late positive component identified as P2 and P3b respectively. An N2 component was also evoked at fronto-central sites, however no analyses are presented for this component following on from studies by

Delplanque et al. (2001) and Schupp et al. (1997) that showed the N2 component not to be sensitive to affective variables, and preliminary analysis performed in Experiment 1 that confirmed these findings. The face-specific N170 component was also not evoked in the current experiment and possible explanations for the absence of this component are outlined later. The dependent variables for the ERP data therefore were P2 and P3b amplitude and latency; and for the behavioural data reaction time, accuracy, and ratings of valence, arousal, approach/avoidance tendency, and social content were the dependent measures.

Data Analysis

Means and standard errors were calculated for the valence, arousal, approach/avoidance, and social content ratings for each social and non-social pleasant, neutral, and unpleasant target. Means and standard errors were also calculated for correct responses for the reaction time and accuracy data. Two-way repeated measures ANOVAs with Affective Content (pleasant, neutral, and unpleasant), and Social Content (social, non-social) as the within subjects factors were used to analyse the behavioural data.

ERP waveforms for each social and non-social pleasant, neutral, and unpleasant target stimulus were scored for peak amplitude. Again as the interest lies with stimuli that were actively evaluated, standard stimuli were not subjected to statistical analysis. The P2 component was scored for peak amplitude at centro-parietal and parietal sites between 160 and 200ms post-stimulus onset, and the P3b component was scored for peak amplitude at central, centro-parietal, and parietal sites between 300 and 500ms post-stimulus onset. The means for each ERP component amplitude and latency were assessed using four-way repeated measures ANOVAs with Affective Content (pleasant, neutral, unpleasant), Social Content (social, non-social), Sagittal site (central, centro-

parietal, and parietal site depending on component topography), and Coronal site (far left, left, midline, right, and far right) as the within subjects factors. Main effects and interactions involving Sagittal and Coronal sites will not be reported unless they are of theoretical significance.

Behavioural ratings of valence, arousal, approach/avoidance tendency, and social content were not obtained for two participants due to equipment malfunction. Statistical procedures were the same as that outlined in Experiment 1.

Results and Discussion

Behavioural Data

STAI

As the same participants participated in both Experiments 2 and 3, the analysis of the STAI data outlined in Experiment 2 also pertains to Experiment 3.

Accuracy

ANOVAs conducted on the accuracy data indicated that accuracy did not differ as a function of Affective Content, $F(1.72, 55.19)=.12$, $MSE=1.3$, $p=.89$, or Social Content, $F(1,32)=.07$, $MSE=1.2$, $p=.80$, and no significant higher order interactions were revealed.

Reaction Time

ANOVAs conducted on the reaction time data indicated that RT differed significantly as a function of Social content, $F(1,32)=14.49$, $MSE=.00035$, $p<.001$, but did not differ significantly as a function of Affective content, $F(1.89, 60.39)=2.44$, $MSE=.00037$, $p=.09$. These main effects were moderated by a significant two-way interaction between

Social Content and Affective Content, $F(1.94, 62.22)=20.72$, $MSE=.00028$, $p<.001$, as shown in Figure 25.

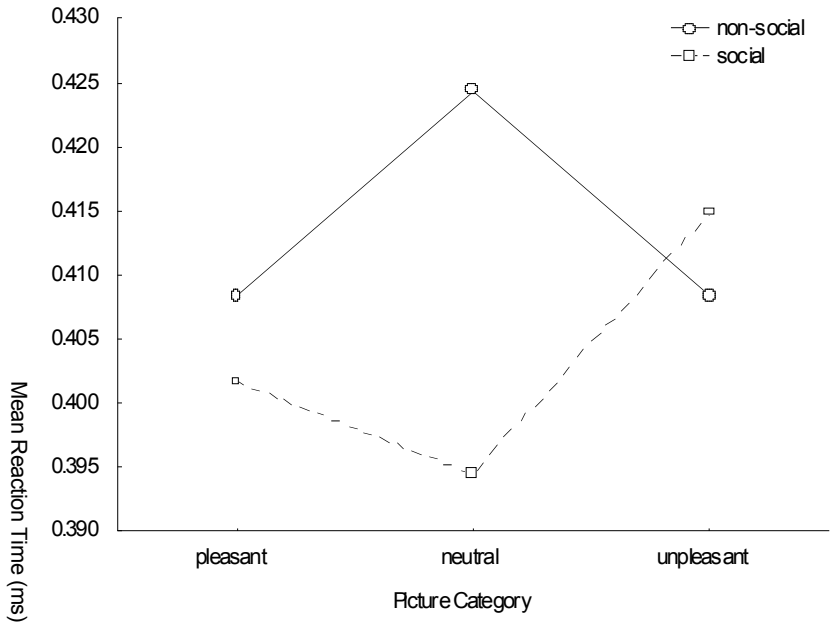


Figure 25. Mean reaction time in response to social and non-social picture types.

Tukey post hoc tests indicated that RT was significantly faster in response to neutral social compared to neutral non-social stimuli ($p<.05$), and no significant difference in RT was revealed between social and non-social pleasant or social and non-social unpleasant stimuli. RT was also significantly faster in response to non-social pleasant and unpleasant stimuli compared to non-social neutral stimuli (ps$<.05$). No significant difference in RT was shown between pleasant and neutral social stimuli and both stimuli were responded to with significantly faster RT than unpleasant social stimuli (ps$<.05$). A quadratic effect was therefore demonstrated at a behavioural level for non-social stimuli, with significantly faster RT exhibited in response to both pleasant and unpleasant stimuli compared to neutral. This pattern of results was not shown for

social stimuli, as unpleasant social stimuli took significantly longer to respond to than pleasant social stimuli and images of neutral faces. These results contradict the negativity bias that would predict unpleasant stimuli to evoke significantly faster responses. Experiment 3 did however use low arousing stimuli, which would not engage the brain's motivational system to the same degree as high arousing stimuli.

Valence Ratings

Valence ratings differed significantly as a function of Affective Content, $F(1.47, 43.98)=299.36$, $MSE=.93$, $p<.001$, but did not differ as a function of Social Content, $F(1,30)=.34$, $MSE=.22$, $p=.56$. A significant two-way interaction was revealed between Affective Content and Social Content, $F(1.96, 58.93)=20.67$, $MSE=.28$, $p<.001$, as shown in Figure 26. Tukey post hoc tests indicated that social and non-social pleasant stimuli were matched on rated valence, as were social and non-social unpleasant stimuli. All pleasant, neutral, and unpleasant picture categories were rated as significantly different from each other (ps$<.05$). Neutral social stimuli were rated as significantly less pleasant than neutral non-social stimuli ($p<.05$), which is consistent with the results of Schupp et al. (2004a) who also reported that neutral faces were rated as significantly less pleasant than neutral objects.

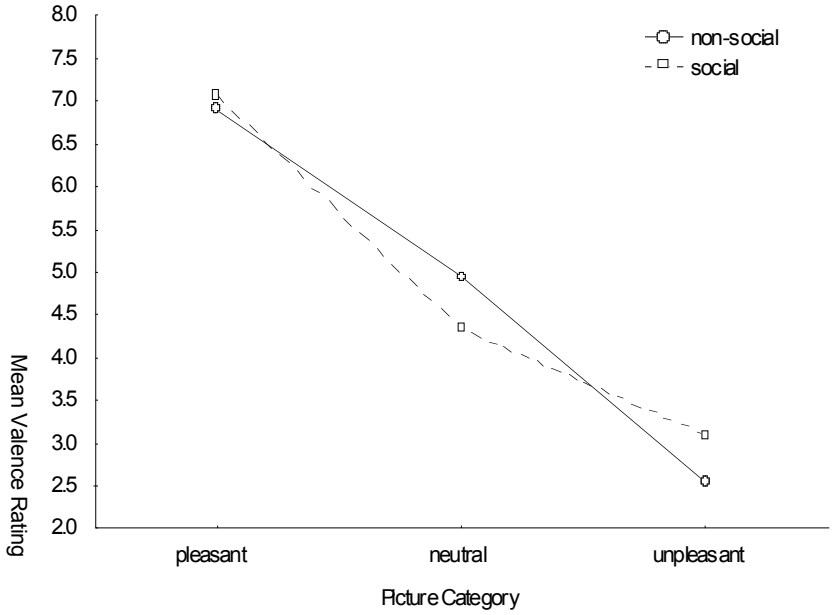


Figure 26. Mean valence ratings for social and non-social picture types.

The valence rating results are also somewhat consistent with a pilot study conducted by Schupp et al. (2004c) who reported that neutral faces were perceived as more threatening than friendly faces. It is possible that the neutral facial stimuli presented in Experiment 3 were perceived as somewhat threatening and/or unpleasant, although no subjective measures of threat were taken. The ratings for neutral social stimuli were however within the normal range to be classified as neutral and were rated as significantly more pleasant than unpleasant social and non-social stimuli, and significantly less pleasant than social and non-social pleasant stimuli ($ps<.05$).

Facial expressions are fundamental to the non verbal communication of emotional states, and it is rare that one's facial expression would be devoid of affect. A neutral expression essentially aims to convey no affect, however as facial expression is such a powerful non verbal communication tool it is likely that participants tried to extract some form of affective meaning from the neutral faces or interpreted a lack of

expression as unpleasant. It is argued then that neutral facial stimuli were perceived as being slightly threatening and/or unpleasant as a result of the ambiguity of the facial expression. However, subjective ratings of threat would be required to substantiate this claim.

Arousal Ratings

The arousal ratings also differed significantly as a function of Affective Content, $F(1.68, 50.45)=31.56$, $MSE=3.09$, $p<.001$, and Social Content, $F(1,30)=13.68$, $MSE=.65$, $p<.001$, however no higher order interactions were revealed. Tukey post hoc tests indicated that pleasant stimuli ($M=4.97$, $SEM=.29$) were rated as significantly more arousing than neutral ($M=2.51$, $SEM=.21$) and unpleasant stimuli ($M=3.92$, $SEM=.31$), and unpleasant stimuli were rated as significantly more arousing than neutral stimuli (ps$<.05$). This result is inconsistent with the arousal rating data from Experiments 1 and 2 which showed pleasant and unpleasant categories of slides to be matched for arousal. It is speculated that the inclusion of highly arousing stimuli makes the discrepancy between arousal categories more salient and thus arousal level is judged more accurately. With only low arousing stimuli presented in Experiment 3 it is argued that arousal level was more difficult to judge and the results demonstrated here are somewhat arbitrary. Social stimuli ($M=4.01$, $SEM=.23$) were rated as significantly more arousing than non-social stimuli ($M=3.58$, $SEM=.20$) which is argued to result from the images of human interaction being perceived as more salient and meaningful.

Approach/Avoidance Ratings

ANOVAs conducted on the approach/avoidance rating data indicated that approach/avoidance tendencies differed significantly as a function of Affective Content

only, $F(1.78, 53.46)=201.51$, $MSE=1.11$, $p<.001$. Approach/avoidance tendencies did not differ as a function of Social content, $F(1.78, 53.46)=.96$, $MSE=.39$, $p=.76$, however a significant two-way interaction between Affective Content and Social Content was revealed, $F(1.44, 43.31)=16.40$, $MSE=.48$, $p<.001$ (see Figure 27). Tukey post hoc tests failed to show any significant difference in approach ratings between social and non-social pleasant stimuli. Approach ratings were significantly lower for neutral social stimuli compared to non-social neutral stimuli ($p<.05$), which adds support to the notion that these stimuli were perceived as somewhat threatening. Avoidance ratings were also significantly higher for unpleasant social compared to unpleasant non-social stimuli ($p<.05$). Given that participants were instructed to think of themselves in relation to the image when rating approach /avoidance tendencies, and social stimuli are more personally relevant, it is reasonable to assume that unpleasant social stimuli would evoke a stronger avoidance tendency than images of deceased animals and pollution.

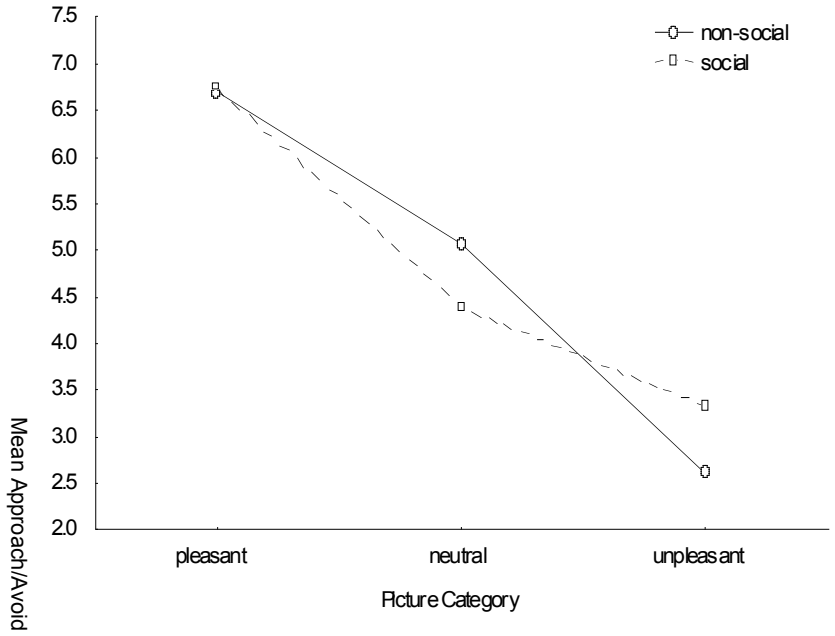


Figure 27. Mean approach/avoidance ratings for social and non-social picture types.

Social Content Ratings

ANOVAs conducted on the social content rating data showed significant main effects of Affective Content, $F(1.62, 48.49)=78.01$, $MSE=1.86$, $p<.001$, and Social Content, $F(1,30)=36.35$, $MSE=2.45$, $p<.001$, which were qualified by a two-way interaction between these variables, $F(1.77, 53.03)=22.23$, $MSE=10.03$, $p<.001$, as shown in Figure 28.

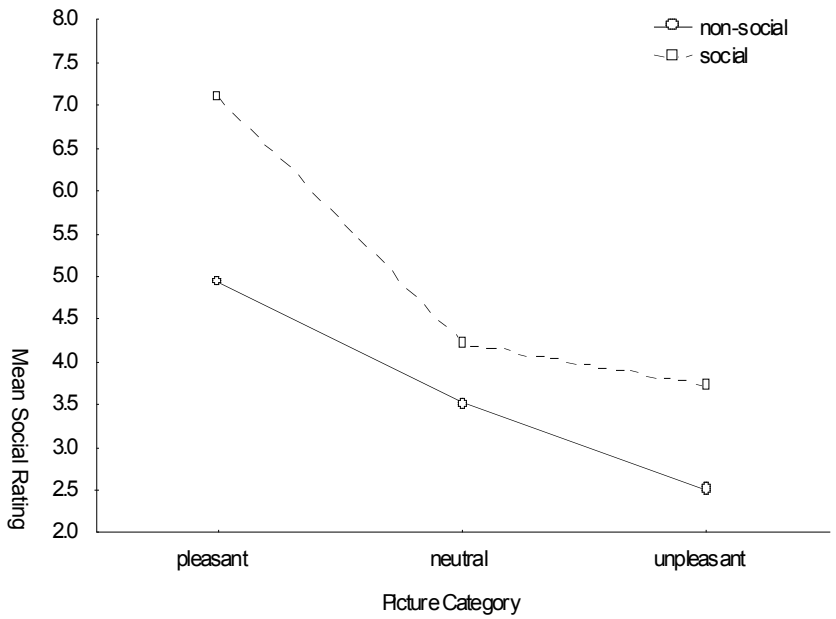


Figure 28. Mean social content ratings for social and non-social picture types.

Tukey post hoc tests showed that all social stimuli were rated as significantly more social than respective non-social stimuli; and for both social and non-social picture types pleasant stimuli were rated as significantly more social than neutral and unpleasant stimuli, and neutral stimuli were rated as significantly more social than unpleasant stimuli (*p*s<.05). The finding that pleasant social stimuli were rated as significantly more social than neutral and unpleasant social stimuli may be a result of the greater degree of

interaction depicted in these images. Importantly, all social stimuli were rated as significantly more social than respective non-social stimuli, which indicate that the scale is measuring the desired variable even though there are differences within each social and non-social picture category.

ERP Data

Grand mean averages for correct responses to social and non-social target stimuli were computed for the 30 electrode sites. As shown in Figures 29a and b, a negative component identified as N2 was observed at frontal sites that is consistent with Experiments 1 and 2. Again no statistical analysis was performed on this component following the findings of Schupp et al. (1997) and Delplanque et al. (2006) who showed the N2 component not to be sensitive to affective variables, and the preliminary analysis of the N2 component in Experiment 1 that confirmed these findings. A positive component identified as P2 was evoked over all sagittal regions in response to social-neutral stimuli, but was only reliably elicited in response to all affective stimuli at centro-parietal and parietal sites, consistent with the topography outlined in Experiment 2. P3b amplitude was maximal over centro-parietal sites, and was larger in response to neutral social compared to pleasant and unpleasant social stimuli (see Figure 29a), with little difference in P3b amplitude between non-social stimuli (see Figure 29b).

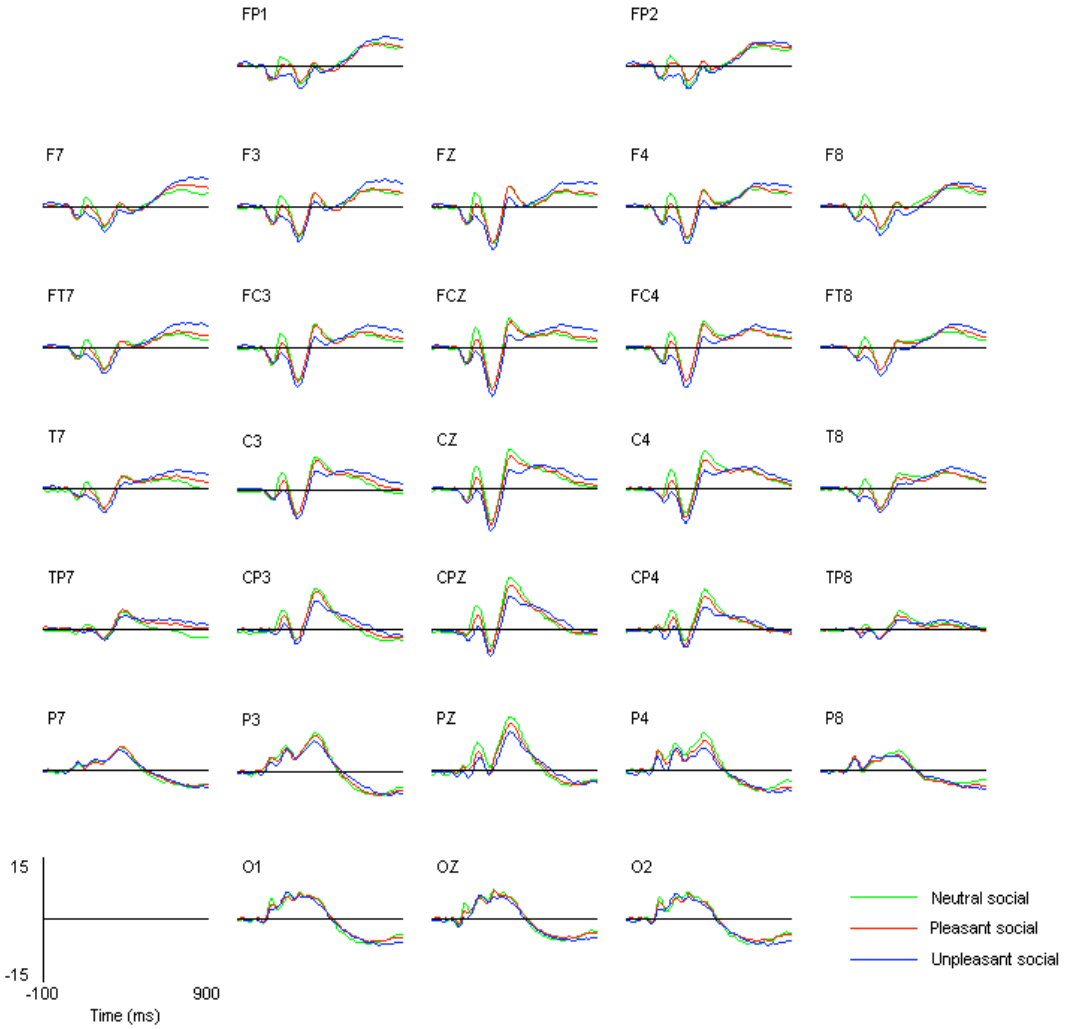


Figure 29a. Grand mean waveforms for neutral, pleasant and unpleasant social stimuli.

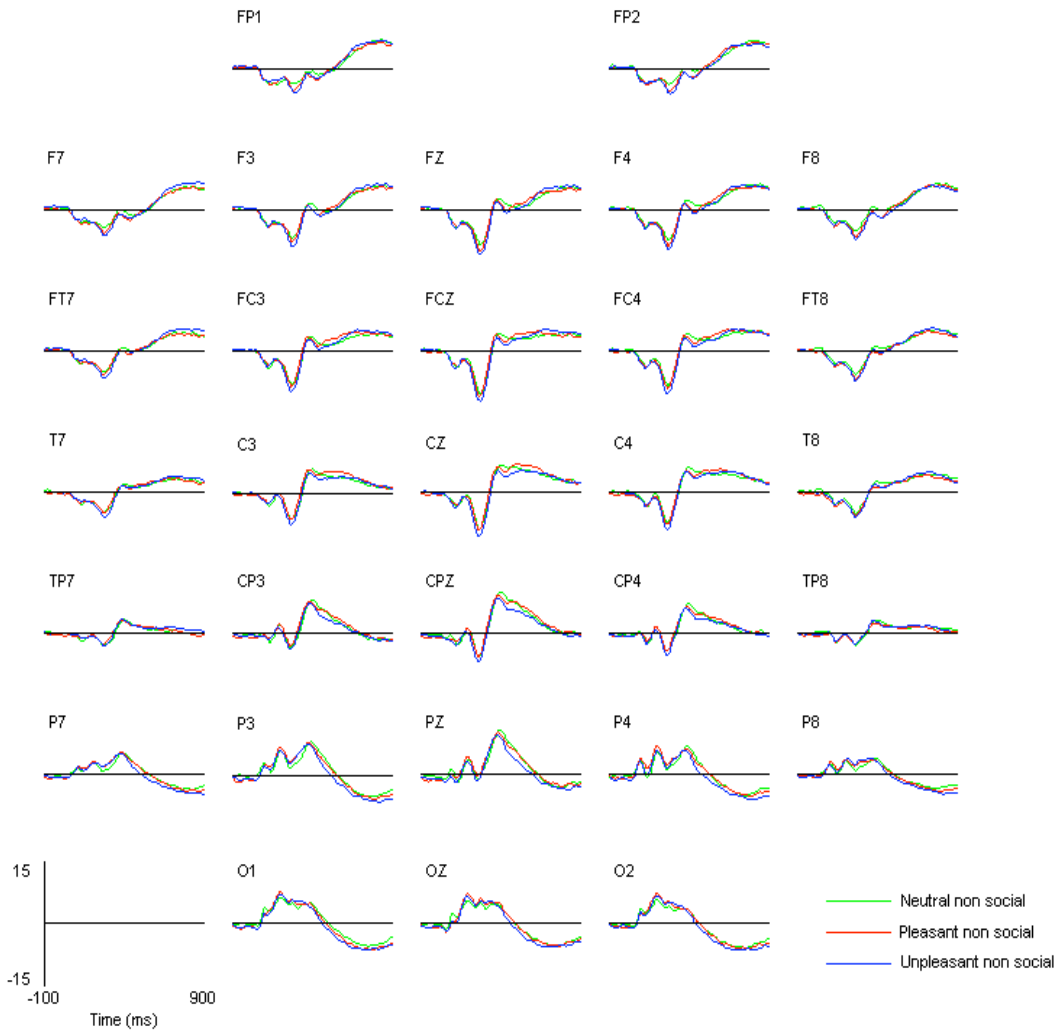


Figure 29b. Grand mean waveforms for neutral, pleasant, and unpleasant non-social stimuli.

P2 Amplitude

ANOVAs conducted on the P2 amplitude data indicated that P2 amplitude differed as a function of Affective Content, $F(1.80, 57.59)=7.09$, $MSE=28.46$, $p<.05$, Social Content, $F(1,32)=9.47$, $MSE=47.24$, $p<.05$, Sagittal site, $F(1,32)=39.59$, $MSE=108.13$, $p<.001$, and Coronal site, $F(2.32, 74.34)=23.98$, $MSE=44.02$, $p<.001$. The main effects of Affective Content and Social Content were qualified by a two-way interaction between these variables, $F(1.95, 62.31)=8.89$, $MSE=33.79$, $p<.001$.

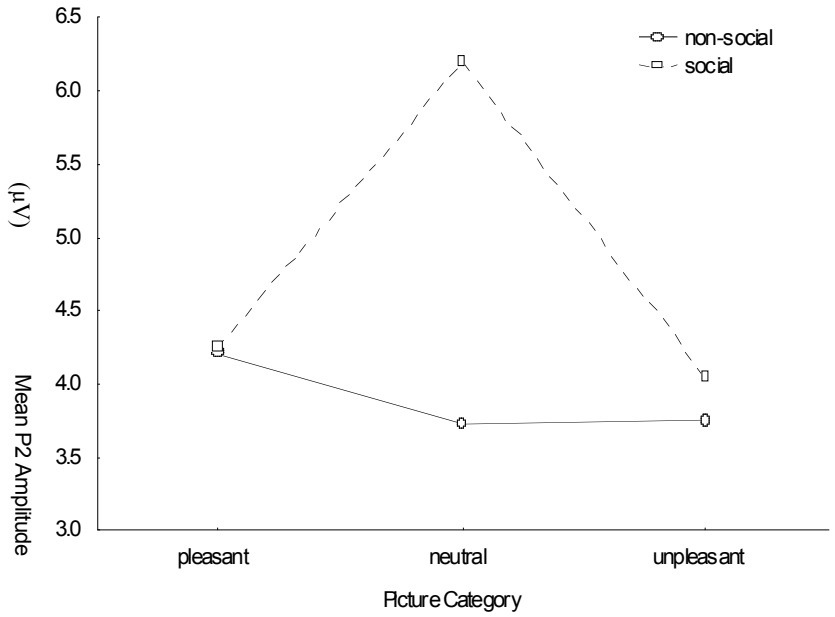


Figure 30. Mean P2 amplitude for social and non-social picture types.

As shown in Figure 30 and confirmed by Tukey post hoc tests, the only significant difference between social and non-social stimuli was shown for neutral stimuli, with significantly larger P2 amplitudes evoked in response to neutral social stimuli ($p<.05$). There was no significant difference between pleasant and unpleasant social stimuli and both picture types evoked significantly smaller P2 amplitudes compared to neutral social stimuli (ps$<.05$), and no significant differences in P2 amplitude were shown between non-social picture types.

Typically, ERP component amplitudes are sensitive to the threat value of facial expressions, for example, enhanced P120 and P250 amplitudes have been demonstrated in response to fearful faces compared to neutral faces (Eimer & Holmes, 2002), and P1 amplitude has shown enhancements for normal and filtered fearful faces compared to normal and filtered neutral faces (Poutrois et al., 2005). In a study conducted by Stekelenburg et al. (2004), P2 and N2 component amplitudes were modulated in response to fearful and neutral faces and not fearful and neutral bodies, however the

amplitudes of these components were larger in response to neutral faces. Stekelenburg et al. however failed to offer an explanation for this discrepant result. In the current study it is speculated that the neutral facial expressions were perceived as somewhat unpleasant following the findings that these stimuli were rated as significantly less pleasant than neutral non-social stimuli, elicited stronger avoidance ratings than neutral non-social stimuli, and based on Schupp et al.'s (2004c) pilot study that showed neutral facial stimuli to be perceived as threatening. P2 amplitude is sensitive to the physical properties of the eliciting stimuli, is assumed to index feature detection and encoding (Dunn et al., 1998), and may also provide an index of recognition potential (Rudell & Hua, 1995). As P2 amplitude was only enhanced in response to neutral social stimuli, it is argued that enhanced amplitudes reflect processes associated with face perception such as feature integration rather than the processing of affect or social characteristics. This is not to suggest that the P2 component is unaffected by the valence qualities of the eliciting stimulus particularly if it is the case that the neutral faces were perceived as threatening. However no specific measures of threat perception were obtained to substantiate that the neutral faces were actually perceived as threatening. Rather, it is postulated that enhanced P2 amplitude reflects the increased difficulty associated with extracting affective information from a somewhat ambiguous neutral expression. It is assumed that P2 amplitude was not differentially modulated by the neutral non-social, or social and non-social pleasant and unpleasant stimuli as these images are more salient than the neutral face stimuli and thus may be processed more quickly and easily.

P2 Latency

P2 latency differed as a function of Sagittal site, $F(1, 32)=16.64$, $MSE=16.40$, $p<.001$, Coronal site, $F(2.49, 79.61)=5.65$, $MSE=7.03$, $p<.05$, and Social content, $F(1,32)=13.90$,

MSE=930, *p*<.001, but not as a function of Affective Content, *F*(1.60, 51.16)=1.10, *MSE*=6.11, *p*=.34. The two-way interaction between Affective Content and Social Content was significant, *F*(1.73, 55.51)=7.70, *MSE*=4283.37, *p*<.05, as shown in Figure 31.

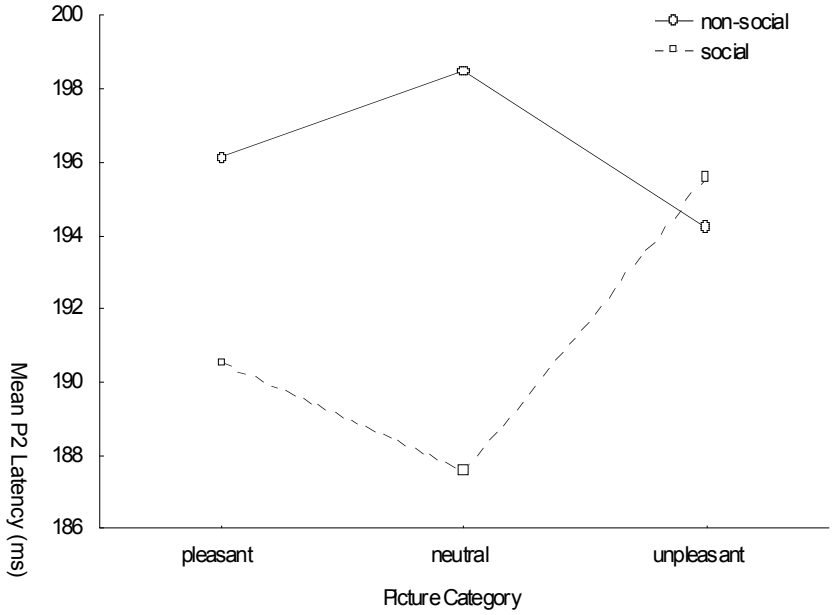


Figure 31. Mean P2 latency for social and non-social picture types.

The results for the P2 latency data could not be interpreted within the theoretical framework of the current thesis. P2 latency was significantly shorter in response to neutral social stimuli compared to neutral non-social stimuli (*p*<.05), which is consistent with increased P2 amplitudes in response to these same stimuli. P2 latency for social pleasant stimuli was shorter than for non-social pleasant stimuli, however this difference did not reach significance, and no significant differences were shown between pleasant, unpleasant, and neutral non-social stimuli or between pleasant and unpleasant social stimuli (*p*s>.05). P2 latency did not differ significantly between pleasant and neutral

social stimuli but was significantly longer in response to unpleasant social stimuli compared to neutral social stimuli (*p*s<.05).

P3b Amplitude

ANOVAs conducted on the P3b amplitude data indicated that P3b amplitude differed as a function of Affective Content, $F(1.93, 61.94)=6.31$, $MSE=54.1$, $p<.001$, Social Content, $F(1,32)=5.34$, $MSE=58.4$, $p<.05$, Sagittal site, $F(1.11, 35.58)=8.93$, $MSE=69.90$, $p<.001$, and Coronal site, $F(2.45, 78.23)=8.93$, $MSE=52.4$, $p<.001$. A significant two-way interaction was also revealed between Affective Content and Social Content, $F(1.92, 61.46)=8.62$, $MSE=561$, $p<.05$, as shown in Figure 32. The results for the P3b amplitude data are highly consistent with that of the P2 amplitude data, with Tukey post hoc tests showing significantly larger P3b amplitudes in response to neutral social stimuli compared to neutral non-social stimuli ($p<.05$). No significant differences were revealed between pleasant and unpleasant social stimuli or between neutral, pleasant, and unpleasant non-social stimuli (*p*s>.05). Also no significant differences were shown between social and non-social pleasant or social and non-social unpleasant stimuli (*p*s<.05). Enhanced P3b amplitude in response to neutral social compared to neutral non-social stimuli is consistent with the results of Schupp et al. (2004a) who also showed enhanced positivity between 400 and 700ms and between 700 and 1000ms in response to neutral faces compared to neutral objects. It is speculated that the enhanced P3b amplitude shown in response to the neutral face stimuli may reflect the same variables thought to account for enhanced P2 amplitudes for the same stimuli; namely the ambiguity of the neutral expression. It is argued that greater attentional resources were allocated to the processing of the neutral face stimuli due to the difficulty

associated with extracting affective information from these stimuli compared to the other more salient pictorial stimuli, resulting in enhanced P3b amplitude.

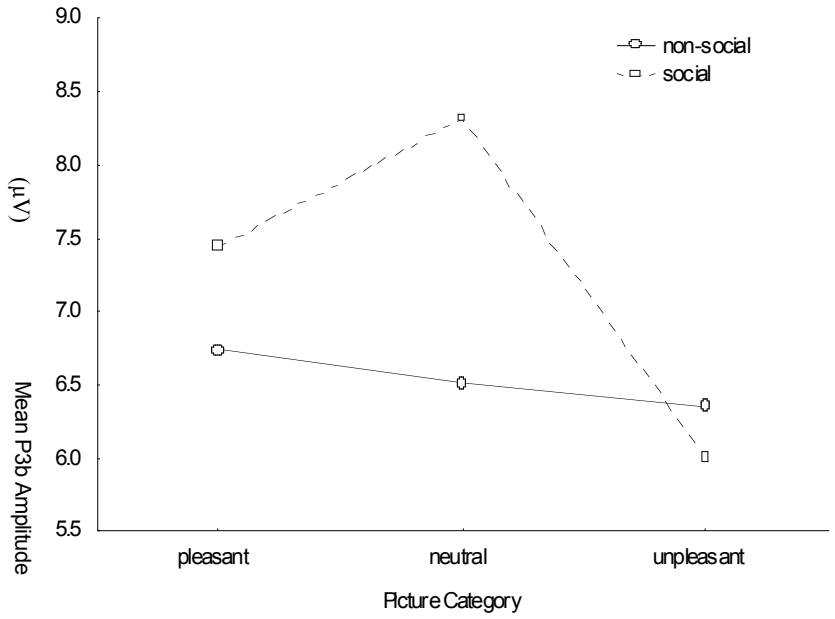


Figure 32. Mean P3b amplitude for social and non-social picture types.

P3b Latency

P3b latency differed as a function of Social Content, $F(1,32)=20.45$, $MSE=29.89$, $p<.01$, Sagittal site, $F(1.24, 39.81)=54.16$, $MSE=53189$, $p<.001$, and Coronal site, $F(2.44, 78.10)=4.79$, $MSE=53.74$, $p<.01$, but did not differ significantly as a function of Affective Content, $F(1.97, 63.00)=.44$, $MSE=4867$, $p=.44$. A significant two-way interaction was revealed between Affective Content and Social Content, $F(1.54, 49.23)=10.82$, $MSE=5432$, $p<.001$, as shown in Figure 33. Tukey post hoc tests indicated that P3b latency was significantly longer in response to pleasant non-social compared to pleasant social stimuli, and was significantly longer in response to neutral

non-social compared to neutral social stimuli (*p*s<.05), with no significant difference in P3b latency between social and non-social unpleasant stimuli (*p*>.05).

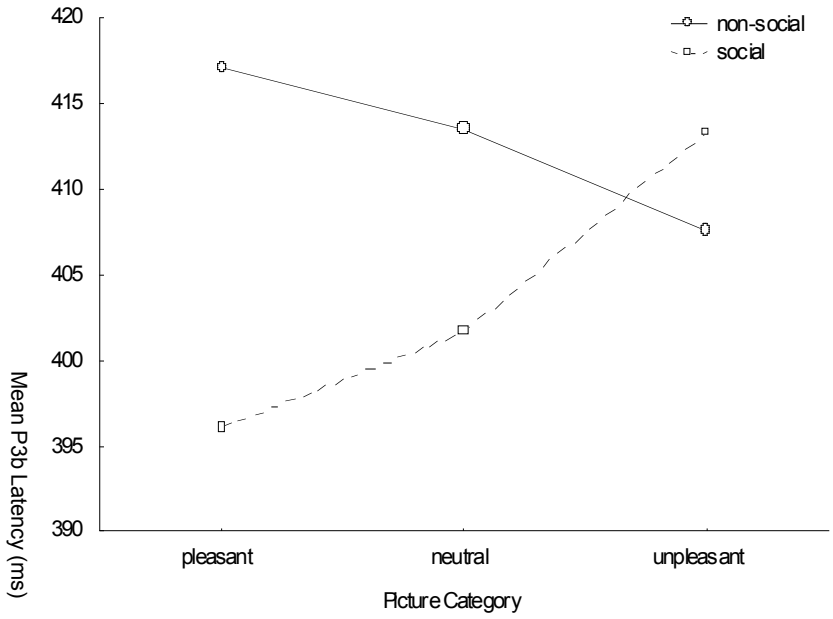


Figure 33. Mean P3b latency for social and non-social picture types

As P3b latency is considered to index stimulus evaluation time (Kutas et al., 1977), it appears that social content influences the stimulus evaluation times for pleasant and neutral stimuli only. Social content did not influence the stimulus evaluation times for unpleasant images, which is consistent with the assumptions of the negativity bias that rapid responses would be made to aversive stimuli regardless of specific contents. However, P3b latency was significantly longer in response to unpleasant social compared to pleasant social stimuli (*p*<.05), with no significant difference in P3b latency between pleasant and neutral social stimuli or unpleasant and neutral social stimuli (*p*s>.05). No significant differences in P3b latency were shown between pleasant, unpleasant, and neutral non-social stimuli (*p*s>.05).

The key findings from the ERP data were that both the amplitudes of the P2 and P3b components were enhanced in response to neutral face stimuli only. It was argued that P2 amplitude enhancements reflect the increased difficulty associated with extracting affective information from a somewhat ambiguous neutral expression. P2 amplitudes were not differentially modulated in response to the other affective stimuli possibly because the affective value of these stimuli was more salient. The extraction of affective value from the neutral face stimuli required greater early and late attentional resources as the same results were shown for both P2 and P3b amplitude. No significant differences were shown between social and non-social pleasant or social and non-social unpleasant stimuli at a behavioural or electrophysiological level. Therefore the hypothesis of no significant difference was partially supported. Images depicting human illness and injury appear to be just as effective at activating the aversive system as images of deceased animals and pollution, and the same holds for pleasant images of landscapes, animals, and pleasant human interactions for the appetitive system. Stimulus evaluation times as indexed by P3b latency did however appear to vary depending on social content. It can be said with a degree confidence that previous research employing both social and non-social stimuli has not been confounded by factors associated with social content, at least for low arousing stimuli. Although viewing facial expressions can activate the motivational systems in the same way as affective non-face stimuli, the results of Experiment 3 indicate that there is a problem associated with intermixing neutral faces and neutral object stimuli, and the general intermixing of facial and non-facial social stimuli.

The N170 component was not evoked in response to the neutral faces and this null effect is thought to arise due to the low task demands and lack of a stimulus or attention manipulation. Schupp et al. (2004c) also failed show reliable modulation of the

face sensitive N170 component during a sustained picture viewing paradigm where participants passively view the experimental stimuli. The N170 component has been reliably evoked when the appearance of the face stimuli are manipulated, for example, by changing the orientation of the stimuli (Stekelenburg et al., 2004), applying a spatial filter (Pourtois et al., 2005) or changing the configuration of facial features (Bousten et al., 2006). The N170 component is also reliably evoked when attentional demands are manipulated, for example when attention is cued to a particular location (Holmes et al., 2003), or when attention is directed to specific stimuli (e.g., faces or numbers: Eimer, 2000). Paradigms with increased task demands such as gender categorisation tasks (Pourtois et al.), stimulus categorisation tasks (Stekelenburg et al.) or instructions to respond to stimulus repetition (Eimer & Holmes) reliably elicit the N170 component. It is possible then that the N170 component is only evoked in response to facial stimuli under cognitively demanding conditions. The modified oddball paradigm utilised in Experiment 3 required responses to all affective stimuli, therefore attention was not specifically directed toward the face stimuli. It was beyond the scope of the current thesis to investigate the conditions under which the N170 is reliably elicited, however future research could be directed to such an area.

Summary

The intermixing of social and non-social IAPS stimuli within pleasant and unpleasant categories does not appear to present a serious confound, unlike the intermixing of arousal and semantic contents demonstrated in Experiments 2. One serious issue that was highlighted in Experiment 3 was the impact that neutral face stimuli have on the modulation of ERP component amplitudes. Neutral face stimuli were perceived as less pleasant than neutral objects and elicited stronger avoidance tendencies than neutral

objects in Experiment 3, therefore it was speculated that the neutral face stimuli were perceived as somewhat threatening. Greater early (P2) and late (P3b) attentional resources were required for the processing of neutral face stimuli compared to all other affective stimuli. It was argued that greater attentional resources were required to extract the affective value from the neutral faces due to the ambiguity of the facial expressions, and further, that the modulation of the early positive component reflects the processing of facial features rather than affective or social content.

CHAPTER 7: PHASE 2 – ATTENTIONAL ORIENTING AND EMOTION

Experiment 4: Attentional Disengagement or Global Response Bias?

Experiments 4 and 5 were designed to test whether focusing of attention as inferred from responses on valid trials and attentional disengagement as inferred from responses on invalid trials, are differentially affected by the motivational relevance of a preceding cue. Previous research using modified peripheral cueing paradigms have been mostly been focused on investigating the attentional processes thought to operate in anxious populations, with the typical finding that anxious participants demonstrate difficulty disengaging attention from threat (Fox et al., 2001; Georgiou et al., 2005; Yiend & Mathews, 2001). Few research efforts have been concerned with investigating the effect that affective or motivationally relevant stimuli have on the attentional processes of normal participants. To our knowledge, this is the first series of empirical studies that presents affective pictorial stimuli as peripheral cues while measuring ERP responses. An important aim of the current series of empirical studies is therefore to determine whether standard cueing effects shown for non-affective peripheral cueing paradigms are observed in the context of this modified peripheral cueing paradigm. The rationale for utilising a peripheral cueing paradigm to investigate the effect that motivationally relevant stimuli have on attentional processes over other cognitive paradigms such as dot-probe tasks, is that peripheral cueing offers increased ecological validity. Peripheral cues summon reflexive attention and provide direct information as to the likely position of subsequent targets (Müller & Rabbitt, 1989), which more closely represents danger cueing in the natural environment. Potential differences in the engagement and disengagement components of covert visual attention can also be more reliably

investigated using peripheral cueing paradigms than dot probe tasks (Fox et al.) Peripheral cues evoke both fast-acting automatic and sustained voluntary mechanisms (Müller & Rabbitt) which is a further advantage of peripheral cueing over the alternative central symbolic cueing paradigm.

A long SOA was used in Experiment 4 in order to investigate the P3b component to the pictorial cue and to determine whether the effects shown for P3b amplitude in Experiments 1 and 2 are paradigm-specific. Inhibitory effects are expected as a result of the long SOA and therefore it is predicted that RTs will be significantly slower and accuracy significantly reduced for validly cued targets compared to invalidly cued targets. Although it is beyond the scope of the current thesis to investigate the likely mechanisms underlying the IOR effect (motor bias versus attentional bias), it is assumed that both motor and attentional biases operate in a bottom-up fashion to influence reorientation to the cued location at long SOAs. As such, semantic variables such as the peripheral cue contents are not expected to influence RT or accuracy on valid trials.

IOR is classically defined in terms of overt responses, however research does suggest that P1 amplitudes are also suppressed in response to validly cued targets at long SOAs and that P1 suppression may therefore be considered a marker of inhibition at an electrophysiological level. P1 suppression in response to validly cued targets at long SOAs has been shown in the presence (see Prime & Ward, 2006) and absence of behavioural IOR effects (e.g., Eimer, 1994; Hopfinger & Mangun, 1998; Stormark et al., 1995). Following these findings, it is predicted that P1 amplitude will be reduced in response to validly cued targets relative to invalidly cued targets in Experiment 4.

From an evolutionary perspective, rapid disengagement from threatening stimuli is highly adaptive and there is evidence to suggest that a failure to rapidly disengage attention from threatening stimuli maintains elevated levels of anxiety in high anxious

individuals (e.g., Fox et al., 2000; Georgiou et al., 2005; Yiend & Mathews, 2001). Rapid disengagement from threatening and/or aversive stimuli has more immediate consequences for survival than would rapid disengagement from similarly intense appetitive stimuli according to the negativity bias (Cacioppo & Berntson, 1994; Cacioppo et al., 1997; Ito & Cacioppo, 2005; Ito et al., 1998b; Rozin & Royzman, 2001). However, responding to stimuli that follow the onset of an appetitive cue also requires a rapid response for example to secure food or a reproductive opportunity. Normal and low anxious participants do not typically demonstrate difficulty disengaging attention from threat and no participant group typically demonstrates facilitation on valid trials when cued by threatening stimuli. The notion that the motivational relevance of the peripheral cues provides more powerful facilitation effects for target processing than the cue validity information conveyed by the location of the peripheral cues is referred to as a global response bias in the context of the current thesis. Response bias as defined here is therefore different to response bias defined in other cognitive settings, typically referring to a selective difference in behaviour that is specific to a particular condition.

Threatening stimuli were included in Experiment 4 in order to investigate whether the different certainties surrounding the consequences of the threatening and mutilation stimuli have differential effects on target processing. The consequences of the threatening stimuli are uncertain and this may influence attentional orienting and target processing differently than for mutilation stimuli where the consequences are obvious. The primary prediction for Experiment 4 is that a global response bias will be observed for the ERP data whereby P1 amplitudes are expected to be enhanced in response to targets cued by motivationally relevant mutilation, threatening, and sexual stimuli compared to neutral stimuli that are validly and invalidly cued. Cue validity therefore is not predicted to interact significantly with peripheral cue contents to modulate the

amplitudes of the target-evoked ERP components. Following the major assumption of the negativity bias, it was predicted that target processing indexed by enhanced P1 amplitude would be greater for targets cued by mutilation and threatening stimuli compared to targets cued by sexual stimuli, again, for targets that are validly and invalidly cued.

The P3b component is sensitive to probability information and amplitudes are enhanced for low probability stimuli (Donchin, 1981). P3b amplitude is also enhanced in response to stimuli that are task relevant, and in the case of peripheral cueing paradigms when responses are required to target location, the peripheral cue provides more task relevant information than when responses are made on the basis of target discrimination. If probability information is the most influential factor for P3b modulation it is expected that target-evoked P3b amplitudes will be enhanced in response to low probability invalidly cued targets. If on the other hand task relevant information has a greater impact on P3b amplitude modulation than subjective probability, target-evoked P3b amplitudes are expected to be larger on valid trials given that responses are made to target location in this experiment. The factors of subjective probability and task relevance should have the same effect on target processing regardless of the content of the preceding cue, however Hopfinger and Mangun (1998) suggest reflexive attention affects higher order aspects of information processing as indexed by P3b amplitude by tagging novel or important stimuli as having greater potential relevance than other stimuli. As a result the stimuli that are tagged as being more task relevant continue to receive facilitated processing at the P3b level resulting in enhanced amplitudes. If this is the case then similar results are expected for target-evoked P1 and target-evoked P3b amplitudes with enhanced amplitudes in response to targets cued by sexual, mutilation, and threatening

stimuli compared to neutral stimuli and in response to mutilation and threatening stimuli compared to sexual stimuli.

The results of Experiment 2 showed significantly larger P3b amplitudes in response to sexual images compared to images of mutilation (high arousing unpleasant), sport/adventure (high arousing pleasant), high and low arousing neutral stimuli, and compared to all low arousing picture categories. Significant differences have also been shown between categories of unpleasant stimuli; as mentioned previously, Schupp et al. (2004a, b) reported significantly enhanced P3b amplitudes in response to images of mutilation compared to images of human threat. Following these lines of research it is predicted that cue evoked P3b amplitude will be significantly larger in response to sexual compared to all other peripheral cue contents, and that P3b amplitude will be significantly larger in response to mutilation compared to threatening stimuli, and in response to mutilation and threatening stimuli compared to neutral stimuli.

Method

Participants

Nineteen female volunteers participated in Experiment 4 after giving informed consent and received course credit for their participation (*M* age=19.89 years, *SD*=4.07, *Age Range* 18-35). All reported normal or corrected-to-normal vision and being right handed. Exclusion criteria were the same as that outlined in previous experiments and all participants were heterosexual. Females were selected to participate in the following series of empirical studies based on the results of the previous series of empirical studies in which no theoretically significant ERP differences between males and females in the processing of affective stimuli were shown and based on the larger proportion of female volunteers undertaking first year psychology classes.

Apparatus, Stimuli, and EEG recording

EEG recording equipment and data acquisition procedures were the same as that outlined in the previous experiments, with the exception that EEG activity was recorded with a high pass filter of 0.05Hz, peripheral cues were epoched for 1000ms, target stimuli were epoched for 2900ms, and baseline correction occurred 100ms before the peripheral cue onset. The experimental parameters are outlined in Figure 34. EEG activity corresponding to correct responses for each validly and invalidly cued target type (i.e., cued by neutral, sexual, mutilation, and threatening stimuli) and for each peripheral cue type was averaged. Averages containing more than 15 trials were accepted for analyses. Grand mean averages were calculated, followed by individual peak detection.

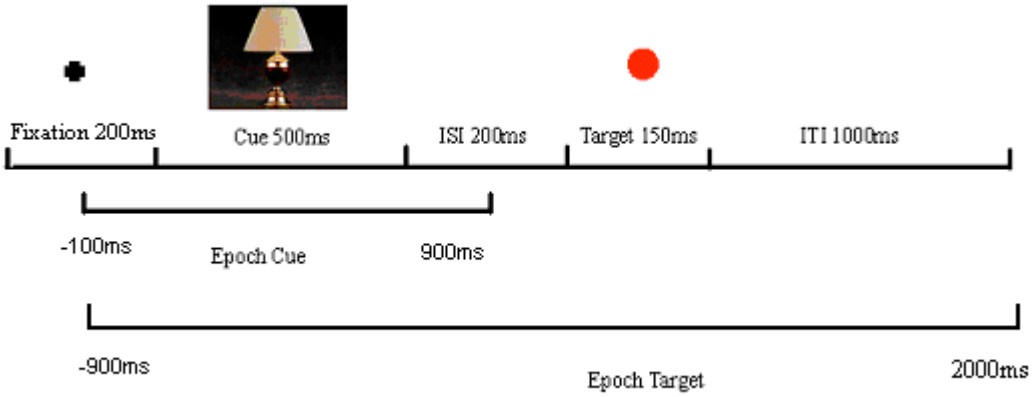


Figure 34. EEG analysis parameters for the modified Posner cueing paradigm in Experiment 4.

Cues consisted of 15 of each of sexual or erotic couple stimuli (valence *M*=6.57, *SD*=.37; arousal *M*=6.47, *SD*=.32), human mutilation (valence *M*=1.83, *SD*=.42; arousal

M=6.46, *SD*=.60), human attack or threatening stimuli (valence *M*=2.93, *SD*=.39; arousal *M*=6.42, *SD*=.53), and neutral stimuli (valence *M*=4.92, *SD*=.25; arousal *M*=3.67, *SD*=4.66), selected from the IAPS (see Appendix D). The sequence of experimental events is illustrated in Figure 35. Cues (150 x 112 pixels) were presented at 6° of visual angle to the left or right of a central fixation point for 500ms, followed by a target stimulus (a red circle 76 x 63 pixels) 200ms later for a duration of 150ms. The visual angle of the cue was chosen based on a study conducted by Mangun and Hillyard (1991) that showed that residual eye movements between the cue and target have little to no observable effect on target evoked ERPs at 6° of visual angle. The inter-trial interval was 1000ms. Seventy five percent (360) of the targets were validly cued and 25 percent (120) of the targets were invalidly cued. Valid and invalid trials were presented equally to the left and right visual fields and the order of both peripheral cue and target type (valid/invalid) were randomised. For ERP averaging purposes each stimulus was presented eight times, twice in the invalid position and six times in the valid position with a total of 480 trials overall, lasting approximately 20 minutes. The STAI was not administered in this experiment, instead Wolpe and Lang's (1964) Fear Survey Schedule (FSS-III) was used to screen for highly fearful participants.

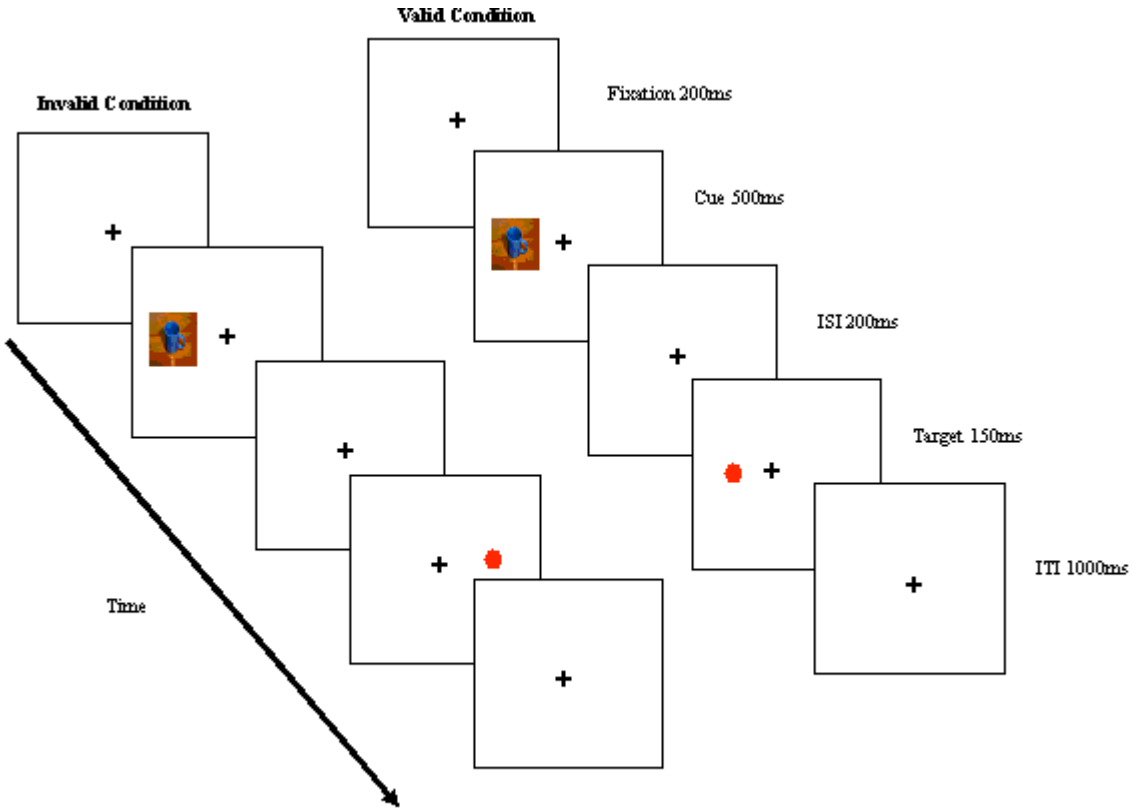


Figure 35. Timing and sequence of events for Experiment 4.

Procedure

Participants had electrodes attached as for previous experiments and were seated in a sound attenuated room. Participants then completed the FSS-III followed by the presentation of the modified Posner cueing task. Participants were instructed to keep their gaze on a central fixation cross. Responses were made to target location with a left hand response for left visual field targets and a right hand response for right visual field targets. Every 120 trials (approximately five minutes) an instruction to "WAIT" appeared. Participants were instructed to use this opportunity to take a short break and when rested to press a response key to continue. After the experimental task was complete, each peripheral cue stimulus was re-presented for 2000ms at a size approximating the 13 inch monitor and participants rated each image on levels of

valence, arousal, novelty, and interest (or attention grabbing capacity) on a nine point Likert scale.

Design and Data Analysis

The experiment followed a 4(Peripheral Cue Content: neutral, sexual, mutilation, threatening) x 2(Cue Validity: valid, invalid) repeated measures design. ERPs were averaged across left and right visual fields in Experiment 4. Electrode site lead to a further repeated measures variable for the ERP data and inspection of the grand mean waveforms (see Figures 36a, b, & c) indicated that the P1 component was evoked over centro-parietal and parietal sites (Electrode sites: CP3, CPz, CP4, P3, Pz, P4). The cue evoked and target evoked P3b component data were also analysed over these electrode sites. The raw scores for the accuracy data were converted to percentages, and the dependent variables for the behavioural data were RT, percentage of correct responses or accuracy, and ratings of valence, arousal, novelty, and interest. Mean RT and accuracy data were analysed using separate repeated measures ANOVAs with factors of Peripheral Cue Content and Cue Validity. The ERP analyses focused on the P3b component elicited by the cue, and the target-elicited P1 and P3b amplitude and latency. Peak amplitudes of the ERP components were measured at centro-parietal and parietal sites where amplitudes were maximal in two post-target intervals corresponding to P1 (100-180ms) and P3b (300-400ms). P3b amplitude to the cue was measured at an interval of 300-700ms post-stimulus onset. The amplitude and latency data for the cue elicited P3b and target elicited P1 and P3b components were analysed using separate repeated measures ANOVAs with factors of Peripheral Cue content, Cue Validity, and Electrode site. Main effects and interactions involving Sagittal and Coronal sites will not

be reported unless they are of theoretical significance. Statistical procedures were the same as that outlined in the previous experiments.

Results and Discussion

Ratings of Valence, Arousal, Novelty, and Interest

Ratings of valence, $F(1.50, 27.05)=123.29$, $MSE=.46$, $p<.001$, arousal $F(1.47, 26.55)=23.76$, $MSE=2.49$, $p<.001$, novelty $F(1.90, 34.23)=115.86$, $MSE=1.36$, $p<.01$, and interest $F(1.90, 34.23)=115.86$, $MSE=1.36$, $p<.01$ differed as a function of Peripheral Cue Content. Sexual ($M=5.39$, $SEM=.23$) and neutral ($M=5.03$, $SEM=.03$) stimuli did not differ significantly on level of rated valence, but were rated as significantly more pleasant than mutilation ($M=1.67$, $SEM=.09$) or threatening stimuli ($M=3.14$, $SEM=.17$) (ps $<.05$). Mutilation stimuli were rated as significantly more unpleasant than threatening stimuli ($p<.05$). Sexual ($M=4.46$, $SEM=.40$), mutilation ($M=6.31$, $SEM=.34$), and threatening stimuli ($M=5.02$, $SEM=.23$) were matched on level of arousal and were rated as significantly more arousing than neutral stimuli ($M=1.08$, $SEM=.03$) ($p<.05$). Sexual ($M=4.86$, $SEM=.33$) and threatening stimuli ($M=5.02$, $SEM=.23$) were matched on rated interest or attention grabbing capacity and were rated as significantly more interesting than neutral stimuli ($M=1.12$, $SEM=.04$) (ps$<.05$). Mutilation stimuli ($M=6.31$, $SEM=.34$) were rated as significantly more attention grabbing than all other peripheral cue stimuli (ps$<.05$). The same results were shown for the novelty ratings, with sexual ($M=4.86$, $SEM=.33$) and threatening stimuli ($M=5.02$, $SEM=.23$) matched on rated novelty, mutilation stimuli ($M=8.16$, $SEM=.19$) were rated as significantly more novel than all peripheral cue stimuli, and neutral stimuli were rated as significantly less novel than all peripheral cue stimuli (ps$<.05$).

The motivationally relevant stimuli (mutilation, threatening, and sexual) were matched on level of arousal, which is particularly important since level of arousal is associated with the level of activation within the appetitive and aversive systems (Lang, 1995; Lang et al., 1997). Sexual stimuli were not rated as significantly more pleasant than neutral stimuli, and it is speculated that embarrassment or discomfort associated with the content of these stimuli may have resulted in more conservative ratings. This effect is assumed to be associated with the all female sample, as similar results were not shown in Experiments 1 and 2 which included male participants. Threatening and sexual stimuli were matched for novelty and attention grabbing capacity therefore subsequent differences between these stimuli in the ERP and behavioural performance data are not assumed to be a result of novelty or attention grabbing capacity. Mutilation stimuli however were rated as significantly more novel and attention grabbing than all other stimuli.

Cueing Effects on Behavioural Performance

To investigate the processes of focusing of attention and attentional disengagement thought to underlie attentional orienting, comparisons were made between valid and invalid trials. ANOVAs conducted on the RT data showed that mean RT for validly cued and invalidly cued targets differed significantly, $F(2.54, 45.68)=3.56$, $MSE=.00021$, $p<.05$, with significantly faster RT for validly cued ($M=.29$ms, $SEM=.01$) than invalidly cued targets ($M=.33$ms, $SEM=2.27$). ANOVAs conducted on the accuracy data also indicated that mean accuracy level for validly cued and invalidly cued targets differed significantly, $F(1,18)=11.78$, $MSE=34.00$, $p<.01$ with significantly greater accuracy for validly cued targets ($M=94.94$ %, $SEM=1.77$) compared to invalidly cued targets ($M=91.71$ %, $SEM=2.27$). No significant main effects or interactions involving

Peripheral Cue Content were revealed. The hypotheses for the behavioural data were therefore not supported, as IOR effects were not evident for either RT or accuracy data, instead classic facilitation effects were observed. Peripheral cue content had no effect on the behavioural data. While this result is inconsistent with previous peripheral cueing research in which a long SOA has been used, some instances are noted where classic facilitation occurred at long SOAs (e.g., Eimer, 1994: Experiment 1; Stormark et al., 1995).

ERP Data

Grand mean average waveforms were calculated for correct responses to targets validly and invalidly cued by neutral, sexual, mutilation, and threatening stimuli. Before the onset of the target a distinct P3b component can be observed in response to the peripheral cues (see Figures 36b & c) that is larger in response to sexual compared to all other picture stimuli. Mutilation stimuli however evoked larger P3b amplitudes compared to threatening and neutral stimuli which do not appear to differ. The grand mean waveforms illustrated in Figure 36a show a P1 and a P3b component evoked in response to the target stimuli with maximal P1 amplitudes at the parietal midline site and maximal P3b amplitudes at centro-parietal midline sites. The largest differences between validly and invalidly cued targets are also observed at these midline sites, with larger P1 and P3b amplitudes evoked in response to invalidly cued targets. As can be seen in Figure 36a, the P1 component evoked at occipital sites is quite small and there appears to be little if any difference between validly cued and invalidly cued targets. Figures 36b and c show a distinct P1 and P3b component to the target stimuli at centro-parietal and parietal sites. The P1 component evoked in response to both validly cued and invalidly cued targets has a cento-parietal maximum and is larger in response to targets both

validly cued and invalidly cued by sexual compared to all other affectively cued targets, and is larger in response to targets both validly and invalidly cued by mutilation compared to targets cued by threatening and neutral stimuli. P3b amplitude for validly cued targets showed the same waveform pattern as the target-evoked P1 component, however little if any observable difference in P3b amplitude is shown between invalidly cued targets. Little difference was observed in the horizontal eye movements recorded for validly and invalidly cued targets (see HEOG: Figure 36a), however horizontal eye movements appear to be influenced by cue validity when the motivational relevance of the preceding cue is considered (see Figure 36b). Larger eye movements were made in response to targets cued by sexual and mutilation stimuli compared to neutral and threatening stimuli in the valid condition, whereas in the invalid condition, larger eye movements were made in response to targets cued by sexual and neutral stimuli compared to mutilation and threatening stimuli.

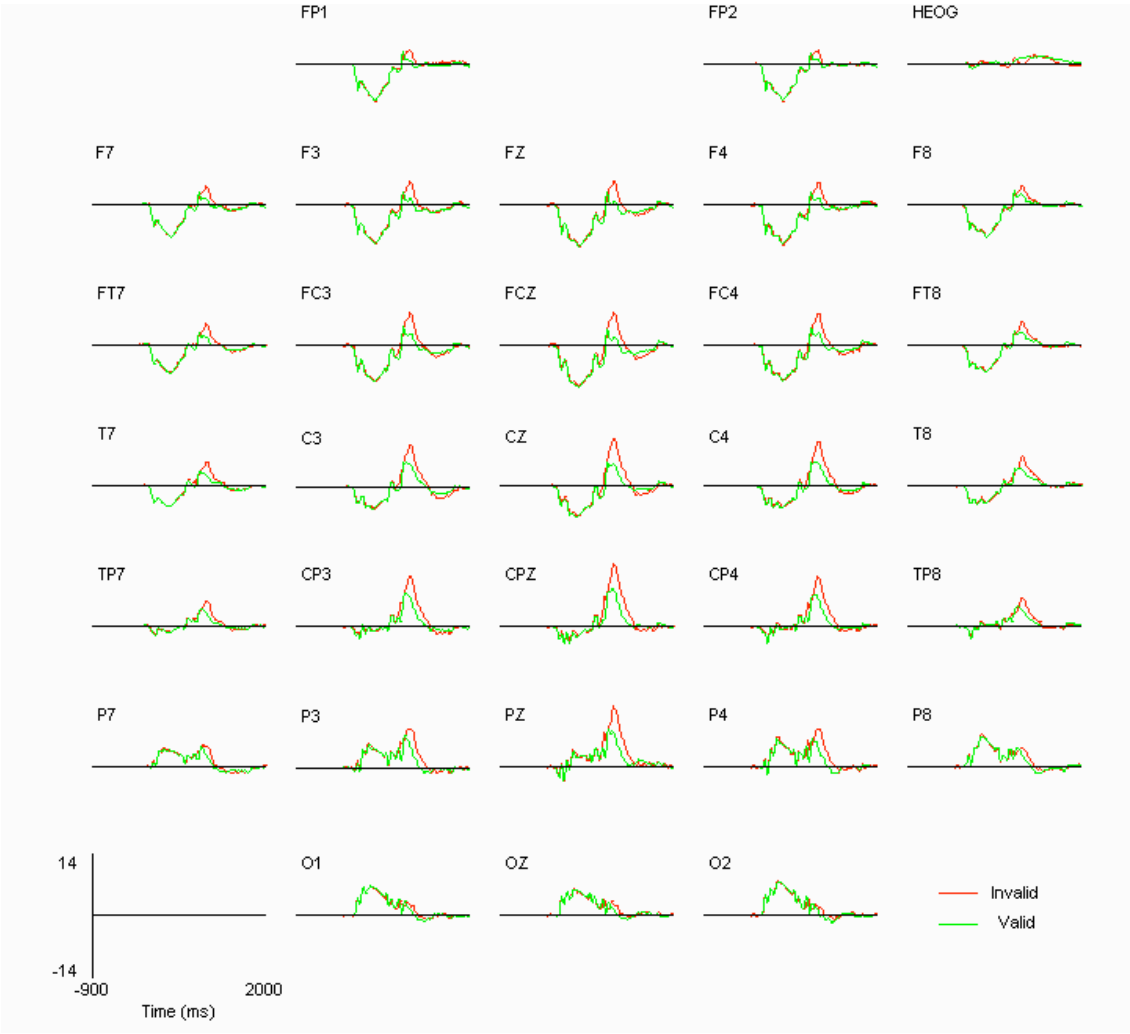


Figure 36a. Grand mean waveforms for validly and invalidly cued targets collapsed across peripheral cue contents.

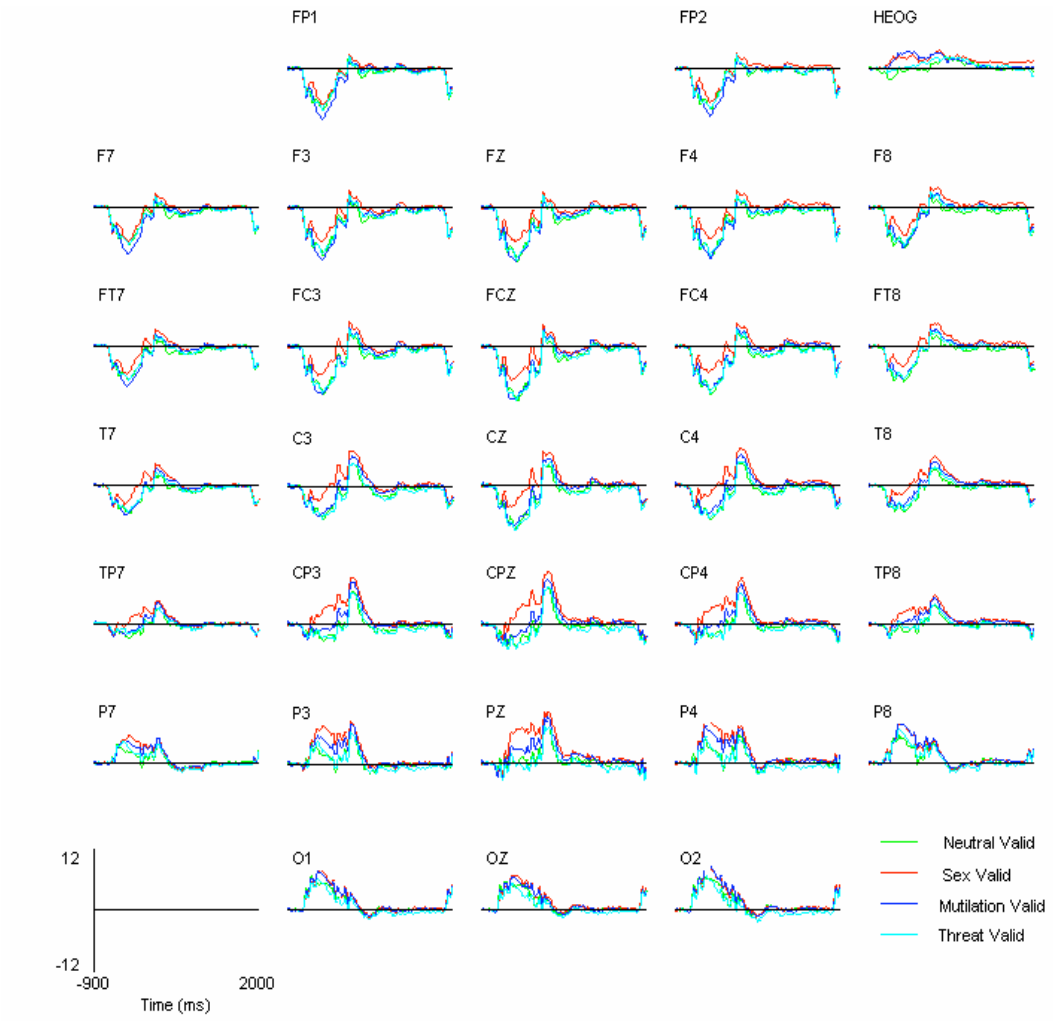


Figure 36b. Grand mean waveforms for targets validly cued by neutral, sexual, mutilation, and threatening stimuli.

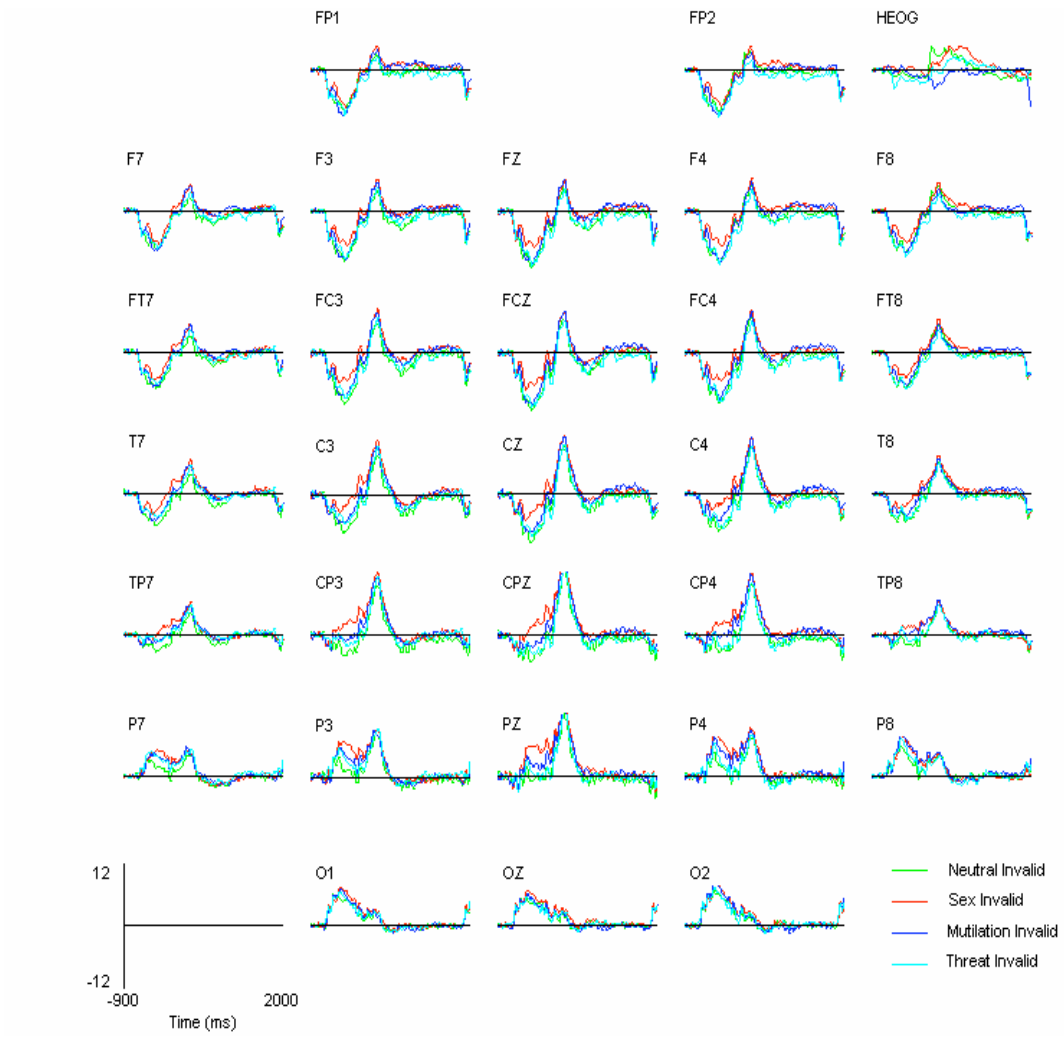


Figure 36c. Grand mean waveforms for targets invalidly cued by neutral, sexual, mutilation and threatening stimuli.

Cue ERPs

The ANOVA conducted on the P3b amplitude data following the cue indicated that P3b amplitude was significantly larger over parietal than centro-parietal sites, $F(2.62, 47.15)=34.91$, $MSE=8.49$, $p<.001$ and differed as a function of Peripheral Cue Content, $F(2.19, 39.38)=26.00$, $MSE=24.67$, $p<.05$. Tukey post hoc tests indicated that P3b amplitude was significantly larger in response to sexual stimuli ($M=9.08\mu V$, $SEM=1.11$)

compared to mutilation (*M*=6.83μV, *SEM*=.91), threatening (*M*=4.17μV, *SEM*=.70), and neutral stimuli (*M*=4.16μV, *SEM*=.70) (*p*s<.05) and was significantly larger in response to mutilation than neutral and threatening stimuli which did not differ significantly. The hypotheses pertaining to the cue-evoked P3b component were supported. Larger P3b amplitudes evoked in response to sexual stimuli compared to all other peripheral cue stimuli, and in response to mutilation compared to neutral stimuli is consistent with the results of Experiment 2, indicating that these effects are not paradigm specific. P3b amplitude was also enhanced in response to mutilation compared to threatening stimuli which is consistent with the results of Schupp et al. (2004a). No significant difference however was shown between neutral and threatening stimuli for cue evoked P3b amplitude and possible explanations for this result will be outlined in the general discussion (Chapter 8). ANOVAs conducted on the cue-evoked P3b latency data showed significant main effects of Peripheral Cue Content, $F(2.79, 50.16)=6.98$, *MSE*=9742, $p<.001$ and Electrode site, $F(2.56, 46.18)=14.12$, *MSE*=20370, $p<.001$. Tukey post hoc tests indicated that P3b latency was significantly longer in response to sexual (*M*=556.63ms, *SEM*=27.62) and mutilation stimuli (*M*=537.89ms, *SEM*=32.25) compared to neutral (*M*=502.82, *SEM*=29.92) and threatening stimuli (*M*=512.48ms, *SEM*=33.44). No significant differences were shown between mutilation and sexual stimuli, mutilation and threatening stimuli, or between threatening and neutral stimuli.

Cueing Effects on Validly and Invalidly Cued Target ERPs

To investigate the effects of attentional orienting on electrophysiological activity, comparisons were made between target ERPs on valid and invalid trials. Target-evoked P1 amplitude differed between Electrode sites, $F(2.55,9, 46.65)=3.41$, *MSE*=18.67, $p<.01$, however Tukey post hoc tests failed to show any systematic differences between

centro-parietal and parietal sites. Target-evoked P1 amplitude differed as a function of Cue Validity, $F(1, 18)=7.84$, $MSE=76.32$, $p<.05$, with amplitudes significantly suppressed in response to validly cued targets ($M=5.88\mu V$, $SEM=.08$) compared to invalidly cued targets ($M=7.50\mu V$, $SEM=.99$), providing support for the hypothesised inhibitory effects. Classic facilitation was however observed at a behavioural level, with RTs significantly faster and accuracy significantly greater in response to validly cued targets. While P1 suppression is usually observed in conjunction with behavioural IOR effects (see Prime & Ward, 2006) there are noted examples where P1 suppression has occurred in conjunction with facilitation effects at a behavioural level (e.g., Eimer, 1994: Experiment 1; Stormark et al., 1995) and when no significant difference was revealed between validly and invalidly cued targets at a behavioural level (e.g., Eimer, 1994: Experiment 2; Hopfinger & Mangun, 1998). The results of the current study lend support for a possible dissociation between behavioural and electrophysiological responses during peripheral cueing, and it is argued that behavioural IOR effects are not a precondition for P1 suppression.

Target-evoked P1 amplitude differed as a function of the Peripheral Cue Content, $F(2.55, 45.91)=10.22$, $MSE=41.54$, $p<.001$ with significantly larger amplitudes in response to targets cued by sexual ($M=8.29\mu V$, $SEM=.88$) and mutilation stimuli ($M=7.35\mu V$, $SEM=.99$) compared to targets cued by neutral ($M=5.72\mu V$, $SEM=.93$) and threatening stimuli ($M=5.41\mu V$, $SEM=.92$) (ps$<.05$) which did not differ significantly. The hypothesis that a global response bias would facilitate target processing following motivationally relevant stimuli was partially supported, as P1 amplitudes were significantly enhanced in response to targets cued by motivationally relevant sexual and mutilation stimuli. No significant difference in P1 amplitude was reported between targets cued by neutral and threatening stimuli and this null effect will be discussed in

detail in the general discussion (Chapter 8). As the main effect of cue validity was significant and no higher order interactions were revealed for target-evoked P1 amplitude, the current data indicate that normal participants display a global response bias that facilitates target processing following the onset of motivationally relevant sexual and mutilation stimuli.

Target-evoked P1 latency differed between Electrode sites only, $F(3.12, 56.19)=4.53$, $MSE=883$, $p<.001$, and the main effects of Peripheral Cue Content, $F(2.62, 47.13)=2.14$, $MSE=1.29$, $p=.10$, and Cue Validity, $F(1,18)=.04$, $MSE=8107$, $p=.84$ were not significant.

Target-evoked P3b amplitude differed as a function of Cue Validity, $F(1, 18)=93.18$, $MSE=67.57$, $p<.001$, with significantly larger P3b amplitude for invalidly cued ($M=12.57\mu V$, $SEM=1.02$) compared to validly cued targets ($M=7.31\mu V$, $SEM=.84$). Subjective probability therefore appears to be a more powerful moderator of P3b amplitude than task relevance in the current study. Task relevance factors did however have an important impact on P3b amplitude modulation as P3b amplitudes differed as a function of Peripheral Cue Content, $F(2.66, 47.98)=9.85$, $MSE=23.93$, $p<.001$. Tukey post hoc tests showed significantly larger P3b amplitudes for targets cued by sexual ($M=11.09\mu V$, $SEM=.86$) and mutilation stimuli ($M=10.42\mu V$, $SEM=.98$) (ps$<.05$) compared to neutral ($M=8.79\mu V$, $SEM=1.01$) and threatening stimuli ($M=9.46\mu V$, $SEM=.91$) which did not differ significantly. These results mirror those of the target-evoked P1 component, supporting the hypotheses and research by Hopfinger and Mangun (1998) who argue that reflexive attention initiated by peripheral cues facilitates the early sensory processing of targets, leading to these targets being treated as more task relevant and thus resulting in enhanced P3b amplitude. The motivational relevance of the sexual and mutilation stimuli are therefore assumed to have facilitated

the early sensory processing of targets, in turn making these stimuli appear more task relevant and facilitating higher order aspects of target processing indexed by P3b amplitude. No significant main effects or higher order interactions were revealed for the target-evoked P3b latency data.

Summary

The inherent motivational relevance of the sexual and mutilation stimuli appears to be a more powerful moderator of attentional processes than spatial or cue validity information, as the responses of normal participants were characterised by a global response bias. Target processing as indexed by target evoked P1 and P3b amplitudes was facilitated by sexual and mutilation stimuli independent of whether cueing was valid or invalid, suggesting that normal participants can rapidly shift attention to process information following motivationally relevant stimuli that may be important for survival. The cue evoked P3b component was enhanced in response to sexual compared to all other affective stimuli and the results for P3b amplitude in Experiment 4 are consistent with that of Experiment 2, indicating that these results are not paradigm specific.

Experiment 5: Facilitation or Global Response Bias?

P1 suppression was shown in response to validly cued targets in Experiment 4, indicating that some standard peripheral cueing effects can be observed during modified peripheral cueing paradigms. This P1 suppression was however observed in the absence of behavioural IOR effects, thus questions were raised as to the possible dissociation between electrophysiological and behavioural manifestations of inhibition. It is likely that the affective pictorial stimuli created a different effect for the peripheral cueing paradigm used here compared to other standard cueing paradigms, especially since cue

validity effects were not observed for targets cued by the neutral stimuli which are not motivationally relevant. Target processing therefore was not influenced by whether the cue was valid or invalid, instead, target processing was facilitated following the onset of motivationally relevant sexual and mutilation cues, referred to here as a global response bias. The standard cueing effect, namely, P1 suppression in response to validly cued targets was considered to be an important variable that required control in the following experiments

Inhibition, at a behavioural, or electrophysiological level, is not considered highly adaptive when detection of threat is necessary as re-sampling areas associated with threat is vital for survival (Terry et al., 1994). In order to provide a more valid investigation of the effect that motivationally relevant stimuli have on processes of attentional orienting in normal participants attempts must be made to reduce the impact of the inhibitory mechanism, namely P1 suppression, observed in Experiment 4. Experiment 5 employs a shorter SOA (300ms) and requires a target discrimination response both of which have been shown to reduce IOR at a behavioural level (see Terry et al. for examples of target discrimination; see Collie et al., 2000; Hopfinger & Mangun, 1998; Maylor, 1985; Posner, 1980 for examples of SOA). Although it is yet to be determined whether P1 suppression and behavioural IOR involve the same inhibitory mechanisms, the experimental manipulations underlying cue validity effects at a behavioural level are also thought to have relevance for ERP cue validity effects. It is acknowledged that IOR effects are not demonstrated with sustained cueing (Collie et al.; Wascher & Tipper, 2004) or symbolic cueing (Mangun, 1995), however the peripheral cueing paradigm used in Experiment 4 is considered to be more ecologically valid, and thus the same paradigm is utilised in Experiment 5 with changes to SOA and response requirements. The inhibitory mechanisms assumed to account for P1 suppression are

also assumed to have concealed the ERP facilitation effects typically shown on valid trials. The primary aim of Experiment 5 is therefore to investigate the effect that motivationally relevant stimuli may have on the engagement component of covert visual attention inferred from responses to validly cued targets by reducing the inhibitory effects observed in Experiment 4. A further aim is to determine whether normal participants display a global response bias when responding to targets that are cued by motivationally relevant stimuli.

Standard facilitation effects are expected for both behavioural and electrophysiological responses as a result of the changes to SOA and response requirements, with significantly faster RT, greater accuracy, and enhanced P1 amplitudes predicted in response to validly cued compared to invalidly cued targets. Responses to validly cued targets are generally very rapid and, as Fox et al. (2001) note, expecting threatening stimuli to further speed responses to validly cued targets may not be realistic. As mentioned previously, high anxious individuals demonstrate difficulty disengaging attention from threat as indicated by slower responses to targets that are invalidly cued by threatening stimuli (Fox et al; Georgiou et al., 2005; Yiend & Mathews, 2001). This effect is not shown for normal or low anxious participants. Following these considerations and the global response bias reported in Experiment 4, the presence of motivationally relevant stimuli is not expected to facilitate target processing at the cued location as indexed by behavioural or electrophysiological responses. Instead a global response bias is again hypothesised, with enhanced P1 amplitudes expected in response to targets cued by motivationally relevant stimuli independent of whether cueing is valid or invalid. Furthermore, based on the results of Experiment 4 in which target processing was facilitated significantly more by sexual and mutilation stimuli than threatening and neutral stimuli, P1 amplitudes are again expected

to be significantly enhanced in response to targets cued by these stimuli. As the peripheral cue content had no effect on the behavioural data in Experiment 4, peripheral cue contents are not expected to influence RT or accuracy measures in Experiment 5.

The response requirements in Experiment 5 are based on target identity rather than location, thus the peripheral cue does not provide task relevant information as to the response requirements. Based on this consideration and the results for target-evoked P3b amplitude in Experiment 4, it is again predicted that P3b amplitude will be larger in response to low probability invalidly cued targets. Finally, Experiment 4 indicated that the early facilitation of targets cued by sexual and mutilation stimuli influenced higher order aspects of target processing, therefore similar results are again expected for target-evoked P1 and P3b amplitudes.

Method

Participants

Eighteen female volunteers (*M age*=21.32 years, *SD*=4.46, *Age Range:* 18-36,) who had not participated in Experiment 4 received course credit for participating in Experiment 5. All participants gave informed consent and exclusion criteria were the same as that outlined in the previous experiments. Participants' scores on the state version of the STAI (Spielberger et al., 1983) ranged between 23-49 (*M*=36.28, *SD*=9.30, *Mdn*=35.5).

Apparatus, Stimuli, and EEG recording

EEG recording equipment and data acquisition procedures were the same as that outlined in Experiment 4, with the exception that the epoch for the cue was 1000ms and the epoch for the target was 1600ms. The experimental parameters are outlined in Figure 37.

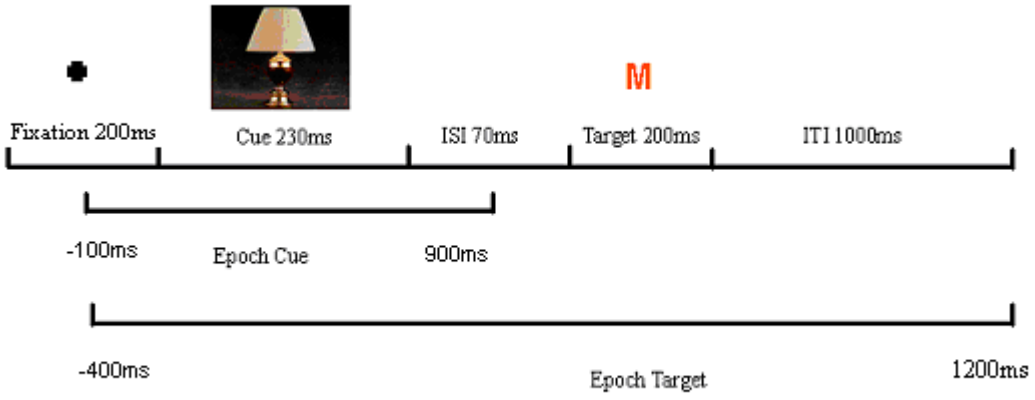


Figure 37. EEG parameters for the modified Posner cueing paradigm used in Experiment 5.

Stimuli were identical to those of Experiment 5, with the addition of filler stimulus depicting a pleasant, unpleasant, and neutral symbolic face (see Appendix D). Stimuli were 248 x 186 pixels presented at 6° of visual angle. Peripheral cues were presented for 230ms, followed 70ms later by the presentation of a target letter (M or T: 50 x 50 pixels) and the ITI again was 1000ms. The sequence of experimental events is outlined in Figure 38. Sixty percent of the trials (360) were validly cued, 20% (120) were invalidly cued, and 20% (120) of trials were cued by the filler stimulus and required no response. There were 600 trials overall and the experiment lasted approximately 20 minutes. The FSS-III was used to screen for highly fearful participants in Experiment 4, however exclusion based on high levels of anxiety may be more appropriate, as research suggests that high anxious individuals show a different pattern of attentional orienting (see Amir et al., 2003; Bradley et al., 2000; Fox et al., 2001; Georgiou et al., 2005; Yiend & Mathews, 2001). Fox et al. suggest that elevated levels of state anxiety activate the fear system more directly than elevated levels of trait anxiety which is considered a personality disposition. The state version of the STAI

(Spielberger et al., 1983) was therefore used to screen for participants with extremely high levels of state anxiety. The state version of the STAI was used purely as a screening tool therefore no post-test measures of state anxiety were taken.

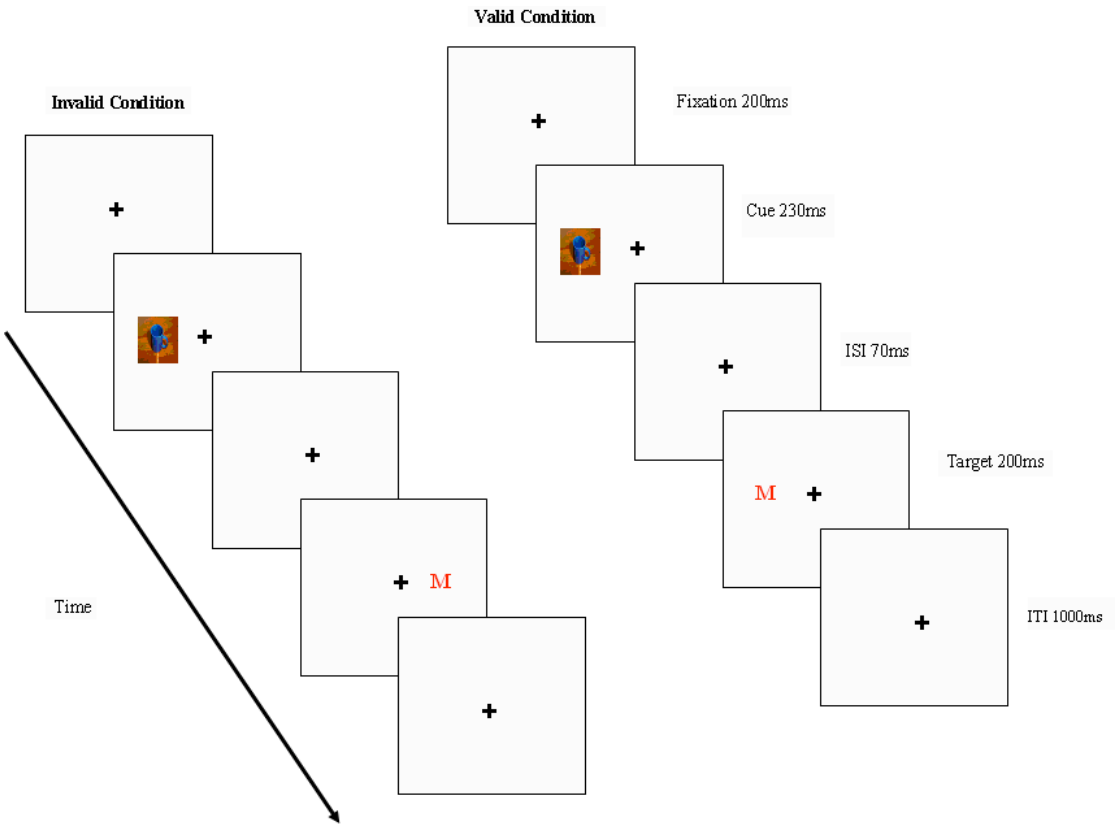


Figure 38. Timing and sequence of events for Experiment 5.

Procedure

The procedure was identical to Experiment 4, with the exception that response requirements concerned target identity, pressing one of two centrally located buttons for target letters M and T respectively, with the right index finger. These requirements were intended to circumvent the motor bias that occurs when target stimuli appear in the same location relative to a response button, known as the Simon effect (Simon, 1969).

Because the peripheral cue draws attention to a specific visual space, the neural pathways for that visual hemi-space are activated in preparation for the target and ipsilateral responses may be faster than contralateral responses. Also, since it is assumed that electrophysiological manifestations of inhibition may be sensitive to the same task parameters as behavioural IOR, a target discrimination task was intended to further reduce the effect of inhibitory mechanisms on ERP measures. As previously mentioned no response was required for targets cued by the filler stimulus. This stimulus was included to increase the likelihood that all peripheral cue contents were evaluated.

Design and Data Analysis

The design was the same as that outlined in Experiment 4 with the exception that visual field differences were inspected. Unfortunately there were insufficient trials in any average of the left and right visual field therefore visual field could not included as an independent variable and further analyses were again conducted with ERP data averaged across the left and right visual fields. Grand mean waveforms for targets validly and invalidly cued by each peripheral cue in the left and right visual fields are however displayed (see Figures 39e, f, g, & h). Peak amplitudes of the ERP components were again measured at centro-parietal and parietal sites in two post-target intervals corresponding to P1 (100-180ms) and P3b (300-400ms). P1 amplitude to the cue was measured at an interval of 140-240ms post-stimulus onset. All behavioural, target ERP, and cue ERP analyses were identical to those in Experiment 4. Seven participants scored above the normal range for state anxiety, however visual inspection of the individual waveforms for these participants did not reveal any unique effects that may be anxiety specific and therefore the data for these participants were included in the analyses.

Results and Discussion

Cueing Effects on Behavioural Performance

ANOVAs conducted on the RT and accuracy data indicated that the mean RT for validly and invalidly cued targets did not differ significantly, $F(1, 17)=.11$, $MSE=.0030$, $p=.74$, however mean accuracy levels did differ as a function of Cue Validity, $F(1, 17)=13.02$, $MSE=13.02$, $p<.001$, with significantly greater accuracy for validly cued ($M=76.59$ %, $SEM=3.27$) compared to invalidly cued targets ($M=72.96$ %, $SEM=3.48$). Peripheral Cue Content did not influence the behavioural data, as no significant main effects or interactions involving Peripheral Cue Contents were revealed.

Facilitated RT for validly cued targets was expected due to the short SOA, however it is possible that the target discrimination response in Experiment 5 reduced both the effects of IOR and facilitation. Although the processes of facilitation and IOR are separable they are not completely independent. A RT advantage for targets appearing at either the cued or uncued location is argued to depend on the SOA, the temporal relationship between the cue and target, and the interaction between facilitatory and inhibitory processes (Collie et al., 2000). The debate continues as to whether inhibition and facilitation are part of a single biphasic process or are completely independent (for reviews see Collie et al.), however given the possible relationship between facilitation and inhibition, it is plausible that reducing the IOR effect through the employment of a target discrimination task and a short SOA reduced facilitation to the same degree accounting for the lack of a significant behavioural facilitation effect in Experiment 5.

IOR was not expected in the current experiment, however it is speculated that the discrimination response may have reduced the inhibitory effect for invalid trials at a short SOA in the same way as for IOR at long SOAs. This seems particularly likely as non-significant differences between valid and invalid trials have been shown at long

SOAs when a target discrimination response was required (SOA 556-766: Hopfinger & Mangun, 1998). Eimer (1994) however investigated the effect of target detection and target discrimination responses during a peripheral cueing paradigm with an SOA of 900ms, and showed significant facilitation effects for valid trials during both target discrimination and target detection tasks, therefore it is unclear what factors may be responsible for facilitation effects at long SOAs. It could be that the target discrimination response circumvented the motor bias or Simon effect associated with target detection and this may account for the non significant effects shown for the RT data. The explanation for the lack of facilitation for valid trials in the current experiment is however unclear.

ERP Data

Grand mean averages were calculated for targets validly and invalidly cued by neutral, sexual, mutilation, and threatening stimuli, and for each of these targets in the left and right visual fields. Figure 39a illustrates the grand mean average waveforms for validly cued and invalidly cued targets. A small early positive component can be observed at parietal sites (P3 and P4 electrode sites), however the peak of this P1 component is not as distinct as that observed in Experiment 4. There also appears to be little if any difference in P1 amplitude between validly cued and invalidly cued targets. A subsequent P3b component is evoked, however there also appears to be little difference in P3b amplitude between validly cued and invalidly cued targets. As illustrated in Figure 39a no distinct P1 or P3b components are evoked at occipital sites. Figure 39b illustrates the grand mean average waveforms for validly cued and invalidly cued targets (averaged across peripheral cue types) in the left and right visual fields. As can be seen, an early positive component is evoked at outer coronal sites that is most pronounced at

frontal regions and is enhanced in response to left visual field targets in the left hemisphere and right visual field targets in the right visual field regardless of cue validity. Figures 39c and d display the grand mean waveforms for targets validly and invalidly cued by neutral, threatening, sexual, and mutilation stimuli. A small P1 component evoked in response to the affective cues can be seen over centro-parietal and parietal sites, however little difference between the picture stimuli can be seen. A P1 component is also observed in response to target stimuli over centro-parietal and parietal sites, with a parietal maximum for both validly cued and invalidly cued targets. The peak of this component is more distinct over parietal sites, especially in the left and right parietal hemispheres. P1 amplitudes are larger in response to targets cued by sexual than all other target types, and for targets cued by mutilation than neutral and threatening stimuli. A P3b component with a centro-parietal maximum directly follows the target-evoked P1 component, and is slightly larger for invalidly cued targets. Targets cued by sexual and mutilation stimuli elicited larger P3b amplitudes than targets cued by neutral and threatening stimuli for both validly cued and invalidly cued targets, however the magnitude of this difference appears larger for invalid trials. Larger horizontal eye movements were made in response to invalidly cued targets (see HEOG in Figure 39d), and consistent with Experiment 4, larger eye movements were made in response to sexual and neutral compared to threatening and mutilation stimuli.

Figures 39e, f, g, and h show the grand mean waveforms for validly and invalidly cued targets cued by each peripheral stimuli in the left and right visual fields. There appears to be little effect of visual field on the P1 and P3b components at centro-parietal and parietal sites. The outer coronal sites, especially at frontal regions show an enhanced early positive component for left visual field targets in the left hemisphere and for right visual field targets in the right hemisphere. Little difference can be observed between

validly and invalidly cued targets presented to the left visual field, however validly cued targets evoke a larger early positive component than invalidly cued targets in the right visual field and this effect is shown for all affectively cued targets.

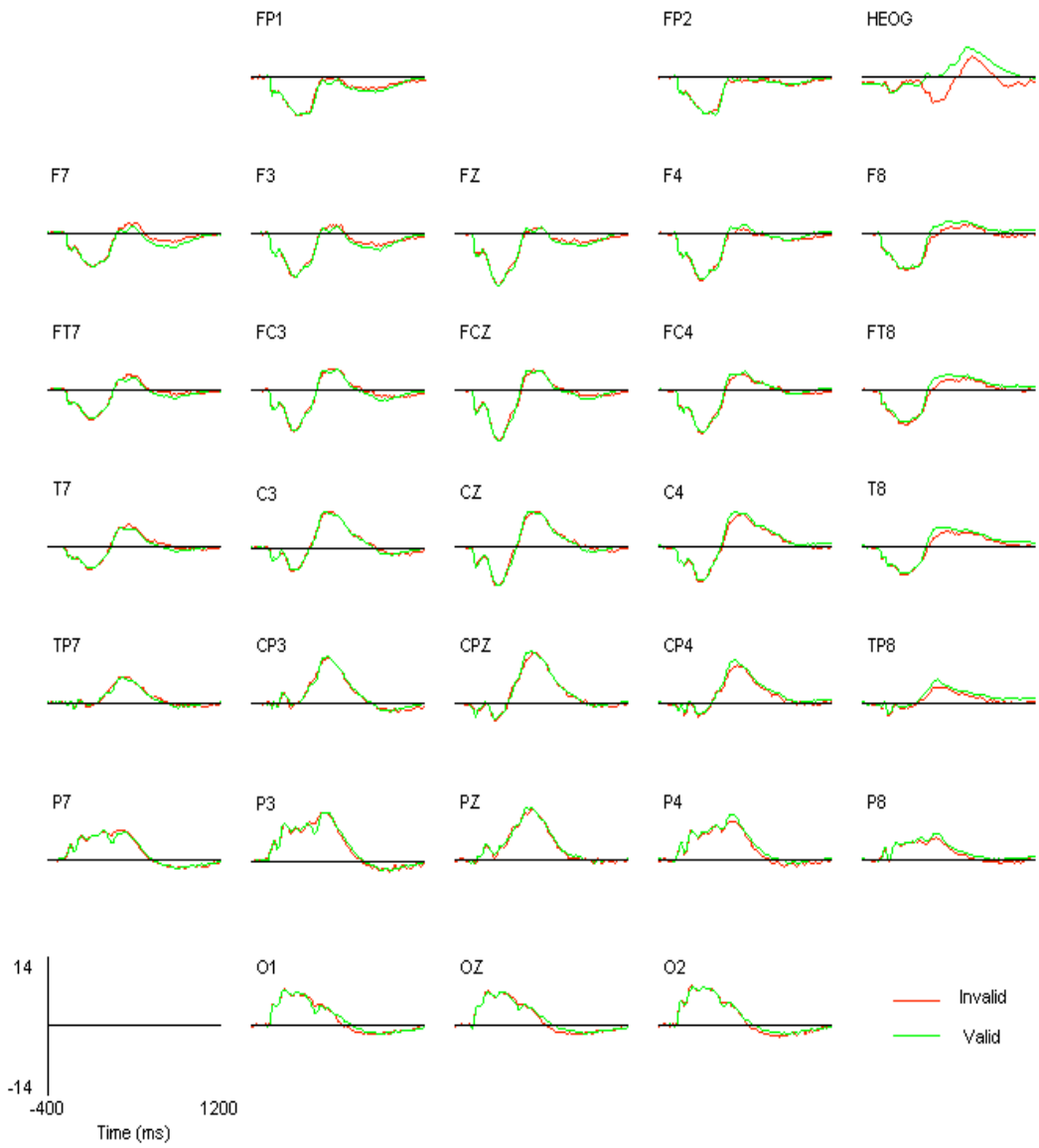


Figure 39a. Grand mean averages for validly and invalidly cued targets collapsed across peripheral cue contents.

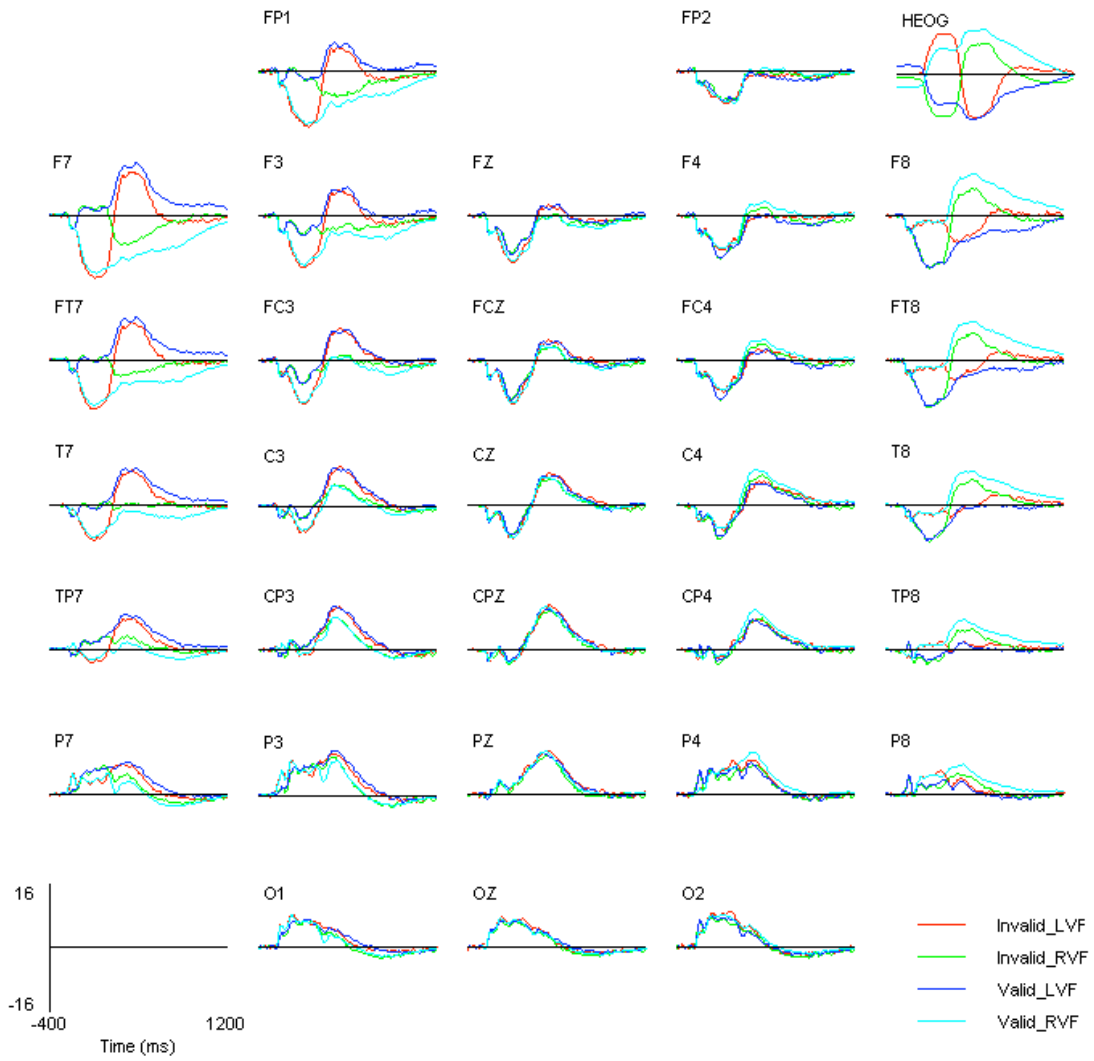


Figure 39b. Grand mean average waveforms for validly and invalidly cued targets in the left (LVF) and right (RVF) visual fields collapsed across peripheral cue contents.

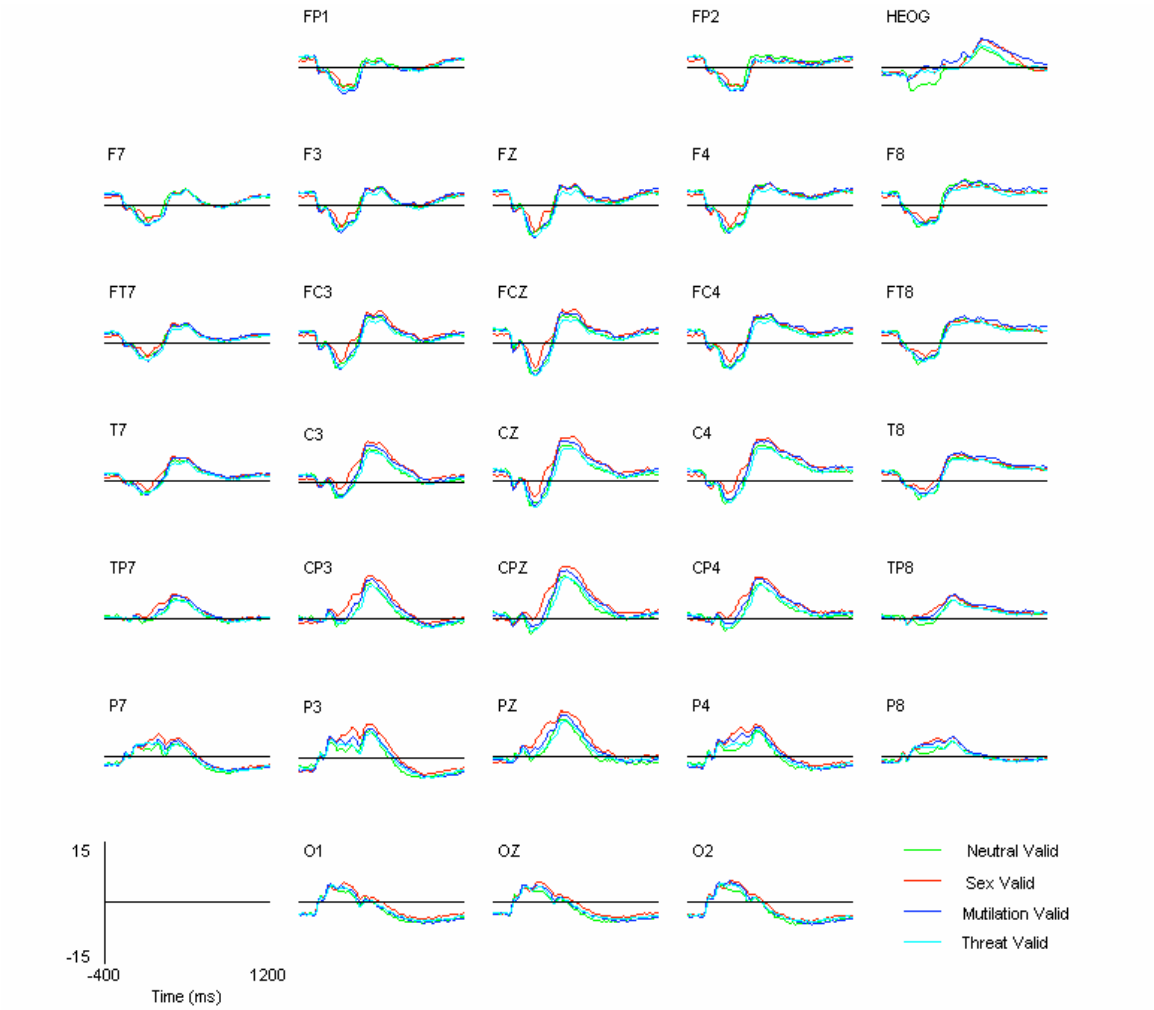


Figure 39c. Grand mean waveforms for targets validly cued by neutral, sexual, mutilation, and threatening stimuli.

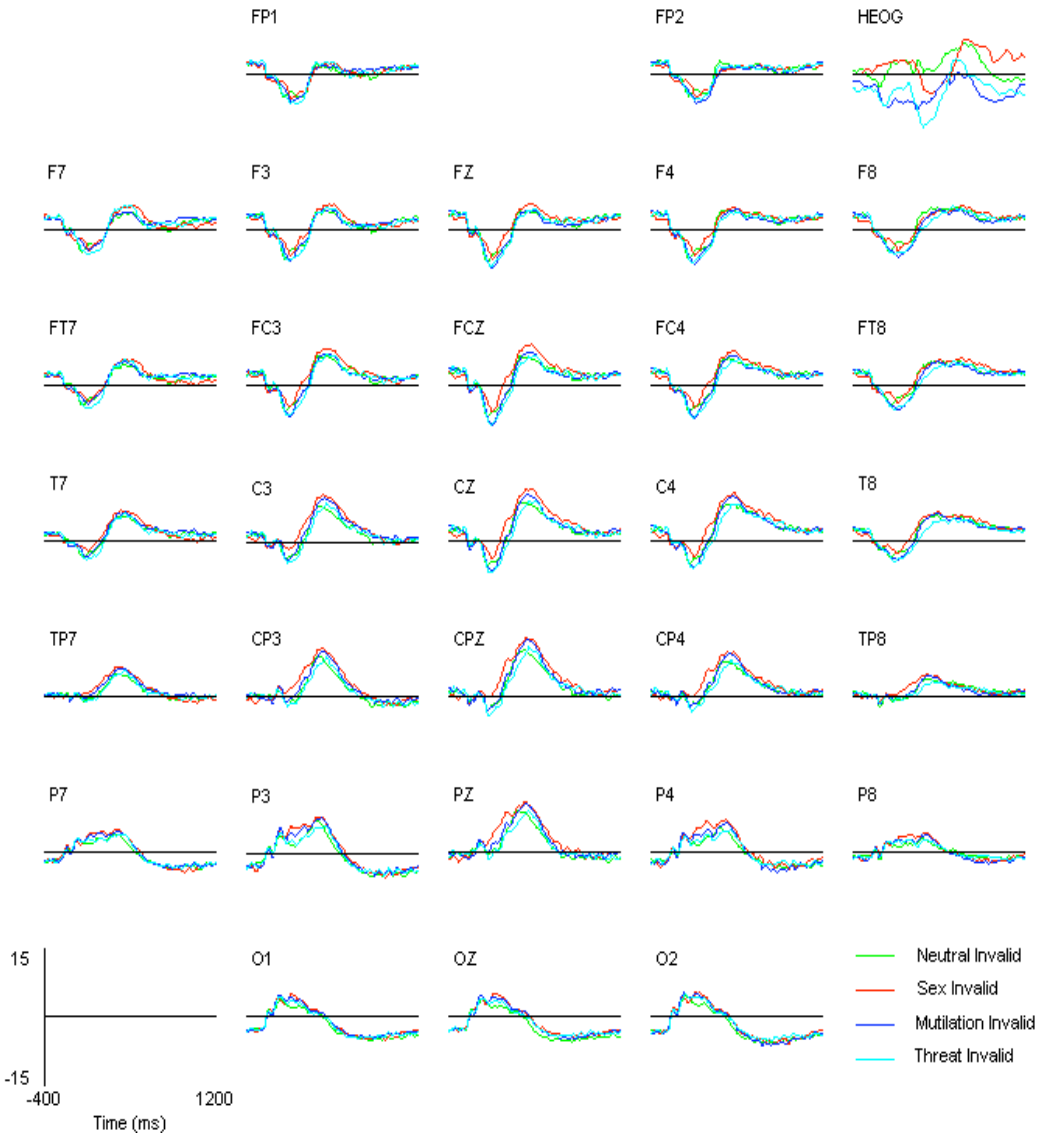


Figure 39d. Grand mean waveforms for targets invalidly cued by neutral, sexual, mutilation, and threatening stimuli.

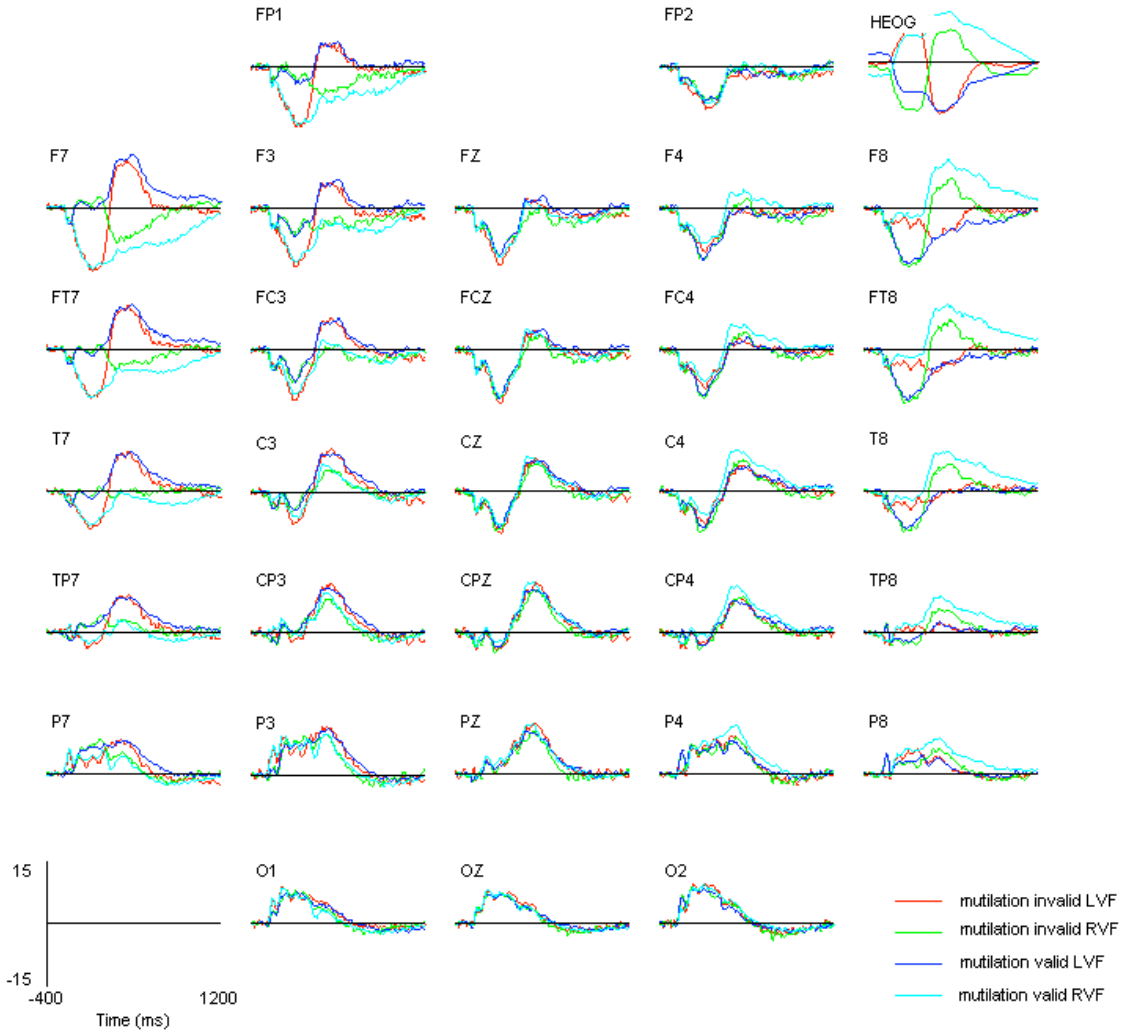


Figure 39e. Grand mean waveforms for targets valid and invalidly cued by mutilation stimuli in the left and right visual fields.

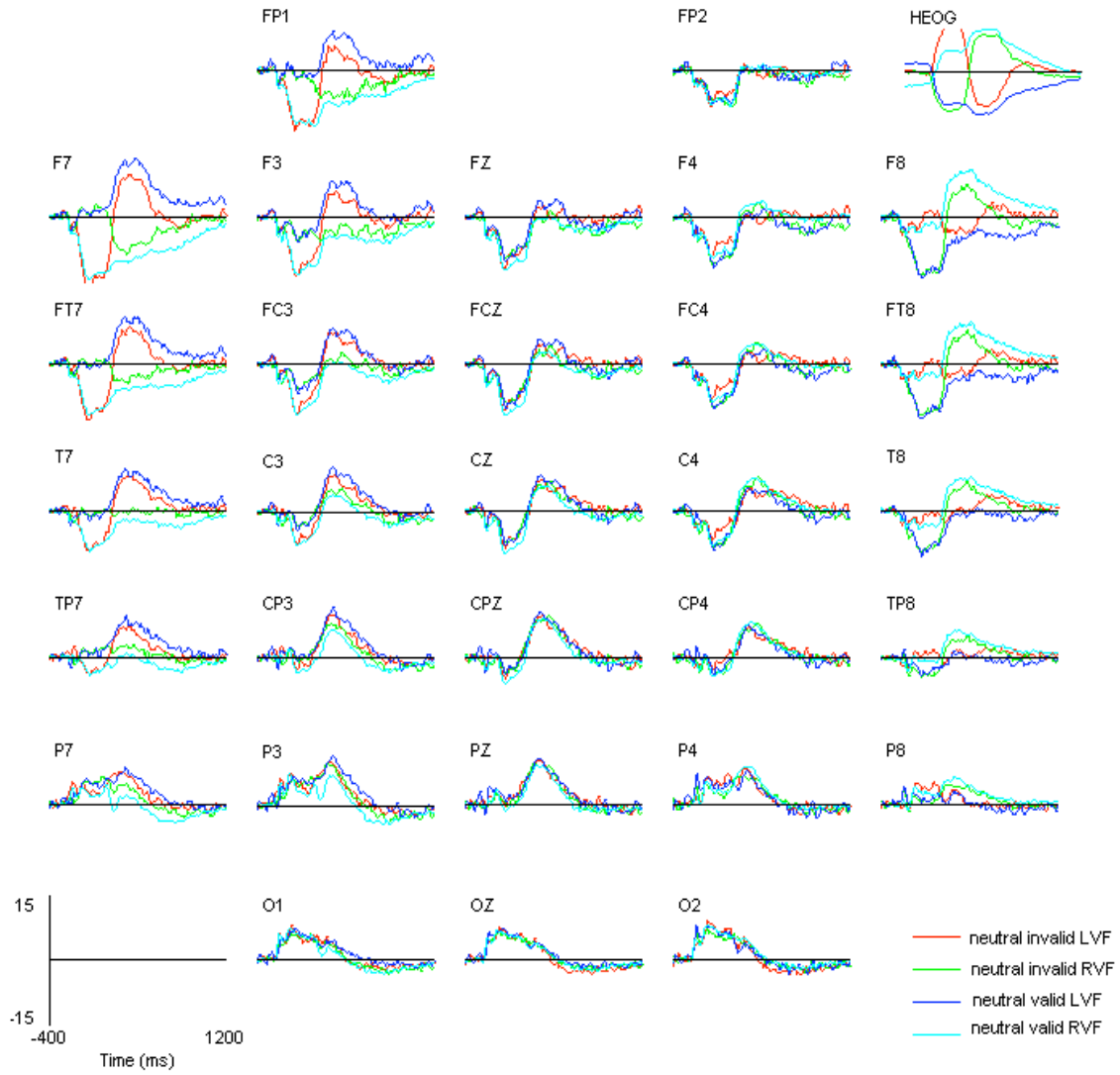


Figure 39f. Grand mean waveforms for targets valid and invalidly cued by neutral stimuli in the left and right visual fields.

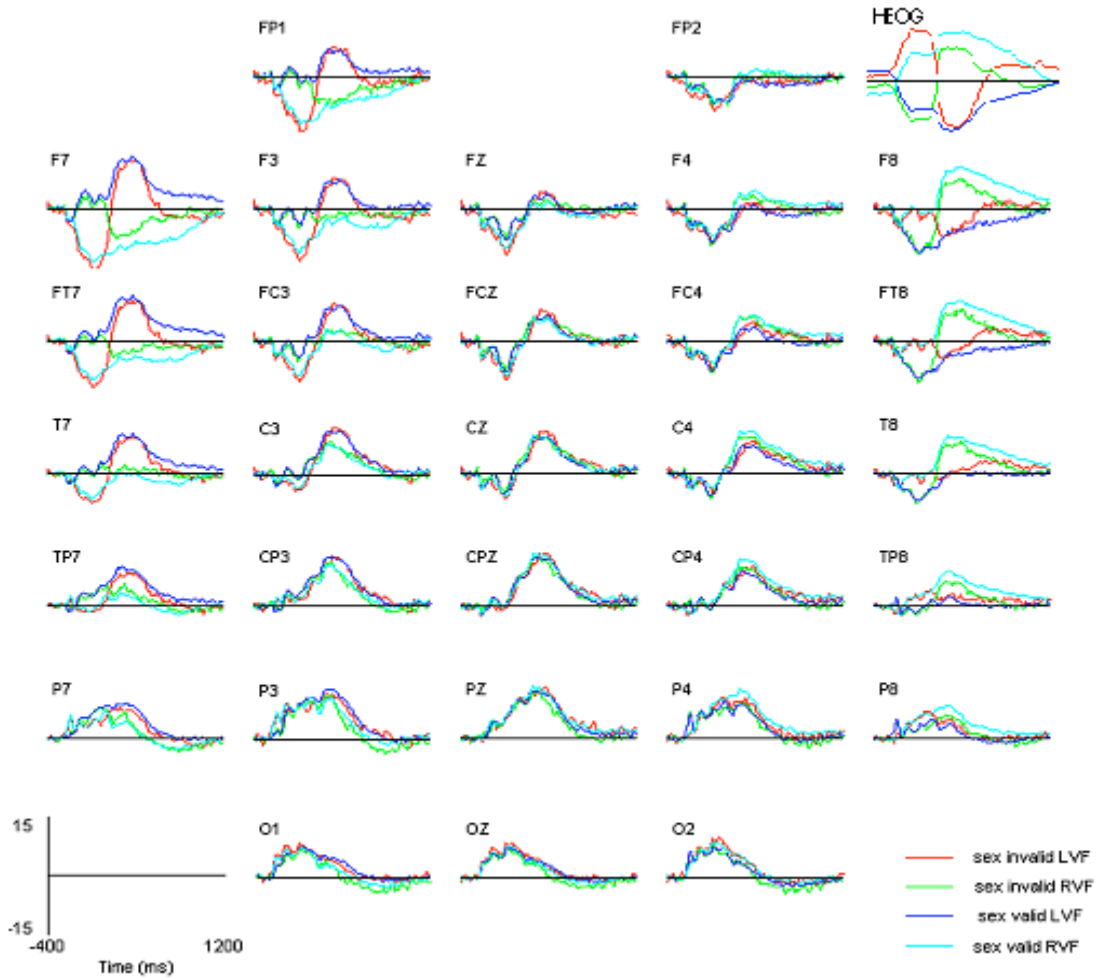


Figure 39g. Grand mean waveforms for targets valid and invalidly cued by sexual stimuli in the left and right visual fields.

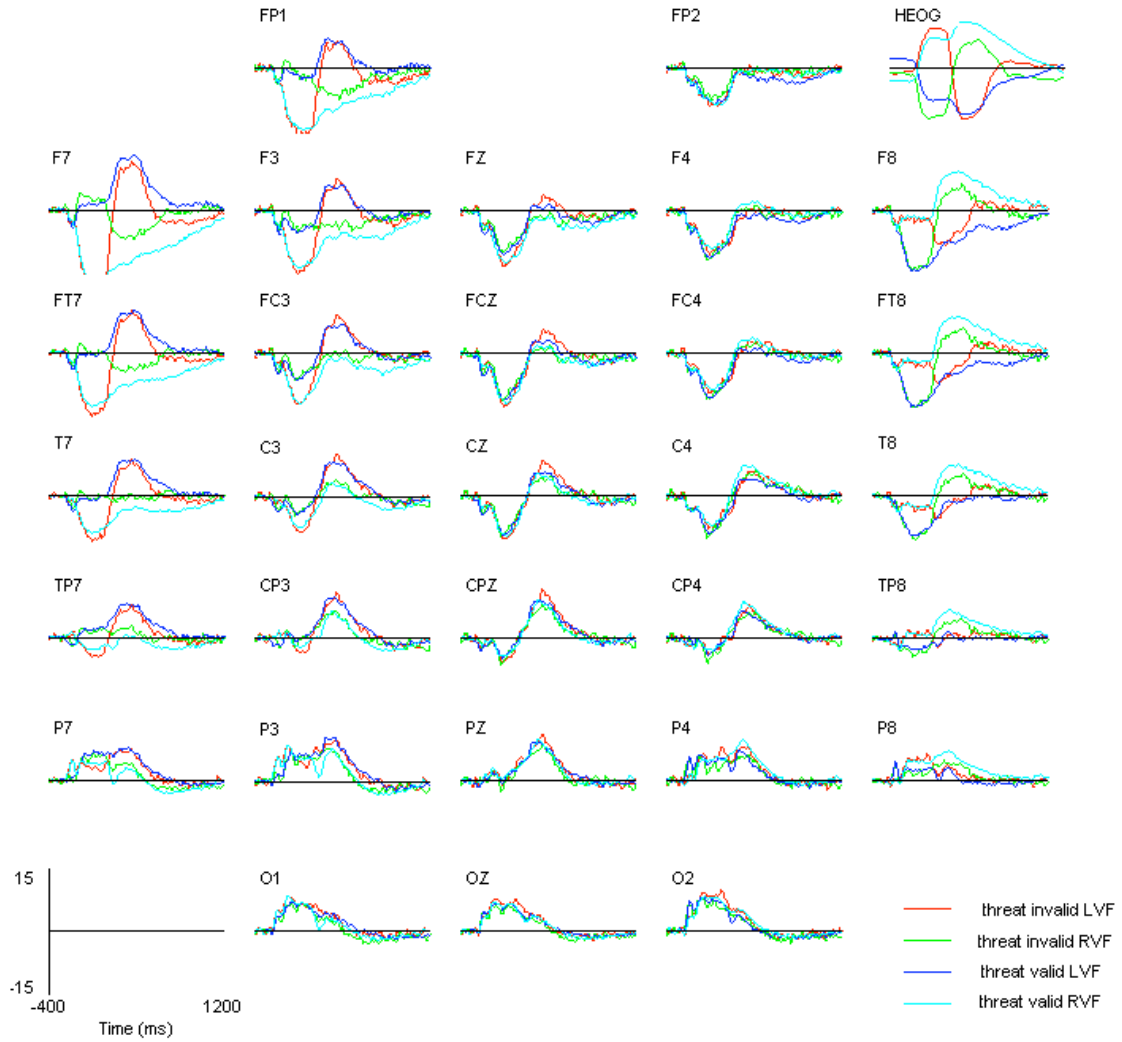


Figure 39h. Grand mean waveforms for targets valid and invalidly cued by threatening stimuli in the left and right visual fields.

Cue ERPs

P1 amplitude to the cue was shown to vary as a function of Peripheral Cue Content, $F(2.07, 35.13)=6.75$, $MSE=10.26$, $p<.001$, however the only significant difference detected by Tukey post hoc tests was between sexual ($M=5.78\mu V$, $SEM=.70$) and neutral stimuli ($M=3.93\mu V$, $SEM=.71$), with significantly larger P1 amplitude evoked in response to sexual stimuli ($p<.05$). P1 latency was shown to differ between electrode

sites, $F(2.23, 46.39)=8.02$, $MSE=6.40$, $p<.001$, and although a significant main effect was shown for Peripheral Cue Content, $F(2.12, 36.12)=2.88$, $MSE=10.88$, $p<.05$, Tukey post hoc tests did not reveal any significant differences between individual means (*p*s>.05). Numerically, sexual ($M=203.46$ms, $SEM=6.83$) stimuli evoked longer P1 latencies than threatening ($M=199.26$ms, $SEM=5.23$), mutilation ($M=193.61$ms, $SEM=6.01$), and neutral stimuli ($M=191.65$ms, $SEM=5.15$).

The hypothesis that the P1 component would be modulated by the motivational relevance of the eliciting stimulus was not supported and these results suggest that early visual processing is not sensitive to the motivational qualities of the peripheral cue, unlike P3b amplitude as shown in Experiment 4.

Cueing Effects on Validly and Invalidly Cued Target ERPs

ANOVAs conducted on the target-evoked P1 amplitude data indicated that amplitudes were significantly larger over parietal sites than centro-parietal sites, $F(2.26, 38.38)=13.27$, $MSE=44.51$, $p<.001$ (*p*s<.05) and thus further analyses were conducted over parietal sites only. No cue validity effect was shown for target-evoked P1 amplitude, $F(1, 17)=2.97$, $MSE=26.60$, $p=.10$, suggesting that the use of a short SOA and a discrimination response was effective at reducing the inhibitory effects on P1 amplitude. On this basis it could be argued that the mechanisms underlying behavioural IOR are applicable to the electrophysiological manifestations of inhibition. The hypothesis that target-evoked P1 amplitudes would be enhanced in response to validly cued targets was not supported, and the non significant effect of Cue Validity implies that the procedures used to reduce the inhibitory effects may also have reduced the ERP facilitation effects. This interpretation is however speculative as the relationship between facilitation and inhibitory effects is not well understood. The results for target-evoked P1

amplitude are however consistent with the RT data and thus add strength to the notion that facilitation and inhibition are interrelated processes involved in covert attentional orienting.

Target-evoked P1 amplitude was shown to differ as a function of Peripheral Cue Content, $F(2.49, 42.27)=30.45$, $MSE=28.35$, $p<.001$. Tukey post hoc tests showed significantly larger target-evoked P1 amplitude in response to targets cued by sexual ($M=11.21\mu V$, $SEM=1.11$) compared to mutilation ($M=9.08\mu V$, $SEM=1.10$), threatening ($M=6.95\mu V$, $SEM=.99$), and neutral stimuli ($M=7.13\mu V$, $SEM=1.11$), and for targets cued by mutilation compared to neutral and threatening stimuli (ps$<.05$), which did not differ significantly. P1 latency differed between electrode sites only, $F(1.45, 24.75)=13.56$, $MSE=11.27$, $p<.001$, the main effects of Peripheral Cue Content, $F(2.33, 39.64)=2.33$, $MSE=11.27$, $p=.08$, and Cue Validity, $F(1, 17)=.01$, $MSE=6599$, $p=0.22$ were not significant and no higher order interactions were significant. There was no evidence of enhanced attentional engagement with validly cued targets (i.e., no significant interaction between Peripheral Cue Content and Cue Validity) as a function of the motivational relevance of the peripheral cues, thus the hypotheses that target-evoked P1 amplitude would reflect a global response bias was supported. The data from Experiment 5 is consistent with that of Experiment 4, with the exception that the targets cued by sexual stimuli were facilitated significantly more than targets cued by mutilation stimuli.

P3b amplitude did not differ as a function of Cue Validity, $F(1, 17)=.38$, $MSE=21.5$, $p=.54$, therefore the hypothesis that P3b amplitude would be enhanced in response to low probability invalidly cued target stimuli was not supported. The target-evoked P3b data from Experiments 4 and 5 are consistent with Eimer (1994) who showed larger P3b amplitudes for invalidly cued targets when responses were made to

target location but not when responses were made to target identity. It would however be expected that target-evoked P3b amplitudes would be larger in response to validly cued targets during target detection (e.g., Hopfinger & Mangun, 1998; Hopfinger & Ries, 2005; McDonald et al., 1999) and as task related factors are assumed to have little impact during target discrimination, it could be argued that subjective probability effects would be expected to have a greater impact on target-evoked P3b amplitude. The results for target-evoked P3b amplitude in both the current studies (Experiments 4 and 5) and Eimer's study are therefore unclear.

P3b amplitude differed as a function of Peripheral Cue Content, $F(1.86, 31.72)=15.63$, $MSE=25.1$, $p<.001$, with significantly larger P3b amplitudes in response to targets cued by both sexual ($M=12.61\mu V$, $SEM=.93$) and mutilation stimuli ($M=11.37\mu V$, $SEM=1.05$) compared to targets cued by neutral ($M=9.75\mu V$, $SEM=.87$) and threatening stimuli ($M=9.90\mu V$, $SEM=1.01$) (ps$<.05$) which did not differ significantly. The hypothesis that the results for target-evoked P3b amplitude would mirror that of target-evoked P1 amplitude was therefore supported. P3b latency differed between Electrode Sites only, $F(2.78, 47.19)=11.83$, $MSE=6.12$, $p<.001$, and was not differentially affected by Peripheral Cue Content, $F(2.60, 44.26)=2.44$, $MSE=2856$, $p=.07$, or Cue Validity, $F(1,17)=1.59$, $MSE=6599$, $p=.22$.

The modulation of target-evoked P1 and P3b amplitudes is consistent with the results of Experiment 4, adding support to the hypothesis that the motivational relevance of the sexual and mutilation stimuli facilitated early sensory processing leading to facilitation of higher order aspects of target processing by virtue of these stimuli being identified as more task relevant.

Summary

Introducing a target discrimination response and a short SOA was intended to reduce the impact of the inhibitory mechanisms assumed to be present in Experiment 4. As no evidence of IOR or classic facilitation was observed at either a behavioural or ERP level, it is speculated that the processes of facilitation and inhibition are interrelated, in that reducing IOR effects appeared to impact on the strength of the facilitation effects. The results of Experiment 5 are highly consistent with that of Experiment 4 as target processing was again characterised by a global response bias, with facilitated processing of targets (at P1 and P3b levels) cued by sexual and mutilation stimuli independent of whether cueing was valid or invalid. The motivational relevance of the stimuli therefore was not successful in enhancing attentional engagement with the subsequent targets.

Experiment 6: Biology or Culture? Investigating Preparedness Theory

A review of the empirical studies underlying Öhman and Mineka's (2001; 2003; Mineka & Öhman, 2002) evolved fear module in Chapter 2 suggests that electrophysiological measures have scarcely been used in the study of preparedness (the theory that humans are biologically prepared to associate fear with stimuli that posed a threat to the pre-technological man: Seligman, 1970; 1971), and that the differential effects of phylogenetically (biological) and ontogenetically (cultural) fear-relevant stimuli have also received limited attention. Experiments 4 and 5 investigated how processes of covert attentional orienting were influenced by motivationally relevant cues, and Experiment 6 aims to further this line of enquiry by investigating the effect of differentially prepared stimuli on processes of attentional orienting. The theory underpinning Experiment 6 is based on evidence from visual search paradigms involving

the presentation of biologically fear-relevant (spiders, snakes, angry faces) and fear-irrelevant stimuli (flowers, mushrooms) in which significantly faster detection of fear-relevant targets among fear-irrelevant distracters compared to fear-irrelevant targets among fear-relevant distracters has been shown (e.g., Öhman et al., 2001a, b). Evidence from fear conditioning and illusory correlation paradigms in which enhanced responses for phylogenetically (biological) fear-relevant compared to ontogenetically (cultural) fear-relevant stimuli have been shown (see Chapter 2) provide further rationale for Experiment 6.

The peripheral cueing paradigm used in Experiment 6 was the same as that used in Experiment 5 due to the afforded control over electrophysiological manifestations of inhibition and increased ecological validity. Although classic facilitation effects were not consistently shown for either RT or accuracy data in Experiments 4 and 5, classic facilitation effects (faster RT and increased accuracy for validly cued targets) are again hypothesised in Experiment 6 based on the continued use of a short SOA. Experiments 4 and 5 failed to show any ERP evidence of enhanced attentional engagement, or difficulty disengaging attention following motivationally relevant cues. Instead, a global response bias was demonstrated whereby target processing was facilitated by sexual and mutilation stimuli independent of whether cueing was valid or invalid. Following these results, it is expected that target processing will show an overall ERP facilitation effect and will not be sensitive to cue validity information. Based on the evidence that phylogenetically fear-relevant stimuli demonstrate greater preparedness effects (e.g., enhanced resistance to extinction for phylogenetically fear-conditioned responses: Hugdahl & Käker, 1981; stronger illusory correlation between phylogenetically fear-relevant stimuli and aversive outcomes: Tomarken et al., 1989), the primary hypothesis for Experiment 6 is that target processing as indexed by target evoked P1 and P3b

amplitude will be significantly enhanced in response to phylogenetically fear-relevant animal threat stimuli compared to ontogenetically fear-relevant human threat and neutral or unprepared stimuli. Based on the results of Experiments 4 and 5 that showed no significant difference between neutral and threatening stimuli, no significant differences are expected between neutral and human threat stimuli in Experiment 6. Possible explanations for the non-significant difference between these stimuli is outlined in the general discussion (see Chapter 8). An early positive component, similar to that of Experiment 5, is expected to be evoked, however the amplitudes of this component are not expected to differ as a function of peripheral cue content based on the results of the cue evoked P1 component in Experiment 5.

Method

Participants

The same participants participated in both Experiments 5 and 6. No participants reported a specific fear of the animals presented as the animal threat stimuli.

Apparatus, Stimuli, and EEG recording

Data acquisition and EEG recording equipment were the same as that outlined in Experiment 5. Cues consisted of 15 human threat (attack with guns or knives), 10 animal threat (snakes, sharks, dangerous dogs, and dangerous bears), and 15 neutral (household objects) stimuli selected from the IAPS (see Appendix F). Only 10 animal threat stimuli had mean valence and arousal ratings that could be satisfactorily matched with the human threat stimuli, and thus each animal threat stimulus was presented 12 times while each human threat and neutral stimulus was presented eight times. Each peripheral cue category (neutral, animal threat, human threat, and filler stimulus) involved the presentation of 120 stimuli overall. Human threat stimuli had higher unpleasant IAPS

valence ratings (*M*=2.39, *SD*=.39) than the animal threat stimuli (*M*=3.80, *SD*=.21), and both categories of stimuli had equal IAPS arousal ratings (animal threat *M*=6.42, *SD*=.44; human threat *M*=6.42, *SD*=.53) and had IAPS valence ratings that were more negative than the neutral household object stimuli and arousal ratings that were greater than the neutral household object stimuli (valence *M*=4.92, *SD*=.25; arousal *M*=3.67, *SD*=4.66). The same filler stimulus presented in Experiment 5 were presented in Experiment 6.

The neutral, animal threat, and human threat stimuli were independently rated by 19 female first year psychology students on levels of valence, arousal, novelty, and interest (or attention grabbing capacity) in order to assure accurate stimulus categorisations for the present sample. Analysis of variance showed significant differences between the picture stimuli on each of these variables [valence, $F(1.52, 27.41)=30.26$, $MSE=.81$, $p<.001$, arousal, $F(1.23, 22.14)=30.26$, $MSE=1.72$, $p<.001$, novelty, $F(1.87, 33.66)=81.34$, $MSE=1.34$, $p<.001$ and interest, $F(1.74, 31.39)=123.94$, $MSE=.80$, $p<.001$]. Tukey post hoc tests showed that human threat stimuli (*M*=2.98, *SEM*=.18) were rated as significantly more unpleasant than animal threat stimuli (*M*=3.99, *SEM*=.15) and neutral stimuli (*M*=5.24, *SEM*=.21), and both animal threat and human threat stimuli were rated as significantly more unpleasant than neutral stimuli (*p*s<.05). Human threat (*M*=4.23, *SEM*=.40) and animal threat stimuli (*M*=4.07, *SEM*=.37) were matched on rated arousal, and were both rated as significantly more arousing than neutral stimuli (*M*=1.24, *SEM*=.21) (*p*s<.05). Human threat (*M*=5.03, *SEM*=.25) and animal threat stimuli (*M*=5.12, *SEM*=.05) were also matched on rated interest or attention grabbing capacity, and were both rated as significantly more interesting than neutral stimuli (*M*=1.13, *SEM*=.05) (*p*s<.05). The same results were shown for the novelty rating data, with human threat (*M*=5.49, *SEM*=.45) and animal

threat stimuli (*M*=4.97, *SEM*=.39) matched on rated novelty, and both stimulus categories were rated as significantly more novel than neutral stimuli (*M*=1.10, *SEM*=.48) (*p*s<.05). The prepared stimuli (animal threat and human threat) were matched on arousal level which is particularly important since level of arousal is associated with the level of activation within the appetitive and aversive systems (Lang, 1995; Lang, et al., 1997). The human threat and animal threat stimuli were also matched for novelty and attention grabbing capacity therefore subsequent differences in behavioural and ERP data between animal threat and human threat stimuli are not assumed to be a result of these variables.

Peripheral cue stimuli were again 248 x 186 pixels presented at 6° of visual angle to the left and right of a central fixation. Peripheral cues were presented for 230ms, followed 70ms later by the presentation of a target letter (M or T). The inter-trial interval from cue to cue was again 1000ms. Sixty percent (270) of the trials were validly cued, 20% (90) were invalidly cued, and 20% (90) of trials were cued by the filler stimulus and required no response. Validly cued and invalidly cued trials were presented with equal frequency to the left and right visual fields and the order of both peripheral cue and target type (valid/invalid) were randomised in the same manner as for Experiment 5. For ERP averaging purposes each individual neutral and human threat stimulus was presented eight times, twice in the invalid position and six times in the valid position. As mentioned previously there were only 10 exemplars of animal threat stimuli, therefore each animal threat stimulus was presented 12 times, four times in the invalid position and eight times in the valid position. Overall each category of stimuli (including filler stimuli) was presented 90 times in the valid position and 30 times in the invalid position, with a total of 450 trials overall, lasting approximately 15 minutes. As the same

participants participated in both Experiments 5 and 6, the state version of the STAI that was used to screen for highly state anxious individuals pertains to Experiment 6 also.

Procedure

The procedure was the same as that outlined in Experiment 5.

Design and Data Analysis

As mentioned in Experiment 5, seven participants had state anxiety scores outside the normal range, however visual inspection of the individual waveforms did not reveal any unique differences that may be anxiety specific, and therefore the data for these participants were included in the analyses. The experiment followed a 3(Picture Category: animal, neutral, human) x 2(Cue Validity: valid, invalid) repeated measures design, with Electrode Site leading to a further repeated measures variable for the ERP data. Again there were insufficient trials in any average of the left and right visual fields, therefore visual field was not included as an independent variable and further analyses were conducted with ERP data averaged across the left and right visual fields. The grand mean waveforms for the left and right visual fields were similar to those as shown for Experiment 5, therefore they are not presented for Experiment 6.

The target ERP components (P1 and P3b) were evoked at the same electrode locations as Experiments 4 and 5 (see Figures 40a, b, & c) and therefore the same electrode sites (CP3, CPZ, CP4, P3, PZ, P4) were included as repeated measures factors. The dependent variables for the behavioural data were again RT and accuracy (percentage of correct responses), and mean RT and accuracy data were analysed using separate repeated measures ANOVAs with factors of Peripheral Cue Content (neutral, animal threat, human threat) and Cue Validity (valid, invalid). Peak amplitudes of the ERP components were measured at centro-parietal and parietal sites where amplitudes

were maximal in two post-target intervals corresponding to P1 (100-180ms) and P3b (300-400ms). P1 amplitude elicited in response to the cue was measured at an interval of 150-250ms post-stimulus onset. The dependent variables for the ERP data were therefore the amplitude and latency of the P1 component evoked in response to the peripheral cues, and the P1 and P3b components evoked in response to the targets. The amplitudes of the cue elicited P1 and target elicited P1 and P3b components were analysed using separate repeated measures ANOVAs with factors of peripheral cue content, cue validity, and electrode site (CP3, CPz, CP4, P3, Pz, P4). Main effects and interactions involving Sagittal site and Coronal site will not be reported unless they are of theoretical significance. Statistical procedures were the same as those outlined in previous experiments.

Results and Discussion

Cueing Effects on Behavioural Performance

To investigate voluntary shifts of attention, comparisons were made between validly cued and invalidly cued trials. ANOVAs conducted on the accuracy data showed that the mean accuracy levels differed significantly between validly and invalidly cued targets, $F(1, 17)=4.55$, $MSE=2.87$, $p<.05$. Accuracy was significantly greater for validly cued targets ($M=78.56$ %, $SEM=4.11$) compared to invalidly cued targets ($M=76.36$ %, $SEM=4.60$). ANOVAs conducted on the RT data however failed to show any significant difference between validly and invalidly cued targets, $F(1, 17)=.004$, $MSE=.001$, $p=.95$, presumably for the same reasons outlined in Experiment 5.

ERP Data

Grand mean averages were calculated for targets validly and invalidly cued by neutral, animal threat, and human threat stimuli. Figure 40a illustrates the grand mean

waveforms for validly and invalidly cued targets collapsed across peripheral cue contents. As can be seen, an early positive component identified as target-evoked P1 can be most clearly identified at parietal regions (P3 and P4); however this component does not appear to have as distinct a peak as the target-evoked P1 evoked in Experiments 4 and 5. In line with Experiment 5 there appears to be little difference in target-evoked P1 amplitude between validly and invalidly cued targets. A P3b component is evoked in response to target stimuli, with a centro-parietal maximum and again there appears to be little difference between validly and invalidly cued targets. Figures 40b and c show the grand mean waveforms for targets validly and invalidly cued by animal threat, human threat, and neutral stimuli. A small P1 component is evoked in response to the peripheral cues at centro-parietal and parietal sites which is larger in response to animal threat stimuli, most clearly shown at centro-parietal sites. A P1 component is also shown in response to the validly and invalidly cued targets, with the most distinct peak shown in the left and right parietal hemispheres (see Figures 40b & c). Little difference however is observed between valid (see Figure 40b) and invalid (see Figure 40c) targets as a function of peripheral cue content. A P3b component is evoked in response to target stimuli, with little observable difference between validly and invalidly cued targets (see Figure 40a). Target-evoked P3b amplitude appears larger in response to targets cued by animal threat stimuli for both validly cued (see Figure 40c) and invalidly cued targets (see Figure 40d). Larger eye movements were also made in response to targets invalidly cued by animal threat stimuli (see HEOG in Figure 40c) while little difference in horizontal eye movements can be observed between differentially cued validly cued targets (see HEOG in Figure 40b).

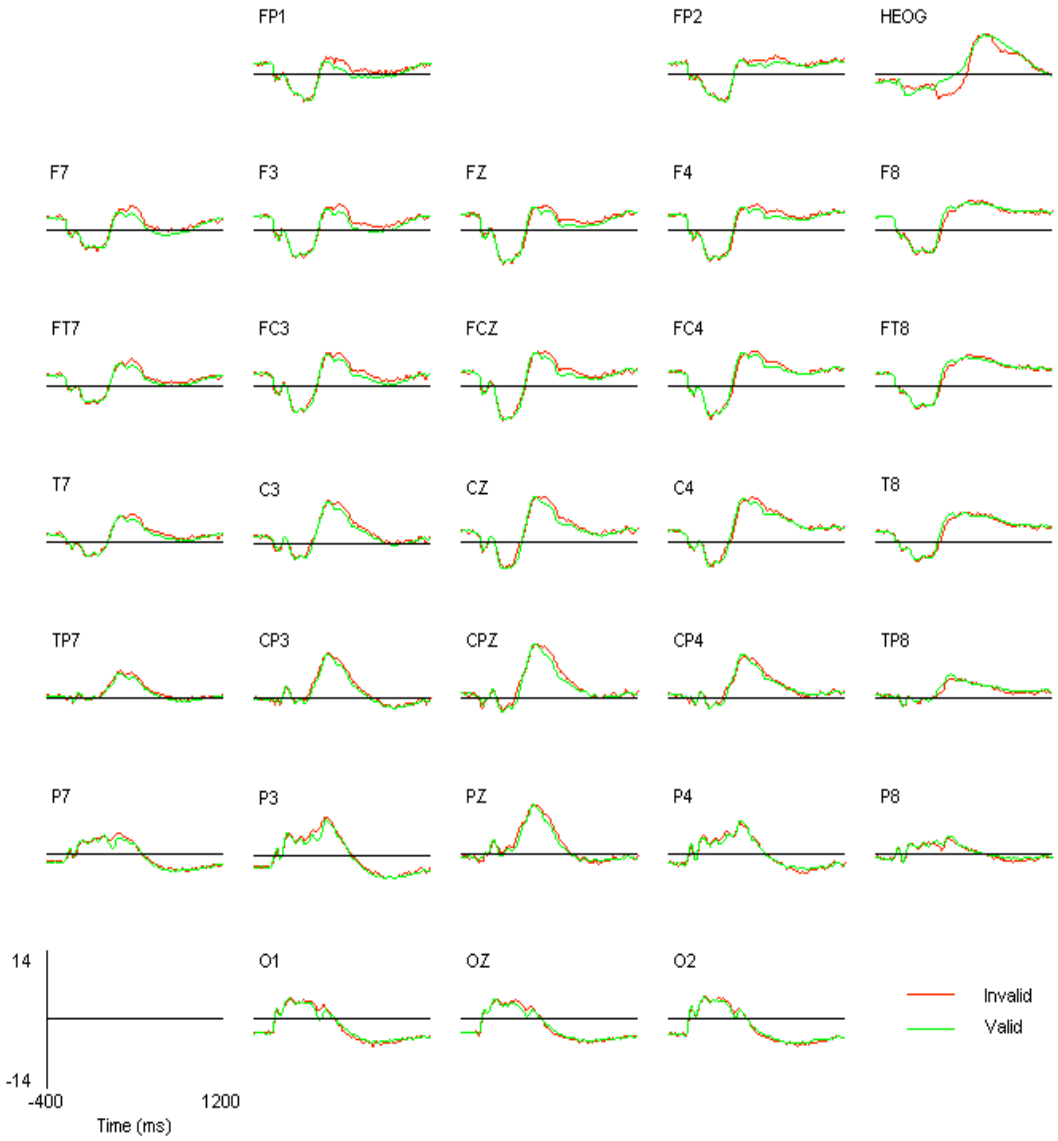


Figure 40a. Grand mean average waveforms for validly and invalidly cued targets collapsed across peripheral cue content.

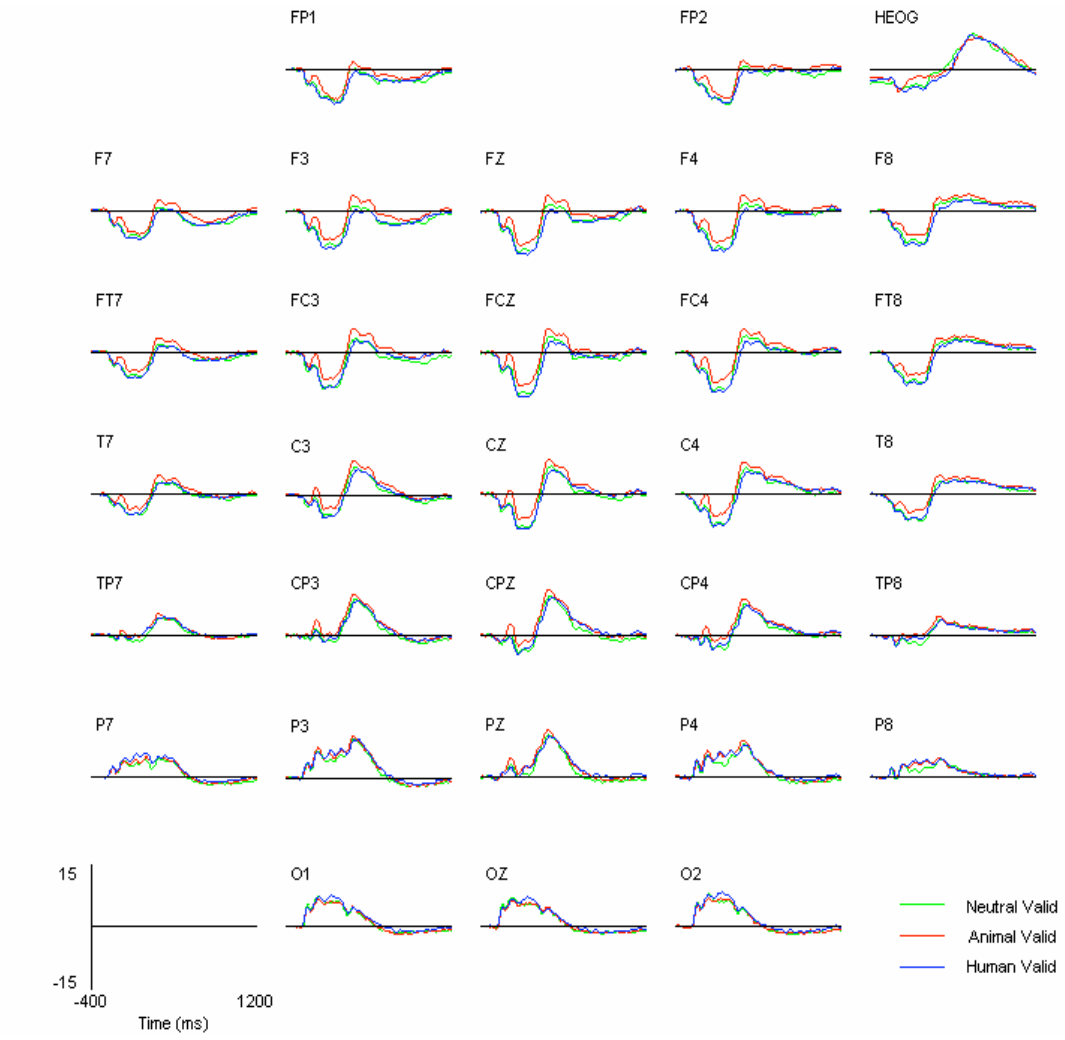


Figure 40b. Grand mean waveforms for targets validly cued by neutral, animal threat, and human threat stimuli.

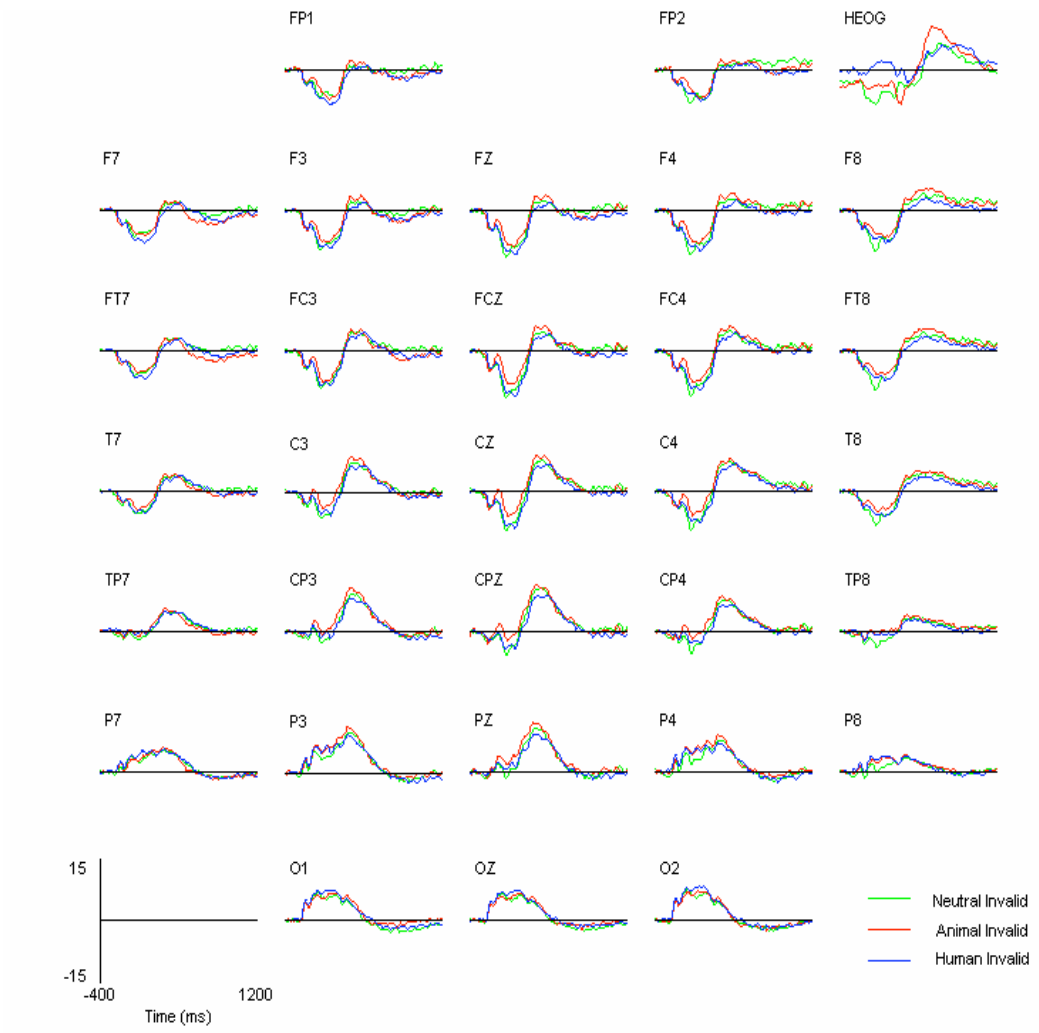


Figure 40c. Grand mean waveforms for targets invalidly cued by neutral, animal threat, and human threat stimuli.

Cue ERPs

ANOVAs conducted on the cue elicited P1 amplitude data indicated that P1 amplitudes were larger over parietal sites and in the left and right hemispheres compared to midline parietal sites, $F(4.78, 81.22)=8.15$, $MSE=.46$, $p<.001$ ($ps<.05$). P1 amplitude to the cue differed as a function of Peripheral Cue Content, $F(1.41, 24.07)=10.33$, $MSE=10.17$, $p<.001$, which is against the primary prediction, and Tukey post hoc tests showed

significantly larger P1 amplitude in response to animal threat (*M*=5.56μV, *SEM*=.84) compared to human threat (*M*=4.16μV, *SEM*=.60) and neutral stimuli (*M*=3.70μV, *SEM*=.65) (*p*s<.05). P1 amplitude was also larger in response to human threat than neutral stimuli, although this difference was not significant. Target-evoked P1 latency differed between Electrode sites only, $F(2.92, 49.66)=19.00$, *MSE*=784, $p<.001$, and did not differ significantly as a function of Peripheral Cue Content, $F(1.74, 29.66)=3.05$, *MSE*=3233, $p=.06$, or Cue Validity, $F(1, 17)=1.29$, *MSE*=3123, $p=.27$.

The results indicate that early levels of visual processing are facilitated by phylogenetically fear-relevant stimuli, and human threat stimuli appear somewhat more prepared than neutral stimuli. These results are not consistent with Experiment 5 in which it was shown that cue elicited P1 amplitude was insensitive to the motivational qualities of the eliciting stimulus. Experiment 5 employed culturally relevant sexual, mutilation, and threatening stimuli as the motivationally relevant cues, therefore the results of Experiment 6 indicate that the very early stages of visual processing are sensitive to animal threat stimuli, adding support for the theory of evolutionary preparedness.

Cueing Effects on Validly and Invalidly Cued Target ERPs

ANOVAs conducted on the target-evoked P1 amplitude data indicated that P1 amplitude was significantly larger over parietal than centro-parietal sites, $F(5.28, 43.84)=12.72$, *MSE*=31.10, $p<.001$, with no significant difference amongst the parietal or centro-parietal sites (*p*s<.05). The main effect of Cue Validity, $F(1, 17)=2.37$, *MSE*=50.29, $p=.15$ was not significant, consistent with the results of Experiment 5 and the reasons for this null effect are attributed to the same factors outlined in Experiment 5. Target-evoked P1 amplitude was shown to differ as a function of the Peripheral Cue Content,

$F(1.76, 30.01)=7.05$, $MSE=28.16$, $p<.01$. Tukey post hoc tests indicated that P1 amplitude was significantly larger in response to targets cued by animal threat ($M=7.66\mu V$, $SEM=.92$) compared to targets cued by human threat ($M=5.78\mu V$, $SEM=.94$) or neutral stimuli ($M=6.40\mu V$, $SEM=1.14$) (ps $<.05$), which did not differ significantly from each other. A global response bias was therefore identified whereby responses to targets cued by animal threat were facilitated independent of whether cueing was valid or invalid. Partial support was provided for the hypotheses that target processing would be facilitated significantly more by animal threat than human threat, and prepared (human threat and animal threat) compared to unprepared or neutral stimuli, as target processing was facilitated in response to targets cued by animal threat compared to human threat. However, no significant difference however was shown between targets cued by human threat and neutral stimuli. Possible reasons for this effect are detailed in the general discussion (Chapter 8). P1 latency differed between Electrode sites only, $F(2.92, 49.66)=19.00$, $MSE=784$, $p<.001$, and the main effects of Peripheral Cue Content, $F(1.74, 29.66)=3.05$, $MSE=3233$, $p=.06$, and Cue Validity, $F(1,17)=1.29$, $MSE=3123$, $p=.27$ were not significant.

There was a strong trend for target-evoked P3b amplitude to differ as a function of Cue Validity, $F(1, 17)=4.14$, $MSE=37.20$, $p=.058$, with larger amplitudes shown in response to invalidly cued targets ($M=10.57\mu V$, $SEM=1.16$) compared to validly cued targets ($M=9.60\mu V$, $SEM=.91$). The main effect of Peripheral Cue Content, $F(1.91, 32.41)=2.37$, $MSE=19.93$, $p=.11$ was not significant, therefore the hypothesis that target-evoked P3b amplitude would reflect the same pattern of results as target-evoked P1 amplitude was not supported. P3b latency differed as a function of Cue Validity, $F(1.86, 31.56)=.03$, $MSE=4606$, $p<.05$, and was significantly longer in response to invalidly cued ($M=339.15$ms, $SEM=5.43$) compared to validly cued targets ($M=325.92$ms,

SEM=7.32). P3b latency also differed between Electrode sites, $F(2.31, 39.22)=10.36$, *MSE*=9.07, $p<.001$, but did not differ as a function of Peripheral Cue Content, $F(1.86, 31.56)=.03$, *MSE*=3853, $p=.97$.

Summary

Target processing was again characterised by a global response bias, with target processing (as indexed by target-evoked P1 amplitude) facilitated by the presence of animal threat cues, independent of whether cueing was valid or invalid. Some evidence to support preparedness theory was therefore provided by the ERP data of Experiment 6, however no significant differences were observed between targets cued by human threat and neutral stimuli. Conclusions regarding the effects of phylogenetically and ontogenetically fear-relevant stimuli on target processing must therefore be made tentatively. Cue elicited P1 amplitude was however enhanced in response to animal threat stimuli compared to all other stimuli and although not significant, cue evoked P1 amplitude was also larger in response to human threat compared to neutral stimuli. Unlike motivationally relevant, cultural stimuli (Experiment 5: mutilation, sexual stimuli), animal threat stimuli appear to modulate the very early level of visual processing, adding further support for preparedness theory (Seligman, 1970; 1971). The differences shown for the cue evoked P1 component, particularly the difference between human threat and neutral stimuli provide some degree of confidence that the ERP differences observed for target processing reflect a valid empirical result.

CHAPTER 8: GENERAL DISCUSSION AND CONCLUSIONS

Discussion of Phase 1: Quadratic Effect and Negativity Bias

There are two dominant accounts of affective picture processing. The first, defined in this thesis as the quadratic effect, holds that attention is more deeply engaged by motivationally relevant stimuli (e.g., stimuli that activate the brain's appetitive and aversive systems). This theory typically accounts for the findings of enhanced P3b (e.g., Keil et al., 2002; Loew et al., 2003; Meinhardt & Pekrun, 2003; Mini et al., 1996; Schupp et al., 2004a; Schupp et al., 2003a), PSW (e.g., Amrhein et al., 2004; Cuthbert et al., 2000; Diedrich et al., 1997; Johnston et al., 1986; Keil et al., 2002; Palomba et al., 1997; Schupp et al., 2000; 2004a) and EPN (Schupp et al., 2003a; 2003b; 2004a) amplitudes in response to pleasant and unpleasant stimuli compared to neutral. The second account, referred to as the negativity bias holds that attention is more deeply engaged by aversive stimuli than equally intense pleasant stimuli. The negativity bias theory can account for enhanced early endogenous (P1: Smith et al., 2003; P2: Carretié et al., 2001a; Delplanque et al., 2004) and late endogenous (P3a: Delplanque et al., 2006; P3b: Delplanque et al., 2005; Ito et al., 1998a) ERP amplitudes evoked in response to unpleasant stimuli compared to pleasant and neutral stimuli. As suggested in Chapter 3, both these lines of enquiry have been limited by methodological problems and thus far a definitive model of affective picture processing is yet to be established.

P3b amplitude modulation in the current series of empirical studies is assumed to reflect the allocation of attentional resources from a limited capacity pool as proposed by Kok (1997; 2001). Phase 1 of the empirical studies involved an oddball paradigm where stimulus categorization and evaluations were simple and did not involve manipulations of task difficulty or priority known to affect the amplitudes of the P3b component (Kok,

1997; 2001). As such, increases in P3b amplitude are assumed to reflect increases in the amount of attentional resources allocated to the categorisation and evaluation of target stimuli. The negativity bias was replicated in Experiment 1 evidenced by enhanced P3b amplitudes in response to high arousing unpleasant compared to high arousing, non-sexual pleasant, and neutral stimuli. The negativity bias is assumed to optimise survival by facilitating the mobilization of resources toward threatening information, and enhanced P3b amplitudes evoked in response to highly arousing unpleasant stimuli are consistent with this claim. Assuming that responses to aversive events have immediate implications for survival, while responses to pleasant events have more long term implications, P3b amplitude was expected to be enhanced in response to highly arousing unpleasant stimuli compared to equally arousing and motivationally relevant sexual stimuli in Experiment 2. However, enhanced P3b amplitudes were however demonstrated in response to sexually explicit stimuli relative to all other stimuli, a finding which is not consistent with either of the dominant theories. A similar result was demonstrated in Schupp et al.'s (2004a) study, and although these authors made no statistical comparisons between high arousing unpleasant and sexual stimuli, the grand mean waveforms at Pz illustrated in Schupp et al.'s study show LPP amplitude to be more pronounced in response to sexually explicit stimuli. It was therefore speculated that sexual arousal influences cognitive processes such as the allocation of attentional resources differently than other forms of affective arousal that are associated motivational relevance. The sexual stimuli were not rated as evoking stronger approach tendencies than non-sexual pleasant stimuli in Experiment 2, adding support to the notion that variables other than the motivational relevance of the sexual stimuli were responsible for ERP modulations, namely sexual arousal.

Aspects of the model of motivated attention and affective states (Bradley & Lang, 2000; Hamm et al., 2003; Lang, 1995; Lang et al., 1990; Lang et al., 1997) from which the quadratic effect owes it origins were upheld by the current studies. In accordance with the results of Schupp et al. (2004a) the current data showed that P3b amplitude was modulated by the motivational relevance of both pleasant and unpleasant stimuli, with larger amplitudes evoked in response to highly arousing unpleasant images of human mutilation and death, compared to low arousing unpleasant images of pollution and deceased animals, and also for highly arousing sexual images of erotic couples compared to highly arousing pleasant sporting images and low arousing romantic images. ERP component amplitudes, specifically P3b, in the current series of empirical studies were modulated by the motivational relevance of specific picture contents. Although this finding provided some support for the quadratic effect, the data are not absolutely consistent with the quadratic effect as P3b amplitude was significantly enhanced in response to high arousing sexual stimuli compared to all other affective stimuli in Experiment 2. The P3b data from Experiment 2 therefore do not provide support for the negativity bias theory either. Instead, the current studies point towards the need for a revised model that closely reflects the model of motivated attention and affective states, but considers the effects of sexual arousal as separate from motivational relevance in terms of appetitive activation. Further research is required to identify the specific effects of sexual arousal on cognitive processes and the development of a more definitive model of affective picture processing is a direction for future research.

It was argued that the intermixing of arousal and hence semantic contents creates a possible confound that may be responsible for the quadratic effect observed in many affective picture processing studies. This claim was qualified by the results of Experiment 2 in which it was shown that P3b amplitude differed as a function of specific

picture content, however, when ERPs were averaged across high and low arousing picture categories (pleasant, unpleasant, and neutral), a quadratic relationship for P3b amplitude was observed. This data was consistent with that of Schupp et al. (2004a, b) and highlights not only the limitations of the quadratic effect as a viable model of affective picture processing, but also the need for systematic control of hedonic valence, arousal, and semantic features in affective picture processing research.

Sex Differences in Behavioural and ERP Responses

Sex differences have been consistently identified in behavioural and physiological responses to affective stimuli (e.g., Bradley et al., 2001b; Hillman et al., 2003; McManis et al., 2001), however reports of sex differences in electrophysiological and neurophysiological responses to such stimuli have been highly inconsistent (see Bradley et al., 2003; George et al., 1996; Karama et al., 2002; Kemp et al., 2003; Lane et al., 1999; Lang et al., 1998; Schieder et al., 2000;Wrase et al., 2003). Females have been shown to exhibit greater defensive activation evidenced by behavioural ratings of valence and arousal and physiological responses (Bradley et al.). In Experiment 1, females were shown to rate unpleasant stimuli as significantly more unpleasant than males, however this effect was shown for all unpleasant stimuli and the magnitude of the differences between males and females was not enhanced for the most highly arousing unpleasant contents as predicted. Females rated the high arousing unpleasant stimuli as more arousing than males in Experiment 2, however no sex differences in the valence ratings were observed. The strength of activation of the appetitive and aversive systems was inferred from the correlation between valence and arousal ratings for males and females. A trend toward a significant negative correlation was shown between ratings of valence and arousal for unpleasant stimuli for female participants only, which adds some

support to previous research that has found females to be more defensively activated than males (Bradley et al.). Partial support was provided for the hypothesis that males would demonstrate greater appetitive activation, as although the differences were not significant, males did rate the pleasantness of the high arousing sexual stimuli higher than females.

There was no electrophysiological evidence from Experiments 1 or 2 to suggest that males and females process affective or motivationally relevant stimuli differently, although some more general sex differences were apparent in the ERP data, most notably that females demonstrated larger P2 amplitudes than males. The cognitive processing of affective and motivationally relevant stimuli as indexed by P3b did not differ between the sexes and this result was argued to reflect the shared survival risks for males and females.

The Effect of Social Content on ERP measures

The effect of social content on ERP and behavioural measures was investigated in Experiment 3. Identifying the effects of social content on behavioural and electrophysiological responses was considered particularly important given the possibility that the effects shown for the sexual stimuli in Experiment 2 may have been confounded by the social content of the sexual stimuli. Furthermore, the rationale for Experiment 3 was motivated by a need to assess whether intermixing the social and non-social contents of affective picture stimuli presents a possible confound for previous research. No significant differences in ERP component measures (P2 and P3b) were revealed between social and non-social unpleasant or social and non-social pleasant stimuli, therefore it appears that images depicting human illness and injury are just as effective at activating the aversive system as images of deceased animals and pollution,

and the same holds for pleasant images of landscapes, animals, and pleasant human interactions for the appetitive system. Given these non-significant differences, it can be argued that previous research employing both social and non-social stimuli (e.g., Delplanque et al., 2004; Ito et al., 1998a) is not confounded by factors associated with social content, at least for low arousing stimuli. Both the amplitudes of the P2 and P3b components were enhanced in response to neutral face stimuli only and it was argued that these amplitude enhancements reflect the increased difficulty associated with extracting affective information from a somewhat ambiguous neutral expression. The valence ratings indicated that neutral face stimuli were perceived as significantly less pleasant than neutral object stimuli, and this was somewhat consistent with a pilot study conducted by Schupp et al. (2004c) who revealed that neutral faces were perceived as slightly threatening. It is possible then that the neutral faces presented in Experiment 3 were perceived as somewhat threatening and/or unpleasant which could account for the observed ERP modulations. Although viewing facial expressions can activate the motivational systems in the same way as affective non-face stimuli, the results of Experiment 3 indicate that there is a potential problem associated with intermixing neutral faces and neutral objects, and generally intermixing face and non-face stimuli.

Discussion of Phase 2: Attentional Orienting and Emotion

Humans have evolved in an environment where appetitive and aversive events occur at both predictable and unpredictable locations, therefore it follows that the attentional system would have evolved to facilitate information processing following appetitive and aversive cues at both attended and unattended locations. The presence of threatening stimuli however has been shown to result in an anxiety related deficit in the disengage component of covert visual attention, such that high anxious individuals are slower to

respond to targets that are invalidly cued by threatening stimuli (Fox et al., 2001; Georgiou et al., 2005; Yiend & Mathews, 2001). Such a deficit in the disengage component of covert visual attention is not highly adaptive and although normal and low anxious participants typically do not display difficulty disengaging attention from threat, few studies have been dedicated to elucidating the attentional processes that operate in normal participants when confronted with motivationally relevant appetitive and aversive stimuli.

A peripheral cueing paradigm was utilised in all three empirical studies that made up Phase 2. By employing a peripheral cueing paradigm it was possible to investigate whether for normal participants, the processes of attentional engagement (inferred by responses to validly cued targets) and attentional disengagement (as inferred by responses to invalidly cued targets) are differentially modulated as a function of motivational relevance; or alternatively, whether normal participants display a global response bias when processing target stimuli that are preceded by motivationally relevant stimuli.

Standard Cueing Effects for Phase 2

Inhibitory effects were observed in Experiment 4 due to the long SOA reflected by significant P1 suppression in response to validly cued targets. Classic facilitation was however observed at a behavioural level in Experiment 4, and although P1 suppression is typically observed in conjunction with behavioural IOR effects, there are noted examples where P1 suppression has occurred in the absence of behavioural IOR effects (e.g., Eimer, 1994: Experiment 2; Hopfinger & Mangun, 1998) and in the presence of behavioural facilitation effects (e.g., Eimer, 1994: Experiment 1; Stormark et al., 1995). To our knowledge, this is the first series of ERP studies conducted with normal

participants that has presented affective pictures as peripheral cues, in a modified peripheral cueing paradigm. Exactly why standard behavioural and ERP cueing effects were not consistently observed using a modified peripheral cueing paradigm is unclear however it is assumed that this effect can be accounted for by the pictorial stimuli. This seems particularly likely as no cue validity effects were shown for the neutral stimuli that are not motivationally relevant therefore factors associated with the use of pictorial stimuli rather than the affective value of these stimuli may account for the lack of standard cueing effects observed. It is further argued that the affective content of the stimuli had a more profound influence on target processing than the cue validity information conveyed by the location of the affective cue. This being the case, the current series of empirical studies cannot be strictly compared to standard peripheral cueing paradigms as different attentional mechanisms are at work when attention is reflexively oriented by affective pictures compared to when attention is reflexively oriented by luminance or geometric stimuli. Further research in this area is greatly required and the current body of work should provide a useful platform for continued research.

Experiment 5 aimed to reduce the inhibitory effects for target-evoked P1 amplitude by manipulating the timing of stimulus presentation and response requirements. No cue validity effects were observed in Experiment 5 at either electrophysiological or behavioural levels (although increased accuracy for validly cued targets provides some indication of a facilitation effect). It was argued that the use of a short SOA and a discrimination response was effective at reducing the inhibitory effects on P1 amplitude, however, given a possible relationship between facilitation and inhibition, reducing the effects of IOR may have reduced the effects of facilitation to a similar degree. However, this interpretation is however highly speculative as the

relationship between facilitation and inhibition and functional significance of behavioural and electrophysiological manifestations of inhibition are not well understood and beg further research.

P3b amplitude was enhanced in response to low probability, invalidly cued targets in Experiment 4 suggesting that probability information was a more powerful moderator of component amplitudes than task relevant information. This is especially likely given that the peripheral cue provides more task relevant information during target detection tasks such as the one presented in Experiment 4, and therefore P3b amplitudes were expected to be enhanced in response to validly cued targets (for examples see Hopfinger & Mangun, 1998; Hopfinger & Ries, 2005; McDonald et al., 1999). No cue validity effect was shown for target-evoked P3b amplitude in Experiment 5 and while this is consistent with the results of Eimer (1994: Experiment 2), whose study also involved a target discrimination task, it is unclear why no cue validity effect emerged, as subjective probability information would be expected to have a larger impact on P3b modulation than task relevance during target discrimination tasks.

The results of Experiments 4 and 5 are not assumed to result from factors such as sensory refractoriness given that the same results for target-evoked P1 and P3b in terms of the affective stimuli (discussed below) were shown at both long and short SOAs. The affective cue stimuli did however evoke a prominent P3b component in Experiment 4 therefore it is possible that the increased late processing of the cue may be overlapping with the early processing of the targets. This is especially important for Experiment 5 which involved a short SOA. Although this possibility requires further investigation it was beyond the scope of the current thesis to do so. However, possible overlap between the cue evoked and target evoked ERPs are not assumed to solely account for the current

data, as standard peripheral cueing effects, for example inhibition or P1 suppression at a long SOA, were still exhibited in the current modified peripheral cueing paradigm.

Motivational Relevance and the Global Response Bias

Global response bias as defined in the current thesis differs from response bias as defined in other cognitive settings. Typically, response bias refers to a selective difference in behaviour that is specific to a particular condition. In the context of the current thesis however, global response bias refers to the finding that overall target processing is facilitated by the presence of motivationally relevant stimuli. The motivational relevance of the peripheral cues in both Experiments 4 and 5 were shown to provide more powerful facilitation effects for target processing than the cue validity information conveyed by the location of the peripheral cues. Target processing as indexed by target-evoked P1 and P3b amplitudes showed significant facilitation following the onset of motivationally relevant sexual and mutilation stimuli both for targets validly and invalidly cued by these stimuli. As mentioned previously, rapid responses to stimuli appearing at both attended and unattended locations is highly adaptive when confronted with both appetitive and aversive events. Equal facilitation for targets appearing at both valid and invalid locations suggests that normal participants can effectively ignore the motivational content of the preceding cue in order to complete task requirements, and also that motivationally relevant sexual and mutilation stimuli facilitate the process of target evaluation and response which in turn would optimise survival. The motivational relevance of the sexual and mutilation cues was also shown to affect higher order aspects of target processing as indexed by target-evoked P3b. In both Experiments 4 and 5, the results for target-evoked P3b mirror that of target-evoked P1, namely that target processing is facilitated by the presence of motivationally relevant

sexual and mutilation stimuli. These results are consistent with the views of Hopfinger and Mangun (1998) who argue that reflexive attention initiated by peripheral cues facilitates the early sensory processing of targets, leading to these targets being treated as more task relevant in turn enhancing the amplitudes of the task sensitive P3b component. The motivational relevance of the sexual and mutilation cues is therefore assumed to have facilitated the early sensory processing of target stimuli, tagging these stimuli as more task relevant and facilitating higher order aspects of target processing.

P1 and P3b Responses to Specific Picture Categories

The P3b component evoked in response to the pictorial cues in Experiment 4 was assessed to determine whether the previous results of the empirical studies included in Phase 1were paradigm specific. A prominent P3b component evoked in response to the pictorial cues in Experiment 4 was significantly larger in response to sexual stimuli compared to all other picture contents and in response to mutilation compared to neutral and threatening stimuli. These results are consistent with those of Experiment 2 and therefore suggest that the results of both Experiment 2 and Experiment 4 are not paradigm specific, and more importantly that valid conclusions can be drawn from the results of the current series of empirical studies that utilise different methodologies. Enhanced P3b amplitude for sexual and mutilation stimuli in Experiment 4 adds electrophysiological support for the results of Buodo, Sarlo, and Palomba's (2002) experiment that showed slower RT to an acoustic probe while viewing mutilation and erotic images compared to when viewing images of sport/adventure, threat, and household objects, indicating that greater attentional resources were allocated to the processing of motivationally relevant erotic and mutilation images. In contrast to the P3b component evoked in Experiment 4, the cue evoked P1 component evoked in

Experiment 5 did not differ in a meaningful fashion as a function of the motivational relevance of the cue. Unlike later processing as indexed by P3b amplitude, early processing does not appear to be influenced by factors such as stimulus salience or affective value. The results for the cue-evoked P1 component in Experiment 6 however suggest that early levels of processing are influenced phylogenetic or biologically fear-relevant stimuli to a greater extent than ontogenetic or culturally fear-relevant stimuli.

Enhanced P3b amplitudes have been shown in response to human/animal threat compared to other low arousing unpleasant stimuli (e.g., contamination, illness) and especially compared to neutral stimuli (Schupp et al., 2004b), therefore it was expected that cue and target evoked ERP components would be enhanced in response to threatening stimuli compared to neutral stimuli. No significant differences were however shown between neutral and threatening stimuli in Experiments 4 or 5 for either cue evoked P3b (Experiment 4), cue evoked P1 (Experiment 5) or target evoked P1 or P3b amplitudes (Experiments 4 & 5) and it is speculated that the threat evoking object (i.e., gun, knife) in many of the threatening images was difficult to detect. The short stimulus durations and small image size may not have allowed for full threat evaluation, despite each stimulus being presented eight times. It is also possible that greater time was required to evaluate the threatening stimuli or that there is an optimal period for human threat appraisal. Budo et al. (2002) for example showed slower RT to a probe stimuli, thus greater allocation of attentional resources for threatening images compared to sport/adventure and household objects at 1800ms post-stimulus onset, however at 4s post-stimulus onset there were no significant differences between these stimuli. It is therefore unclear whether the non significant difference between threatening and neutral stimuli found in Experiments 4 and 5 represent an experimental effect or was due to the experimental parameters (e.g., stimulus size and duration). Further research is therefore

required to find a time period for which evaluation of threat stimuli is optimal. It may also be desirable to restrict the number of exemplars for both animal (e.g., snakes and spiders only) and threat (e.g., guns and knives only) categories in order to make the content of the images more salient. Singular images of guns and knives are generally rated as less arousing than images of human attack and difficulty may be encountered when trying to equate the arousal level of these images with that of the animal threat stimuli. It was therefore decided that images of human attack or threat were more desirable for presentation in the current series of studies over singular images of guns or knives because the former images are more strongly associated with aversive outcomes and were therefore expected to be more effective at activating the fear defense system.

Phylogenetically Fear-Relevant Stimuli Facilitate Target Processing

The same peripheral cueing paradigm was utilised in Experiments 4 and 5 was employed in Experiment 6 to investigate further the global response bias by presenting phylogenetic (animal threat), ontogenetic (human attack), and unprepared (neutral object) stimuli as peripheral cues. Evidence for a global response bias was provided as target-evoked P1 amplitude was enhanced in response to targets cued by animal threat compared to human threat and neutral stimuli for both validly and invalidly cued targets. The results of Experiment 6 add support for preparedness theory (see Seligman 1970; 1971) as increased processing efficiency was associated with the biologically or phylogenetically, fear-relevant animal stimuli. No significant differences were shown between human threat and neutral stimuli. As mentioned previously, it was argued that the small stimulus size and short stimulus durations were not sufficient for the appraisal of the human threat stimuli. Given the non-significant difference between neutral and human threat stimuli, conclusions regarding the effect of phylogenetically and

ontogenetically fear-relevant stimuli on target processing must therefore be made tentatively. The cue evoked P1 component was however significantly more pronounced in response to animal threat than human threat and neutral stimuli, and larger in response to human threat compared to neutral stimuli although not significantly so. The results for the cue evoked P1 component thus provide some confidence that the observed differences between phylogenetically and ontogenetically fear-relevant stimuli are genuine, though further investigation of the salience of the human threat stimuli is required to substantiate this claim. As mentioned previously, the cue evoked P1 component in Experiment 5 did not reflect any meaningful sensitivity to the motivational relevance of the peripheral cue contents. As culturally relevant but not necessarily biologically prepared appetitive and aversive stimuli were used in Experiments 4 and 5, the results of Experiment 6 suggest that the early attentional system is preferentially sensitive to biologically fear-relevant stimuli, adding further support for preparedness theory.

What does the P1 Component Index in the Current Empirical Studies?

Previous research indicates that spatial attention modulates visual processing at an early stage as indexed by the P1 component (70-100ms) (Mangun & Hillyard, 1991) and the occipital maximum of the P1 component reported in a number of spatial attention studies points to a neural generator in the visual cortex (Mangun & Hillyard, 1991; Hillyard et al., 1994; Hopfinger & Mangun, 1998; Hopfinger & Ries, 2005; McDonald et al., 1999; Müller & Rabbitt, 1989). While the P1 component is typically assumed to reflect processes associated with visual spatial attention, modulation of the P1 component is not based exclusively on spatial attentional factors as evidenced by Taylor (2002) who showed the P1 component to be sensitive to stimulus saliency.

The target-evoked P1 component in Experiments 4 and 5 peaked between 100 and 180ms and had a parietal maximum. Although P1 amplitude is typically measured at temporal, occipital, and parieto-occipital sites during peripheral cueing paradigms, the parietal topography of the P1 component evoked in the current studies and Washer and Tipper's (2004) study is consistent with the involvement of the posterior parietal lobe in shifts of covert attention (for review see Posner & Petersen, 1990). It is however speculated that the P1 component evoked in the empirical studies included in Phase 2 does not index visual spatial processing per se, as the grand mean average waveforms for validly and invalidly cued targets averaged across peripheral cue contents (see Figures 36a, 39a, 40a) did not show a parieto-occipital or occipital maximum. Instead it is argued that the P1 component evoked in the current studies reflects a more general form of early attentional processing based on other stimulus features such as salience.

P1 components evoked in previous studies of affective picture processing have also shown later peak amplitudes and have rarely shown an occipital maximum (see Carretié, Hinojosa, Martín-Loeches, Mercardo, & Tapia, 2004; Delplanque et al., 2004; Stormark et al., 1995) and this is consistent with the view that affective stimuli influence the allocation of early attentional resources that are not specific to visual spatial attention.

Summary

Two important lines of enquiry were investigated in the current dissertation. Firstly, a systematic investigation of the effects of valence, arousal, and semantic variables on behavioural and electrophysiological responses was undertaken in Phase 1, which laid the foundation for the investigation of the effects of motivational relevance on processes of attentional orienting in Phase 2. The empirical studies of Phase 1 indicated that

neither the quadratic effect nor the negativity bias can be identified as the definitive model for affective picture processing due to the enhanced P3b amplitudes shown in response to sexually explicit stimuli compared to all other affective contents. Aspects of the model of motivated attention and affective states (Bradley & Lang, 2000; Hamm et al., 2003; Lang, 1995; Lang et al., 1990; Lang et al., 1997) were upheld as P3b amplitudes were significantly enhanced in response to motivationally relevant sexual and mutilation stimuli compared to less arousing and less motivationally relevant picture contents. Again the enhanced P3b amplitudes evoked in response to sexually explicit stimuli identifies a need for a revised model of affective picture processing and further investigation of the effects of sexual arousal on cognitive processes. The quadratic effect was replicated in Experiment 2 when high and low arousing picture contents were combined into general pleasant, unpleasant, and neutral picture categories, however P3b amplitude varied with specific picture categories. It was therefore concluded that the intermixing of stimulus arousal and semantic contents contributes to the quadratic effect frequently observed in previous research (e.g., Mini et al., 1996; Palomba et al., 1997).

Both the P2 and P3b components in Experiment 3 were sensitive to the neutral face stimuli, with enhanced component amplitudes in response to neutral face compared to neutral object stimuli taken to reflect the increased difficulty associated with extracting affective information from a somewhat ambiguous facial expression. It was therefore concluded that the intermixing of neutral face and neutral object stimuli and the general intermixing of face and non-face stimuli presents an important confound to be considered when conducting affective picture processing research.

Phase 1 was primarily concerned with the allocation of attentional resources at an endogenous level however initial orienting toward motivationally relevant stimuli and the ability to rapidly shift attention to process subsequent information has great survival

value, thus these processes were investigated in Phase 2. Experiments 4 and 5 of Phase 2 showed facilitation of target processing at both early (target-evoked P1) and late (target-evoked P3b) cognitive stages following sexual and mutilation stimuli, regardless of whether cueing was valid or invalid. The topography and measurement window of the P1 component arguably represents a more general early attentional process and therefore the results of Experiments 4 and 5 suggest that stimuli that strongly activate the brain's motivational systems facilitate the processing of subsequent sensory information. Spatial information is highly important for the correct detection of, and response to, threatening stimuli. In order for spatial information to aid responses to threat, rapid shifts of attention must be made toward both the source of the threat and, in order to facilitate escape, to other aspects of the environment. The results of Experiments 4 and 5 suggest that normal participants demonstrate a global response bias and have little difficulty shifting attention from motivationally relevant stimuli in order to process subsequent information, and stimuli that strongly engage the brain's appetitive and aversive systems facilitate sensory processing equally for valid and invalid trials. It was further argued that difficulty disengaging attention from threat is anxiety specific as this effect was not demonstrated in a normal sample.

Aspects of preparedness theory (Seligman, 1970; 1971) were investigated in Experiment 6, also using a peripheral cueing paradigm. The presence of animal threat stimuli resulted in enhanced P1 amplitudes compared to human threat and neutral stimuli indicating that the early attentional system is sensitive to phylogenetically fear-relevant stimuli. Target processing as indexed by P1 amplitude was also facilitated by the presence of animal threat stimuli compared to human threat and neutral stimuli and again a global response bias was demonstrated. It was concluded that phylogenetically fear-relevant animal stimuli prompt the most facilitation for target processing, adding

support for the notion that humans are biologically prepared to associate fear with stimuli that posed a threat to the pre-technological man (Seligman, 1970; 1971).

In conclusion, the current dissertation involved the investigation of a number of theoretically pertinent issues identified in the affective picture processing literature. A systematic investigation of the effects of hedonic valence, arousal, and semantic content on ERP component measures revealed that the components of the ERP waveform vary systematically not only with level of hedonic valence and arousal, but importantly, as a function of specific picture categories. Support was provided for the model of motivated attention and affective states (Bradley & Lang, 2000; Hamm et al., 2003; Lang, 1995; Lang et al., 1990; Lang et al., 1997), as ERP component measures were enhanced in response to stimuli that strongly activate the brain's appetitive and aversive systems. However the current studies highlight the need for a more definitive model of affective picture processing to be established, as although the negativity bias can account for the observed results when sexually explicit stimuli are excluded, neither the negativity bias or quadratic effect can account for the observed results when sexually explicit stimuli are included.

At a more practical level, it was concluded that normal participants display a global response bias when processing targets that are cued by motivationally relevant stimuli, particularly mutilation and sexual stimuli. The presence of animal threat stimuli was also found to be effective in facilitating target processing, providing support for preparedness theory. The current dissertation provides valuable information concerning the validity of the models underlying the interpretation of ERP responses during affective picture processing and highlights some important directions for future research, particularly in the area of emotion and attentional orienting and the effects of sexual arousal on cognitive processes.

REFERENCES

Adolphs, R. (2002). Neural systems for recognizing emotion. *Current Opinions in Neurobiology, 12*, 169-177.

Aftanas, L., Varlamov, A., Pavlov, S., Makhnev, V., & Reva, N. (2001). Event-related synchronization and desynchronization during affective processing: Emergence of valence-related time-dependent hemispheric asymmetries in theta and upper alpha band. *International Journal of Neuroscience, 110*, 197-219.

Amir, N., Elias, J., Klumpp, H., & Prezeworski, A. (2003). Attentional bias to threat in social phobia: Facilitated processing of threat or difficulty disengaging attention from threat? *Behaviour and Research Therapy, 41*, 1325-1335.

Amrhein, C., Mühlberger, A., Pauli, P., & Wiedemann, G. (2004). Modulation of event-related brain potentials during affective picture processing: A complement to startle reflex and skin conductance response? *International Journal of Psychophysiology, 54*, 231-240.

Birbaumer, N., Elbert, T., Canavan, A. G. M., & Rockstroh, B. (1990). Slow potentials of the cerebral cortex and behavior. *Physiological Reviews, 79*, 1-41.

Bledowski, C., Prvulovic, D., Goebel, R., Zanella, F. E., & Linden, D. E. J. (2004). Attentional systems in target and distractor processing: A combined ERP and fMRI study. *NeuroImage, 22*, 530-540.

Bousten, L., Humphreys, G. W., Praamstra, P., & Warbrick, T. (2006). Comparing neural correlates of configural processing in faces and objects: An ERP study of the Thatcher illusion. *NeuroImage, 32*, 352-367.

Bradley, M. M. (2000). Emotion and motivation. In J. Cacioppo, T. L. G. Tassinary & G. G. Berntson (Eds.), *Handbook of psychophysiology* (2nd ed., pp. 602-642). USA: Cambridge University Press.

Bradley, M. M., Codispoti, M., Sabatienlli, D., & Lang, P. J. (2001). Emotion and motivation II: Sex differences in picture processing. *Emotion, 1*, 3000-3319.

Bradley, M. M., Codispoti, M., Cuthbert, B., N, & Lang, P. J. (2001). Emotion and motivation I: Defensive and appetitive reactions in picture processing. *Emotion, 1*, 276-298.

Bradley, M. M., & Lang, P. J. (2000). Measuring emotion: Behavior, feeling, and physiology. In R. D. Lane & L. Nadel (Eds.), *Cognitive neuroscience of emotion*. New York: Oxford University Press.

Bradley, M. M., Sabatienlli, D., Lang, P. J., Fitzsimmons, J., R, King, W., & Desai, P. (2003). Activation of the visual cortex in motivated attention. *Behavioural Neuroscience, 117*, 369-380.

Budo, G., Sarlo, M., & Palomba, D. (2002). Attentional resources measured by reaction times highlight differences within pleasant and unpleasant, high arousing stimuli. *Motivation and Emotion, 26*, 123-137.

Cacioppo, J., T, & Berntson, G., G. (1994). Relationship between attitudes and evaluative space: A critical review, with emphasis on the separability of positive and negative substrates. *Psychological Bulletin, 115*, 401-423.

Cacioppo, J. T., Crites, S. L., Gardner, W. L., & Berntson, G. G. (1994). Bioelectrical echoes from evaluative categorizations: I a late positive brain potential that varies as a function of trait negativity and extremity. *Journal of Personality and Social Psychology, 67*, 115-125.

Cacioppo, J. T., Gardner, W. L., & Berntson, G. G. (1997). Beyond bipolar conceptualizations and measures: The case of attitudes and evaluative space model. *Personality and Social Psychology Review, 1*, 3-25.

Canli, T., Desmond, J. E., Zhao, Z., & Gabrieli, J. D. E. (1998). Hemispheric asymmetry for emotional stimuli detected with fMRI. *Neuroreport, 9*, 3233-3239.

Carretié, L., Hinojosa, J. A., Martín-Loeches, M., Mercardo, F., & Tapia, M. (2004). Automatic attention to emotional stimuli: Neural correlates. *Human Brain Mapping, 22*, 290-299.

Carretié, L., Iglesias, T., Garcia, M., & Ballesteros, M. (1996). N300, P300 and the emotional processing of visual stimuli. *Electroencephalography and Clinical Neurophysiology, 103*, 298-303.

Carretié, L., Iglesias, T., & Garcia, T. (1997). A study on the emotional processing of visual stimuli through event-related potentials. *Brain and Cognition, 34*, 207-217.

Carretié, L., Martín-Loeches, M., Hinojosa, J. A., & Mercardo, F. (2001b). Emotion and attention interactions studies through event-related potentials. *Journal of Cognitive Neuroscience, 13*, 1109-1128.

Carretié, L., Mercardo, F., Tapia, M., & Hinojosa, J. A. (2001a). Emotion, attention, and the 'negativity bias', studied through event-related potentials. *International Journal of Psychophysiology, 41*, 75-85.

Clark, V. P., & Hillyard, S. A. (1996). Spatial selective attention affects early extrastriate but not specific striate components of the visual evoked potential. *Journal of Cognitive Neuroscience, 8*, 387-402.

Collie, A., Maruff, P., Yucel, M., Currie, J., & Danckert, J. (2000). Spatiotemporal distribution of facilitation and inhibition of return arising from the reflexive orienting of covert attention. *Journal of Experimental Psychology: Human Perception and Performance, 26*, 1733-1745.

Comerchero, M. D., & Polich, J. (1999). P3a and P3b from typical auditory and visual stimuli. *Clinical Neurophysiology, 110*, 24-30.

Cook, M., & Mineka, S. (1989). Observational conditioning of fear to fear-relevant versus fear-irrelevant stimuli in rhesus monkeys. *Journal of Abnormal Psychology, 98*, 448-459.

Cook, M., & Mineka, S. (1990). Selective associations in the observational conditioning of fear in rhesus monkeys. *Journal of Experimental Psychology: Animal Behavior Processes, 16*, 372-389.

Courchesne, E., Hillyard, S. A., & Galambos, R. (1975). Stimulus novelty, task relevance and the visual evoked potential in man. *Electroencephalography and Clinical Neurophysiology, 39*, 131-143.

Crites, S. L., Cacioppo, J. T., Gardner, W. L., & Berntson, G. G. (1995). Bioelectrical echoes from evaluative categorization: II A late positive brain potential that varies as a function of attitude registration rather than attitude report. *Journal of Personality and Social Psychology*.

Crowley, K. E., & Colrain, I. M. (2004). A review of the evidence for P2 being an independent component process: Age, sleep, and modality. *Clinical Neurophysiology, 115*, 732-744.

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology, 52*, 95-111.

Damasio, A. R. (1995). Toward a neurobiology of emotion and feeling: Operational concepts and hypotheses. *The Neuroscientist, 1*, 19-25.

Davidson, R. J. (1992). Emotion and affective style: Hemispheric substrates. *Psychological Science, 3*, 39-43.

Davidson, R. J. (1993a). Cerebral asymmetry and emotion: Conceptual and methodological conundrums. *Cognition and Emotion, 7*, 115-138.

Davidson, R. J. (1993b). Parsing affective space: Perspectives from neuropsychology and psychophysiology. *Neuropsychology, 7*, 464-475.

Davidson, R. J., Ekman, P., Saron, C. D., Senulis, J. A., & Friesen, W. (1990). Approach-withdrawal and cerebral asymmetry: Emotional expression and brain physiology I. *Journal of Personality and Social Psychology, 58*, 330-341.

de Jong, P. J., Merckelbach, H., & Arntz, A. (1995). Covariation bias in phobic women: The relationship between a priori expectancy, on-line expectancy, autonomic responding, and a posteriori contingency judgement. *Journal of Abnormal Psychology, 104*, 55-62.

De Silva, P., Rachman, S. S., & Seligman, M. P. E. (1977). Prepared phobias and obsessions: Therapeutic outcome. *Behaviour and Research Therapy, 15*, 65-77.

Decon, D., Breton, F., Ritter, W., & Vaughan, H. G. (1991). The relationship between N2 and N400: Scalp distribution, stimulus probability, and task relevance. *Psychophysiology, 28*, 185-200.

Delplanque, S., Lavoie, M. E., Hot, P., Silvert, L., & Sequeira, H. (2004). Modulation of cognitive processing by emotional valence studied through event-related potentials in humans. *Neuroscience Letters, 365*, 1-4.

Delplanque, S., Silvert, L., Hot, P., Rigoulot, S., & Sequeira, H. (2006). Arousal and valence effects on event-related P3a and P3b during emotional categorization. *International Journal of Psychophysiology, 60*, 315-322.

Delplanque, S., Silvert, L., Hot, P., & Sequeira, H. (2005). Event-related P3a and P3b in response to unpredictable emotional stimuli. *Biological Psychology, 68*, 107-120.

Demaree, H. A., Everhart, D. E., Youngstrom, E. A., & Harrison, D. W. (2005). Brain lateralization of emotional processing: Historical roots and a future incorporating "dominance". *Behavioural and Cognitive Neuroscience Reviews, 4*, 3-20.

Derryberry, D., & Reed, M. A. (1996). Regulatory processes and the development of cognitive representations. *Development and Psychopathology, 8*, 215-235.

Derryberry, D., & Tucker, D. M. (1992). Neural mechanisms of emotion. *Journal of Consulting and Clinical Psychology, 60*, 329-338.

Diedrich, O., Naumann, E., Maier, S., Becker, G., & Bartussek, D. (1997). A frontal slow wave in the ERP associated with emotional slides. *Journal of Psychophysiology, 11*, 71-84.

Dien, J., Spencer, K. M., & Donchin, E. (2004). Parsing the late positive complex: Mental chronometry and the ERP components that inhabit the neighbourhood of the P300. *Psychophysiology, 41*, 665-678.

Donchin, E. (1981). Surprise!...surprise? *Psychophysiology, 18*, 491-513.

Donchin, E., & Coles, M. G. G. (1988). Is the P300 component a manifestation of context updating? *Behavioural and Brain Sciences, 11*, 357-374.

Dunn, B. R., Dunn, D. A., Languis, M., & Andrews, D. (1998). The relation of ERP components to complex memory processing. *Brain and Cognition, 36*, 355-376.

Eimer, M. (1996). ERP modulations indicate the selective processing of visual stimuli as a result of transient and sustained spatial attention. *Psychophysiology, 33*, 13-21.

Eimer, M. (2000). Event-related brain potentials distinguish processing stages involved in face perception and recognition. *Clinical Neurophysiology, 111*, 694-705.

Eimer, M., & Holmes, A. (2002). An ERP study on the time course of emotional face processing. *Cognitive Neuroscience and Neuropsychology, 13*, 1-5.

Ekman, P., & Friesen, W. V. (1976). *Pictures of facial affect.* Consulting Psychology Press, Plato Alto, CA.

Empson, J. (1986). *Human Brain Waves: The Psychological Significance of the Electroencephalogram*. New York: Stockon Press.

Esteves, F., Parra, C., Dimberg, U., & Öhman, A. (1994). Nonconscious associative learning: Pavlovian conditioning of skin conductance responses to masked fear-relevant facial stimuli. *Psychophysiology, 31*, 375-385.

Fabiani, M., Gratton, G., & Coles, M. G. H. (2000). Event-related brain potentials: methods, theory, and applications. In J. Cacioppo, T. L. G. Tassinary & G.. Berntson (Eds.), *Handbook of psychophysiology (2nd ed.)* (pp. 53-84). USA: Cambridge University Press.

Fox, E., Russo, R., Bowels, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General, 130*, 681-700.

Friedmann, D., Cycowitz, M. Y., & Gaeta, H. (2001). The novelty P3: An event-related brain potential (ERP) sign on the brain's evaluation of novelty. *Neuroscience and Behavioural Reviews, 25*, 355-373.

Gaeta, H., Friedmann, D., & Hunt, G. (2003). Stimulus characteristics and task category dissociate the anterior and posterior aspects of the novelty P3. *Psychophysiology, 40*, 198-208.

Gainotti, G. (2000). Neuropsychological theories of emotion. In J. C. Borod (Ed.), *The Neuropsychology of Emotion* (pp. 214-235). Oxford, UK: Oxford University Press.

García-Larrea, L., Lukaszewicz, A-C., & Mauguiere, F. (1992). Revisiting the oddball paradigm. Non-target vs neutral stimuli and the evaluation of ERP attentional effects. *Neuropsychologia, 30*, 723-741.

Gehring, W. J., Gratton, G., Coles, M. G. H., & Donchin, E. (1992). Probability effects on stimulus evaluation and response processes. *Journal of Experimental Psychology: Human Perception and Performance, 18*, 198-216.

George, M. S., Ketter, T. A., Parekh, P. I., Herscovitch, P., & Post, R. M. (1996). Gender differences in regional cerebral blood flow during transient self-induced sadness or happiness. *Biological Psychiatry, 40*, 859-871.

Georgiou, G., A, Bleakley, C., Hayward, J., Russo, R., Dutton, K., Eltiti, S., et al. (2005). Focusing on fear: Attentional disengagement from emotional faces. *Visual Cognition, 12*, 145-158.

Goldstein, A., Spencer, K. M., & Donchin, E. (2002). The influence of stimulus deviance and novelty on the P300 and Novelty P3. *Psychophysiology, 39*, 781-790.

Guttman, L. (1954). A new approach to factor analysis: The new radix. In P. R. Lazarsfeld (Ed.), *Mathematical thinking in the social sciences*. Glencore: Free Press.

Hagemann, D., Hewig, J., Naumann, E., Seifert, J., & Bartussek, D. (2005). Resting brain asymmetry and affective reactivity: Aggregated data support the right-hemisphere hypothesis. *Journal of Individual Differences, 26*, 139-154.

Hamm, A. O., Schupp, H., T., & Weike, A., I. (2003). Motivational organization of emotions: Autonomic changes, cortical responses, and reflex modulation. In R. J. Davidson, K. R. Scherer & H. H. Goldsmith (Eds.), *Handbook of affective science* (pp. 187-212). Oxford: Oxford University Press.

Heller, W. (1990). The neuropsychology of emotion: Developmental patterns and implications form psychopathology. In N. Stein, B. L. Leventhal & T. Trabasso (Eds.), *Psychological and biological approaches to emotion* (pp. 167-211). Hillsdale. NJ: Erlbaum.

Heller, W. (1993). Neuropsychological mechanisms of individual differences in emotion, personality, and arousal. *Neuropsychology, 7*, 476-489.

Henriques, J. B., & Davidson, R. J. (1990). Regional brain electrical asymmetries discriminate between previously depressed and healthy controls. *Journal of Abnormal Psychology, 99*, 22-31.

Henriques, J. B., & Davidson, R. J. (1991). Left frontal hypo-activation in depression. *Journal of Abnormal Psychology, 100*, 535-545.

Hillman, C. H., Rosengren, K. S., & Smith, D. (2003). Emotion and motivated behavior: Postural adjustments to affective picture viewing. *Biological Psychology, in press*, 1-12.

Hillyard, S. A., Luck, S. J., & Mangun, G. R. (1994). The cuing of attention to visual field locations: Analysis with ERP recordings. In H. J. Heinze, T. F. Munte & G. R. Mangun (Eds.), *Cognitive electrophysiology* (pp. 1-25). Boston: Birhauser.

Holmes, A., Vuilleumier, P., & Eimer, M. (2003). The processing of emotional facial expression is gated by spatial attention: Evidence from event-related brain potentials. *Cognitive Brain Research, 16*, 174-184.

Hopfinger, J., & Mangun, G. R. (1998). Reflexive attention modulates processing of visual stimuli in the human extrastriate cortex. *Psychological Science, 9*, 441-447.

Hopfinger, J. B., & Mangun, G. R. (2001). Tracking the influence of reflexive attention on sensory and cognitive processing. *Cognitive, Affective, and Behavioral Neuroscience, 1*, 56-65.

Hopfinger, J., & Ries, A. (2005). Automatic versus contingent mechanisms of sensory-driven neural biasing and reflexive attention. *Journal of Cognitive Neuroscience, 17*, 1341-1352.

Hugdahl, K., & Johnsen, B. H. (1989). Preparedness and electrodermal fear-conditioning: Ontogenetic vs phylogenetic explanations. *Behaviour and Research Therapy, 27*, 269-278.

Hugdahl, K., & Karker, A.-C. (1981). Biological vs experimental factors in phobic conditioning. *Behaviour and Research Therapy, 19*, 109-115.

Ito, T. A., & Cacioppo, J. T. (2005). Variations on a human universal: Individual differences in positivity offset and negativity bias. *Cognition and Emotion, 19*, 1-26.

Ito, T. A., Cacioppo, J. T., & Lang, P. J. (1998). Eliciting affect using the international affective picture system: Trajectories through evaluative space. *Personality and Social Psychology Bulletin, 24*, 855-879.

Ito, T. A., Larsen, J. T., & Cacioppo, J. T. (1998). Negative information weighs more heavily on the brain: The negativity bias in evaluative categorizations. *Journal of Personality and Social Psychology, 75*, 887-900.

Jasper, H. H. (1958). The 10-20 electrode system of the international federation. *Electroencephalography and Clinical Neurophysiology, 10,* 371-375..

Johnson Jr, R. (1986). A triarchic model of P300 amplitude. *Psychophysiology, 23*, 367-383.

Johnson Jr, R. (1993). On the neural generators of the P300 component of the event-related potential. *Psychophysiology, 30*, 90-97.

Johnston, V. S., Miller, D. R., & Burleson, M. H. (1986). Multiple P3s to emotional stimuli and their theoretical significance. *Psychophysiology, 23*, 684-693.

Jones, N. A., & Fox, N. A. (1992). Electroencephalogram asymmetry during emotionally evocative films and its relation to positive and negative affectivity. *Brain and Cognition, 20*, 280-299.

Junghöfer, M., Bradley, M. M., Elbert, T., & Lang, P. J. (2001). Fleeting images: A new look at early emotion discrimination. *Psychophysiology, 38*, 175-178.

Karama, S., Lecours, A. R., Lerox, J-M., Bourgouin, P., Beaudoin, G., Jourbert, S., et al. (2002). Areas of brain activation in males and females during viewing of erotic film excerpts. *Human Brain Mapping, 16-13*.

Katayma, J., & Polich, J. (1998). Stimulus context determines the P3a and P3b. *Psychophysiology, 35*, 23-33.

Kayser, J., Tenke, C., Nordby, H., Hammerborg, D., Hugdahl, K., & Erdmann, G. (1997). Event-related potential (ERP) asymmetries to emotional stimuli in a visual half-field paradigm. *Psychophysiology, 34*, 414-426.

Keil, A., Bradley, M. M., Hauk, O., Rockstroh, B., Elbert, T., & Lang, P. J. (2002). Large-scale correlates of affective picture processing. *Psychophysiology, 39*, 641-649.

Kemp, A. H., Silberstein, R. B., Armstrong, S. M., & Nathan, P. J. (2004). Gender differences in the cortical electrophysiological processing of visual emotional stimuli. *NeuroImage, 21*, 632-646.

Kenedy, S. J., Rapee, R. M., & Mazurski, J. (1997). Covariation bias for phylogenetic vs ontogenetic fear-relevant stimuli. *Behaviour and Research Therapy, 35*, 415-422.

Kenntner-Mabials, R., & Pauli, P. (2005). Affective modulation of brain potentials to painful and nonpainful stimuli. *Psychophysiology, 42*, 559-567.

Kok, A. (1997). Event-related potential (ERP) reflections of mental resources: A review and synthesis. *Biological Psychology, 45*, 19-56.

Kok, A. (2001). On the utility of P3 amplitude as a measure of processing capacity. *Psychophysiology, 38*, 557-577.

Konorski, J. (1967). *Integrative activity of the brain: an interdisciplinary approach*. Chicago: Chicago University Press

Kopp, B., & Altmann, R. (2005). Neurocognitive effects of phobia-related stimuli in animal-fearful individuals. *Cognitive, Affective, and Behavioural Neuroscience, 5*, 373-387.

Kutas, M., McCarthy, G., & Donchin, E. (1977). Augmenting mental chronometry: The P300 as a measure of stimulus evaluation time. *Science, 197*, 792-795.

Lane, R. D., Chua, P. M. L., & Dolan, R. .J. (1999). Common effects of emotional valence, arousal and attention on neural activation during visual processing of pictures. *Neuropsychologia, 37*, 989-997.

Lang, P. J. (1995). The emotion probe. *American Psychologist, 50*, 372-385.

Lang, P. J., Bradley, M. M., & Cuthbert, B., N. (1990). Emotion, attention, and the startle reflex. *Psychological Review, 97*, 377-395.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1992). A motivational analysis of emotion: Reflex-cortex connections. *Psychological Science, 3*, 44-49.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Affect, activation, and action. In P. J. Lang, R. F. Simons & M. T. Balaban (Eds.), *Attention and orienting: sensory and motivational processes* (pp. 97-135). Manhwah, New Jersey: Lawrence Erlbaun Associates Publishers.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). University of Florida Patent No. Technical Report A-4, The Centre for Research in Psychophysiology.

Lang, P. J., Bradley, M. M., Fitzsimmons, J. R., Cuthbert, B. N., Scott, J. D., Moulder, B., et al. (1998). Emotional arousal and activation of the visual cortex: An fMRI analysis. *Psychophysiology, 32*, 199-210.

Lang, P. J., Davis, M., & Öhman, A. (2000). Fear and anxiety: Animal models and human cognitive psychophysiology. *Journal of Affective Disorders, 61*, 137-159.

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioural reactions. *Psychophysiology, 30*, 261-273.

Lavric, A., Pizzagalli, D. A., & Forstmeier, S. (2004). When 'go' and 'nogo' are equally frequent: ERP components and cortical tomography. *European Journal of Neuroscience, 20*, 2483-2488.

Lazarus, R. S. (1982). Thoughts on the relations between emotion and cognition. *American Psychologist, 37*, 1019-1024.

Lazarus, R. S. (1984). On the primacy of cognition. *American Psychologist, 39*, 124-129.

LeDoux, J. E. (1989). Cognitive-emotional interactions in the brain. *Cognition and Emotion, 3*, 267-289.

LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience, 23*, 155-184.

Leventhal, H., & Scherer, K. (1987). The relationship of emotion to cognition: A functional approach to a semantic controversy. *Cognition and Emotion, 1*, 3-28.

Lewis, M. D., & Stieben, J. (2004). Emotion regulation in the brain: Conceptual issues and directions for developmental research. *Child Development*, *75*, 371-376

Livesey, P. J. (1986). *Learning and emotion: A biological synthesis* (Vol. 1). Hillsdale, N.J: Lawrence Erlbaum Associates

Loew, A., Bradley, M. M., Keller, A. R., & Lang, P. J. (2003). Emotional arousal and novelty: Effects of within-session repetition on ERPs and skin conductance. *Psychophysiology*, S55.

Mangun, G. R. (1995). Neural mechanisms of visual selective attention. *Psychophysiology, 32*, 4-18.

Mangun, G. R., & Hillyard, S. A. (1991). Mechanisms and models of selective attention. In M. D. Rugg & M. G. H. Coles (Eds.), *Electrophysiology of mind*. Oxford, England: Oxford University Press.

Maylor, E. A. (1985). Facilitatory and inhibitory components of orienting in visual space. In M. I. Posner & O. S. M. Marin (Eds.), *Attention and Performance XI* (pp. 189-204). Hillsdale: Lawrence Erlbaum Association.

McDonald, J. J., Ward, L. M., & Kiehl, K. A. (1999). An event-related brain potential study of inhibition of return. *Perception and psychophysics, 61*, 1411-1423.

McManis, M. H., Bradley, M. M., Berg, W. K., Cuthbert, B. N., & Lang, P. J. (2001). Emotional reactions in children: Verbal, physiological, and behavioural responses to affective pictures. *Psychophysiology, 38*, 222-231.

Meinhardt, J., & Pekrun, R. (2003). Attentional resource allocation to emotional events: An ERP study. *Cognition and Emotion, 17*, 477-500.

Miller, N. E. (1944). Experimental studies of conflict. In J. M. Hunt (Ed.), *Personality and the behavioural disorders: A handbook based on experimental clinical research*. USA: The Ronald Press Company.

Miller, N. E. (1959). Liberalization of basic S-R concepts: Extensions to conflict behavior, motivation, and social learning. In S. Koch (Ed.), *Psychology: A study of a science. General systematic formulations, learning, and special processes*. USA: McGraw-Hill Book Company.

Mineka, S., & Öhman, A. (2002). Phobias and preparedness: The selective, automatic, and encapsulated nature of fear. *Biological Psychiatry, 52*, 927-937.

Mini, A., Palomba, D., & Bravi, S. (1996). Emotional information processing and visual evoked brain potentials. *Perceptual and Motor Skills, 83*, 143-152.

Mourão-Miranda, J., Volchan, E., Moll, J., de Oliveira-Souza, R., Oliveira, L., Bramati, I., et al. (2003). Contributions of stimulus valence and arousal to visual activation during emotional perception. *NeuroImage, 20*, 1955-1963.

Mühlburger, A., Wiedemann, G., Hermann, M. J., & Pauli, P. (2006). Phylo- and ontogenetic fears and the expectancy of danger: Differences between spider- and flight-phobic subjects in cognitive and physiological responses to disorder-specific stimuli. *Journal of Abnormal Psychology, 115,* 380-589.

Müller, H. J., & Rabbitt, P. M. A. (1989). Reflexive and voluntary orienting of visual attention: Time course of activation and resistance to interruption. *Journal of Experimental Psychology: Human Perception and Performance, 15*, 315-330.

Näätänen, R., Alho, K., & Schroger, E. (2002). Electrophysiology of attention. In H. Pashler & J. Wixted (Eds.), *Steven's handbook of experimental psychology* (pp. 601-653). New York: John Wiley & Sons. Inc.

Nelson, C. A., & Nugent, K. M. (1990). Recognition memory and resource allocation as revealed by children's event-related potential responses to happy and angry faces. *Developmental Psychology, 26*, 171-179.

Öhman, A. (1986). Face the beast and fear the face: Animal and social fears as prototypes for evolutionary analyses of emotion. *Psychophysiology, 23*, 123-145.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General, 130*, 466-478.

Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic faces. *Journal of Personality and Social Psychology, 80*, 381-396.

Öhman, A., & Mineka, S. (2001). Fears, Phobias, and Preparedness: Toward an evolved module of fear and fear learning. *Psychological Review, 108*, 483-522.

Öhman, A., & Mineka, S. (2003). The malicious serpent: Snakes as a prototypical stimulus for an evolved module of fear. *Current Directions in Psychological Science, 12*, 5-9.

Öhman, A., & Soares, J. J. F. (1993). On the automatic nature of phobic fear-conditioned electrodermal responses to masked fear-relevant stimuli. *Journal of Abnormal Psychology, 102*, 121-132.

Öhman, A., & Soares, J. J. F. (1998). Emotional conditioning to masked stimuli: Expectancies for aversive outcomes following nonrecognized fear-relevant stimuli. *Journal of Experimental Psychology: General, 127*, 69-82.

Palomba, D., Angrilli, A., & Mini, A. (1997). Visual evoked potentials, heart rate responses and memory to emotional pictorial stimuli. *International Journal of Psychophysiology, 27*, 55-67.

Panksepp, J. (2003). At the interface of the affective, behavioural, and cognitive neurosciences: Decoding the emotional feelings of the brain. *Brain and Cognition, 52*, 4-14.

Patterson, D. W., & Schmidt, L. A. (2003). Neuroanatomy of the human affective system. *Brain and Cognition, 52*, 24-26.

Perchet, C., & García-Larrea, L. (2000). Visuospatial attention and motor reaction in children: An electrophysiological study of the "Posner" paradigm. *Psychophysiology, 37*, 231-241.

Picton, T. W. (1992). The P300 wave of the human event-related potential. *Journal of Clinical Neurophysiology, 9*, 456-479.

Picton, T. W., Bentin, S., Berg, P., Donchin, E., Hillyard, S. A., Johnson Jr, R., et al. (2000). Guidelines for using human event-related potentials to study cognition: Recording standards and publication criteria. *Psychophysiology, 37*, 127-152.

Polich, J., & Camerchero, M. D. (2003). P3a from visual stimuli: Typicality, task, and topography. *Brain Topography, 15*, 141-152.

Polich, J., & Kok, A. (1995). Cognitive and biological determinants of P300: An integrative review. *Biological Psychology, 41*, 103-146.

Pollack, S. D., & Tolley-Schell, S. A. (2003). Selective attention to facial emotion in physically abused children. *Journal of Abnormal Psychology, 112*, 323-383.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25.

Posner, M. I. (1988). Structures and functions of selective attention. In T. Boll & B. K. Bryant (Eds.), *Neurophysiology and brain function: The master lectures series* (Vol. 7, pp. 173-202). Washington DC: American Psychological Association.

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma & T. U. Bouwhuis (Eds.), *Attention and performance X* (pp. 531-556). Hillsdale, NJ: Lawrence Erlbaum Associates Publishers.

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13*, 25-42.

Posner, M. I., & Rafal, R. D. (1982). Neural systems control spatial orienting. *Philosophical Transactions of the Royal Society of London Series B, 298*, 187-198.

Pourtois, G., Dan, E. S., Grandjean, D., Sander, D., & Vuilleumier, P. (2005). Enhanced extrastriate visual response to bandpass spatial frequency filtered fearful-faces: Time course and topographic evoked-potentials mapping. *Human Brain Mapping, 26*, 65-79.

Prime, D. J, & Ward, L. M. (2004). Inhibition of return from stimulus to response. *Psychological Science, 15*, 272-276.

Prime, D., J, & Ward, L., M. (2006). Cortical expressions of inhibition of return. *Brain Research, 1072*, 161-174.

Pritchard, W. S. (1981). Psychophysiology of P300. *Psychological Bulletin, 89*, 506-540.

Pritchard, W. S., Brandt, M., & Barratt, E. S. (1986). Analyzing event-related potentials: The utility of high and low pass filtering in improving the relationship between various amplitude measures and principal components analysis factor scores. *Psychophysiology, 23*, 166-173.

Pury, C. L. S., & Mineka, S. (1997). Covariation bias for blood-injury stimuli and aversive outcomes. *Behaviour and Research Therapy, 35*, 35-47.

Rösler, F., & Heil, M. (1991). Toward a functional categorization of slow waves: Taking into account past and future events. *Psychophysiology, 28*, 344-358.

Rozin, P., & Royzman, E. B. (2001). Negativity bias, negative dominance, and contagion. *Personality and Social Psychology Review, 5*, 296-320.

Ruchkin, D., Johnson, J. R., Mahaffey, D., & Sutton, S. (1988). Toward a functional categorization of slow waves. *Psychophysiology, 25*, 339-353.

Rudell, A. P., & Hua, J. (1995). Recognition potential latency and word image degradation. *Brain and Language, 51*, 229-241.

Rushby, J., Barry, R. J., & Doherty, R. (2005). Separation of the components of the late positive complex in an ERP dishabituation paradigm. *Clinical Neurophysiology, 116*, 2363-2380.

Russell, J. A. (1979). Affective space is bipolar. *Journal of Personality and Social Psychology, 37*, 345-356.

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

Schneider, F., Habel, U., Kessler, C., Salloum, J. B., & Posse, S. (2000). Gender differences in regional cerebral activity during sadness. *Human Brain Mapping, 9*, 226-238.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Cacioppo, J. T., Ito, T. A., & Lang, P. J. (2000). Affective picture processing: The late positive potential is modulated by motivational relevance. *Psychophysiology, 37*, 257-261.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Hillman, C. H., Hamm, A. O., & Lang, P. J. (2004). Brain processes in emotional perception: Motivated attention. *Cognition and Emotion, 18*, 593-611.

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2003b). Attention and emotion: An ERP analysis of facilitated emotional stimulus processing. *NeuroReport, 14*, 1-5.

Schupp, H. T., Junghöfer, M., Weike, A. I, & Hamm, A. O. (2003a). Emotional facilitation of sensory processing in the visual cortex. *Psychological Science, 14*, 7-13.

Schupp, H. T., Junghöfer, M., Weike, A. I, & Hamm, A. O. (2004). The selective processing of briefly presented affective pictures: An ERP analysis. *Psychophysiology, 41*, 441-449.

Schupp, H., T., Öhman, A., Junghöfer, M., Weike, A., I, Stockburger, J., & Hamm, A. O. (2004). The facilitated processing of threatening faces: An ERP analysis. *Emotion, 4*, 189-200.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Birbaumer, N., & Lang, P. J. (1997). Probe P3 and blinks: Two measures of affective startle modulation. *Psychophysiology, 34*, 1-6.

Seifert, J., Naumann, E., Hewig, J., Hagemann, D., & Bartussek, D. (2006). Motivated executive attention-incentives and the noise compatibility effect. *Biological Psychology, 71*, 80-89.

Seligman, M. P. E. (1970). On the generality of the laws of learning. *Psychological Review, 77*, 406-418.

Seligman, M. P. E. (1971). Phobias and preparedness. *Behavior Therapy, 2*, 307-320.

Simon-Thomas, E. R., Role, K. O., & Knight, R. T. (2005). Behavioural and electrophysiological evidence of a right hemisphere bias for the influence of negative emotion on higher cognition. *Journal of Cognitive Neuroscience, 17*, 518-529.

Simon, J. R. (1969). Reactions toward the source of stimulation. *Journal of Experimental Psychology, 81*, 174-176.

Smith, N. K., Cacioppo, J. T., & Larsen, J. T. (2003). May I have your attention please: Electrocortical responses to positive and negative stimuli. *Neuropsychologia, 41*, 171-183.

Speilberger, C. D., Gorsuch, R. L., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory (form Y)*. Redwood City, California: Mind Garden.

Stormark, H., Morten, K., Nordby, H., & Hugdahl, K. (1995). Attentional shifts to emotionally charged cues: Behavioural and ERP data. *Cognition and Emotion, 9*, 507-523.

Sutton, S., Braren, M., Zubin, J., & John, E. R. (1965). Evoked potential correlates of stimulus uncertainty. *Science, 150*, 1187-1188.

Taylor, M. J. (2002). Non-spatial attentional effects on P1. *Clinical Neurophysiology, 113*, 1903-1908.

Terry, K. M., Valdes, L. A., & Neill, W. T. (1994). Does "inhibition of return" occur in discrimination tasks? *Perception and Psychophysics, 55*, 279-286.

Tipples, J., & Sharma, D. (2000). Orienting to exogenous cues and attentional pictures reflect separate processes. *British Journal of Psychology, 91*, 87-97.

Tomarken, A. J., & Mineka, S. (1989). Fear-relevant selective associations and covariation bias. *Journal of Abnormal Psychology, 98*, 381-394.

Tomarken, A. J., Sutton, S. K., & Mineka, S. (1995). Fear-relevant illusory correlations: What types of associations promote judgemental bias. *Journal of Abnormal Psychology, 104*, 312-326.

van de Laar, M. C., Licht, R., Franken, I. H. A., & Hendriks, V. M. (2004). Event-related potentials indicate motivational relevance of cocaine cues in abstinent cocaine addicts. *Psychopharmacology, 177*, 121-129.

Verleger, R. (1988). Event-related potentials and cognition: A critique of the context updating hypothesis and an alternative interpretation of P3. *Behavioural and Brain Sciences, 11*, 343-427.

Wascher, E., & Tipper, S. (2004). Revealing effects of noninformative spatial cues: An EEG study of inhibition of return. *Psychophysiology, 41*, 716-728.

Watson, D., & Tellegen, A. (1985). Towards a consensual structure of mood. *Psychological Bulletin, 98*, 219-235.

Wolpe, J., & Lang, P. J. (1964). A fear survey schedule for use in behaviour therapy. *Behaviour and Research Therapy, 2*, 27-30.

Wrase, J., Klein, S., Gruesser, S. M., Hermann, D., Flor, H., Mann, K., et al. (2003). Gender differences in the processing of standardized emotional visual stimuli in humans: A functional magnetic resonance imaging study. *Neuroscience Letters, 348*, 41-45.

Yiend, J., & Mathews, A. (2001). Anxiety and attention to threatening pictures. *The Quarterly Journal of Experimental Psychology, 54*, 665-681.

Zafiropoulou, M., & McPherson, F. M. M. (1986). 'Preparedness" and the severity and outcomes of clinical phobias. *Behaviour and Research Therapy, 24*, 221-222.

Zajonc, R. B. (1980). Feeling and thinking: Preferences need no inferences. *American Psychologist, 35*, 151-175.

Zajonc, R. B. (1984). On the primacy of affect. *American Psychologist, 39*, 117-123.

APPENDIX A

PICTORIAL STIMULI PRESENTED IN EXPERIMENT 1

Table 3a

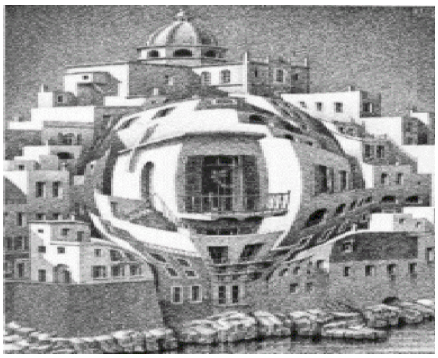
Mean Valence and Arousal Ratings for IAPS and Non-IAPS Stimuli Presented in Experiment 1.

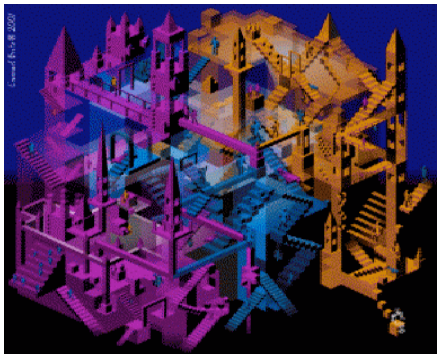
Description	Slide No.	Valence Mean (SD)	Arousal Mean (SD)
Neutral Low Arousal			
Rolling Pin	7000	5.00 (0.84)	2.42 (1.79)
Towel	7002	4.97 (0.97)	3.16 (2.00)
Spoon	7004	5.04 (0.620)	2.00 (1.67)
Bowel	7006	4.88 (0.99)	2.33 (1.67)
Cup	7009	4.93 (1.00)	3.01 (1.97)
Fan	7020	4.97 (1.04)	2.17 (1.71)
Stool	7025	4.63 (1.17)	2.71 (2.20)
Iron	7030	4.69 (1.04)	2.99 (2.09)
Dust Pan	7040	4.69 (1.09)	2.39 (1.93)
Hair Dryer	7050	4.93 (0.81)	2.75 (1.80)
Rubbish Bin	7060	4.43 (1.16)	2.55 (1.77)
Fork	7080	5.27 (1.09)	2.32 (1.84)
Book	7090	5.19 (1.46)	2.61 (2.03)
Fire Hydrant	7100	5.24 (1.20)	2.89 (1.70)
Basket	7101	4.94 (1.07)	1.76 (1.48)
Truck	7130	4.77 (1.03)	3.35 (1.90)
Bus	7140	5.50 (1.00)	2.61 (1.76)
Umbrella	7150	4.72 (1.00)	2.61 (1.76)
Lamp	7175	4.87 (1.00)	1.72 (1.26)
Clock	7211	4.81 (1.78)	4.20 (2.40)
Neutral High Arousal			
Escher Building	non-IAPS	5.05	5.71
Escher Chess	non-IAPS	5.09	1.52
Dali Salvador Clock	non-IAPS	5.09	2.43
Escher Leaf	non-IAPS	5	4.38
Escher Hands	non-IAPS	5.33	4.43
Escher Colour Building	non-IAPS	5	2.47
Surreal Dimensions	non-IAPS	6.28	4.71
Escher Tree	non-IAPS	6.19	4.14
Escher Sphere	non-IAPS	5.04	1.43
Abstract woman	non-IAPS	5.09	3.52
Desert	non-IAPS	5.62	3.86
Pyramid	non-IAPS	4.9	1.81
Figure	non-IAPS	6	4.19
Escher Lizards	non-IAPS	5.67	4.9
Swirl 1	non-IAPS	5.15	4.25
Escher Waterfall	non-IAPS	5.09	2.33
Swirl 2	non-IAPS	4.9	2.33
Spots 1	non-IAPS	4.9	4.86
Spots 2	non-IAPS	5.19	5.24
Spots 3	non-IAPS	5.57	5.33

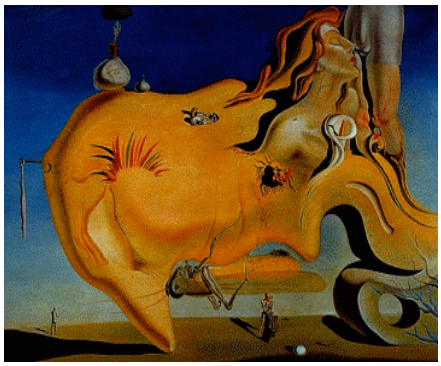
Pleasant Low Arousal			
Women	1340	7.13 (1.57)	4.75 (2.31)
Butterfly	160	6.50 (1.64)	3.43 (1.83)
Rabbit	1610	7.82 (1.34)	3.08 (2.19)
Sprgbok	1620	7.37 (1.56)	3.54 (2.34)
Tigers	1721	7.30 (2.02)	4.53 (2.21)
Chimpanzees	1811	7.62 (1.59)	5.12 (2.25)
Couple	2530	7.80 (1.55)	3.99 (2.11)
Child	2655	6.88 (2.09)	4.57 (2.19)
Flowers	5010	7.14 (1.50)	3.00 (2.25)
Flowers	5030	6.51 (1.73)	2.74 (2.13)
Garden	5200	7.36 (1.52)	3.20 (2.16)
Nature	5220	7.01 (1.50)	3.91 (2.27)
Nature	5270	7.26 (1.57)	5.49 (2.54)
Boat	5390	5.59 (1.54)	2.88 (1.97)
Nature	5780	7.52 (1.45)	3.75 (2.54)
Sunset	5830	8.00 (1.48)	4.92 (2.65)
Seagulls	5831	7.63 (1.15)	4.43 (2.49)
Watermelon	7325	7.06 (1.65)	3.55 (2.07)
Hot Air Balloon	8162	6.97 (1.55)	4.98 (2.25)
Carnival Ride	8497	7.26 (1.44)	4.19 (2.18)
Pleasant High Arousal			
Sky Diving	5621	7.57 (1.42)	6.99 (1.95)
Watersurfers	5623	7.19 (1.44)	5.67 (2.32)
Castle	7502	7.75 (1.40)	5.91 (2.31)
Skier	8021	6.79 (1.44)	5.67 (2.37)
Ramp Skier	8030	7.33 (1.76)	7.35 (2.02)
Skier	8031	6.76 (1.39)	5.58 (2.24)
Ice Skater	8032	6.38 (1.57)	4.19 (2.08)
Sailing	8080	7.73 (1.34)	6.65 (2.20)
Cliff Divers	8180	7.12 (1.88)	6.59 (2.10)
Skydivers	8185	7.57 (1.52)	7.27 (2.08)
Skier	8190	8.10 (1.39)	6.28 (2.57)
Water Skier	8200	7.54 (1.37)	6.35 (1.98)
Pilot	8300	7.02 (1.60)	6.14 (2.21)
Rafting	8370	7.77 (1.29)	6.73 (2.24)
Roller Coaster	8490	7.20 (2.35)	6.68 (1.97)
Water Slide	8496	7.58 (1.63)	5.79 (2.26)
Roller Coaster	non-IAPS	7.28	6.9
Sky Diving	non-IAPS	5.23	3.71
Water Slide	non-IAPS	5.24	4.91
Surfer	non-IAPS	6.05	5.74
Unpleasant Low Arousal			
Rat	1280	3.66 (1.75)	4.93 (2.01)
Baby	2053	2.47 (1.87)	5.25 (2.46)
Baby	2661	3.90 (2.49)	5.76 (2.37)
Riot	2691	3.04 (1.73)	5.85 (2.03)
Drug Addict	2710	2.52 (1.69)	4.63 (2.56)
Bum	2750	2.56 (1.32)	4.31 (1.81)
Battered Female	3180	2.30 (1.43)	5.06 (2.11)

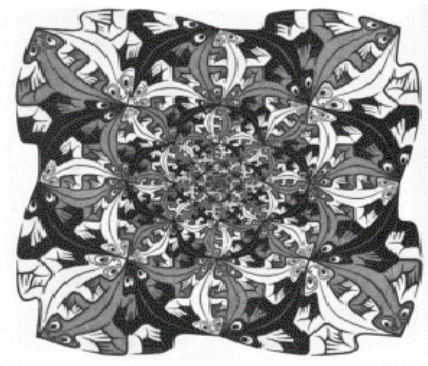
Hospital	3220	2.49 (1.29)	5.52 (1.29)
Dying Man	3230	2.02 (1.30)	5.41 (2.21)
Injured Child	3301	1.80 (1.28)	5.21 (2.26)
Electric Chair	6020	3.41 (1.98)	5.58 (2.01)
Flies on Pies	7360	3.59 (1.95)	5.11 (2.25)
Scared Child	9041	2.98 (1.58)	4.64 (2.26)
Seal	9180	2.99 (1.61)	5.02 (2.09)
Garbage	9340	2.41 (1.48)	5.16 (2.35)
Burial	9430	2.63 (1.59)	5.26 (2.55)
Skulls	9440	3.67 (1.86)	4.55 (2.02)
Skulls	9480	3.51 (2.08)	5.57 (1.87)
Kids	9520	2.46 (1.61)	5.41 (2.27)
Cigarettes	9830	2.54 (1.75)	6.62 (2.26)
Unpleasant High Arousal			
Mutilation	3000	1.45 (1.20)	7.26 (2.10)
Accident	3015	1.52 (0.95)	5.90 (2.82)
Mutilation	3060	1.79 (1.56)	7.12 (2.09)
Mutilation	3063	1.49 (0.96)	6.35 (2.60)
Mutilation	3064	1.45 (0.97)	6.41 (2.62)
Mutilation	3080	1.48 (0.95)	7.22 (1.97)
Burn Victim	3100	1.60 (1.07)	6.49 (2.23)
Burn Victim	3110	1.79 (1.30)	6.70 (2.16)
Mutilation	3150	2.26 (1.57)	6.55 (2.20)
Mutilation	3168	1.56 (1.06)	6.00 (2.46)
Injury	3266	1.56 (0.98)	6.79 (2.09)
Severed Hand	3400	2.35 (1.90)	6.91 (2.22)
Starving Child	9040	3.94 (1.70)	4.14 (2.05)
Stick Through Lip	9042	3.15 (1.89)	5.78 (2.48)
Dead Body	9252	1.98 (1.59)	6.64 (2.33)
Mutilation	9253	2.00 (1.19)	5.53 (2.40)
Sliced Hand	9405	1.83 (1.17)	6.08 (2.40)
Soldier	9410	1.51 (1.15)	7.07 (2.06)
Soldier	9420	2.31 (1.59)	5.69 (2.28)

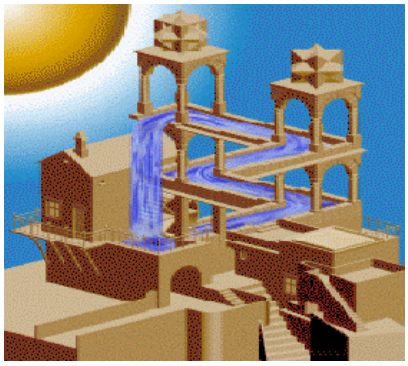
EXAMPLES OF NEUTRAL HIGH AROUSING STIMULI

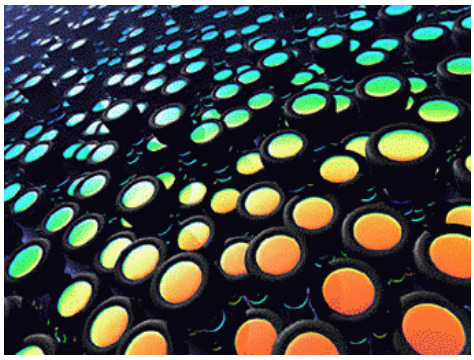


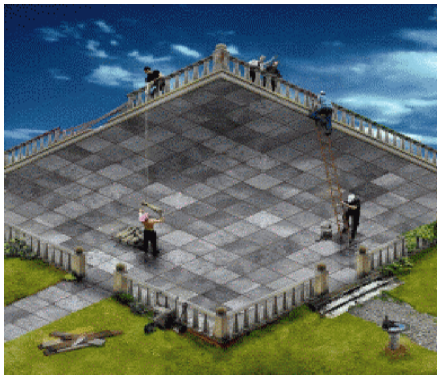


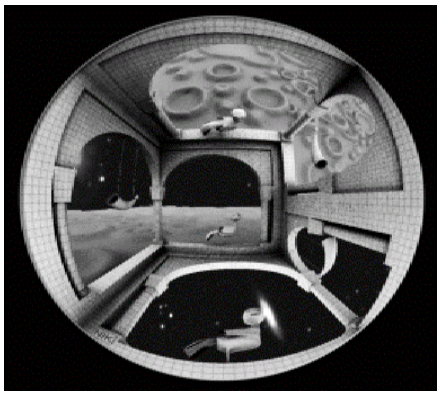












APPENDIX B

PICTORIAL STIMULI PRESENTED IN EXPERIMENT 2

Table 3b

Mean Valence and Arousal Ratings for IAPS and Non-IAPS Stimuli Presented in Experiment 2

Description	Slide No.	Valence Mean (SD)	Arousal Mean (SD)
Neutral Low Arousal			
Rolling Pin	7000	5.00 (0.84)	2.42 (1.79)
Towel	7002	4.97 (0.97)	3.16 (2.00)
Spoon	7004	5.04 (0.620)	2.00 (1.67)
Bowel	7006	4.88 (0.99)	2.33 (1.67)
Cup	7009	4.93 (1.00)	3.01 (1.97)
Fan	7020	4.97 (1.04)	2.17 (1.71)
Stool	7025	4.63 (1.17)	2.71 (2.20)
Iron	7030	4.69 (1.04)	2.99 (2.09)
Dust Pan	7040	4.69 (1.09)	2.39 (1.93)
Hair Dryer	7050	4.93 (0.81)	2.75 (1.80)
Rubbish Bin	7060	4.43 (1.16)	2.55 (1.77)
Fork	7080	5.27 (1.09)	2.32 (1.84)
Book	7090	5.19 (1.46)	2.61 (2.03)
Fire Hydrant	7100	5.24 (1.20)	2.89 (1.70)
Basket	7101	4.94 (1.07)	1.76 (1.48)
Neutral High Arousal			
Escher Building	non-IAPS	5.05	5.71
Escher Chess	non-IAPS	5.09	1.52
Dali Salvador Clock	non-IAPS	5.09	2.43
Escher Colour Building	non-IAPS	5	2.47
Surreal Dimensions	non-IAPS	6.28	4.71
Escher Sphere	non-IAPS	5.04	1.43
Abstract woman	non-IAPS	5.09	3.52
Desert	non-IAPS	5.62	3.86
Pyramid	non-IAPS	4.9	1.81
Escher Lizards	non-IAPS	5.67	4.9
Swirl 1	non-IAPS	5.15	4.25
Escher Waterfall	non-IAPS	5.09	2.33
Spots 1	non-IAPS	4.9	4.86
Spots 2	non-IAPS	5.19	5.24
Spots 3	non-IAPS	5.57	5.33
Pleasant Low Arousal			
Women	1340	7.13 (1.57)	4.75 (2.31)
Butterfly	1602	6.50 (1.64)	3.43 (1.83)
Rabbit	1610	7.82 (1.34)	3.08 (2.19)
Sprgbok	1620	7.37 (1.56)	3.54 (2.34)
Tigers	1721	7.30 (2.02)	4.53 (2.21)
Chimpanzees	1811	7.62 (1.59)	5.12 (2.25)
Couple	2530	7.80 (1.55)	3.99 (2.11)
Child	2655	6.88 (2.09)	4.57 (2.19)

Flowers	5030	6.51 (1.73)	2.74 (2.13)
Garden	5200	7.36 (1.52)	3.20 (2.16)
Nature	5220	7.01 (1.50)	3.91 (2.27)
Nature	5270	7.26 (1.57)	5.49 (2.54)
Nature	5780	7.52 (1.45)	3.75 (2.54)
Watermelon	7325	7.06 (1.65)	3.55 (2.07)
Carnival Ride	8497	7.26 (1.44)	4.19 (2.18)
Pleasant High Arousal			
Sky Diving	5621	7.57 (1.42)	6.99 (1.95)
Watersurfers	5623	7.19 (1.44)	5.67 (2.32)
Skier	8021	6.79 (1.44)	5.67 (2.37)
Ramp Skier	8030	7.33 (1.76)	7.35 (2.02)
Skier	8031	6.76 (1.39)	5.58 (2.24)
Cliff Divers	8180	7.12 (1.88)	6.59 (2.10)
Skydivers	8185	7.57 (1.52)	7.27 (2.08)
Skier	8190	8.10 (1.39)	6.28 (2.57)
Water Skier	8200	7.54 (1.37)	6.35 (1.98)
Rafting	8370	7.77 (1.29)	6.73 (2.24)
Roller Coaster	8490	7.20 (2.35)	6.68 (1.97)
Water Slide	8496	7.58 (1.63)	5.79 (2.26)
Roller Coaster	non-IAPS	7.28	6.9
Water Slide	non-IAPS	5.24	4.91
Surfer	non-IAPS	6.05	5.74
Unpleasant Low Arousal			
Rat	1280	3.66 (1.75)	4.93 (2.01)
Baby	2053	2.47 (1.87)	5.25 (2.46)
Baby	2661	3.90 (2.49)	5.76 (2.37)
Riot	2691	3.04 (1.73)	5.85 (2.03)
Drug Addict	2710	2.52 (1.69)	4.63 (2.56)
Bum	2750	2.56 (1.32)	4.31 (1.81)
Battered Female	3180	2.30 (1.43)	5.06 (2.11)
Hospital	3220	2.49 (1.29)	5.52 (1.29)
Dying Man	3230	2.02 (1.30)	5.41 (2.21)
Injured Child	3301	1.80 (1.28)	5.21 (2.26)
Scared Child	9041	2.98 (1.58)	4.64 (2.26)
Seal	9180	2.99 (1.61)	5.02 (2.09)
Garbage	9340	2.41 (1.48)	5.16 (2.35)
Kids	9520	2.46 (1.61)	5.41 (2.27)
Cigarettes	9830	2.54 (1.75)	6.62 (2.26)
Unpleasant High Arousal			
Mutilation	3000	1.45 (1.20)	7.26 (2.10)
Accident	3015	1.52 (0.95)	5.90 (2.82)
Mutilation	3060	1.79 (1.56)	7.12 (2.09)
Mutilation	3063	1.49 (0.96)	6.35 (2.60)
Mutilation	3064	1.45 (0.97)	6.41 (2.62)
Mutilation	3080	1.48 (0.95)	7.22 (1.97)
Burn Victim	3110	1.79 (1.30)	6.70 (2.16)

Mutilation	3150	2.26 (1.57)	6.55 (2.20)
Mutilation	3168	1.56 (1.06)	6.00 (2.46)
Injury	3266	1.56 (0.98)	6.79 (2.09)
Severed Hand	3400	2.35 (1.90)	6.91 (2.22)
Mutilation	9253	2.00 (1.19)	5.53 (2.40)
Sliced Hand	9405	1.83 (1.17)	6.08 (2.40)
Soldier	9410	1.51 (1.15)	7.07 (2.06)
Soldier	9420	2.31 (1.59)	5.69 (2.28)
Sex Low Arousal			
Artist	4000	4.82 (1.66)	3.97 (2.15)
Attractive Female	4150	6.53 (1.86)	4.86 (2.55)
Attractive Male	4532	6.40 (1.78)	4.15 (2.44)
Couple	4598	6.33 (2.76)	5.53 (2.39)
Romance	4599	7.12 (1.48)	5.69 (1.94)
Romance	4601	6.82 (1.22)	5.08 (2.01)
Romance	4603	7.10 (1.58)	4.89 (2.26)
Couple	4605	5.59 (1.52)	3.84 (2.12)
Romance	4606	6.55 (1.62)	5.11 (2.15)
Couple	4609	6.71 (1.67)	5.54 (2.05)
Romance	4610	6.62 (1.82)	6.04 (2.11)
Romance	4614	7.15 (1.44)	4.67 (2.47)
Attractive Female	4617	6.60 (1.57)	5.19 (2.10)
Romance	4641	7.18 (1.97)	5.43 (2.10)
Couple	4700	6.91 (1.94)	4.05 (1.90)
Sex High Arousal			
Erotic Couple	4651	6.32 (2.18)	6.34 (2.05)
Erotic Couple	4652	6.79 (2.02)	6.62 (2.04)
Erotic Couple	4656	6.73 (1.94)	6.41 (2.19)
Erotic Couple	4658	6.62 (1.89)	6.47 (2.14)
Erotic Couple	4659	6.87 (1.99)	6.93 (2.07)
Erotic Couple	4664	6.61 (2.23)	6.72 (2.08)
Erotic Couple	4666	6.24 (1.78)	6.10 (2.20)
Erotic Couple	4669	5.97 (2.13)	6.11 (2.42)
Erotic Couple	4670	6.99 (1.73)	6.74 (2.03)
Erotic Couple	4672	6.00 (2.04)	6.29 (2.37)
Erotic Couple	4680	7.25 (1.83)	6.02 (2.27)
Erotic Couple	4687	6.87 (1.51)	6.51 (2.10)
Erotic Couple	4690	6.83 (1.94)	6.06 (2.12)
Erotic Couple	4800	6.44 (2.22)	7.07 (1.78)
Erotic Couple	4810	6.56 (2.09)	6.66 (2.14)

APPENDIX C

PICTORIAL STIMULI PRESENTED IN EXPERIMENT 3

Table 3c

Mean Valence and Arousal Ratings for IAPS and Non-IAPS Stimuli Presented in Experiment 3.

Description	**Slide No.**	**Valence Mean (SD)**	**Arousal Mean (SD)**
Neutral Non-Social			
Fan	7020	4.97 (1.04)	2.17 (1.71)
Stool	7025	4.63 (1.17)	2.71 (2.20)
Iron	7030	4.69 (1.04)	2.99 (2.09)
Dust Pan	7040	4.69 (1.09)	2.39 (1.93)
Hair Dryer	7050	4.93 (0.81)	2.75 (1.80)
Rubbish Bin	7060	4.43 (1.16)	2.55 (1.77)
Fork	7080	5.27 (1.09)	2.32 (1.84)
Book	7090	5.19 (1.46)	2.61 (2.03)
Fire Hydrant	7100	5.24 (1.20)	2.89 (1.70)
Basket	7101	4.94 (1.07)	1.76 (1.48)
Truck	7130	4.77 (1.03)	3.35 (1.90)
Bus	7140	5.50 (1.42)	2.92 (2.38)
Umbrella	7150	4.72 (1.00)	2.61 (1.76)
Lamp	7175	4.87 (1.00)	1.72 (1.26)
Clock	7211	4.81 (1.78)	4.20 (2.40)
Neutral Social			
Neutral Face	2200	4.79 (1.38)	3.18 (2.17)
Neutral Face	2210	4.38 (1.64)	3.56 (2.21)
Neutral Face	(Ekman: Disk 1) 006		
Neutral Face	(Ekman: Disk 1) 013		
Neutral Face	(Ekman: Disk 1) 021		
Neutral Face	(Ekman: Disk 1) 028		
Neutral Face	(Ekman:Disk 2) 003		
Neutral Face	(Ekman: Disk 2) 011		
Neutral Face	(Ekman: Disk 2) 017		
Neutral Face	(Ekman: Disk 3) 005		
Neutral Face	(Ekman: Disk 3) 012		
Neutral Face	(Ekman: Disk 3) 023		
Neutral Face	(Ekman:Disk 4) 002		
Neutral Face	(Ekman: Disk 4) 009		
Neutral Face	(Ekman: Disk 4) 020		
Pleasant Non-Social			
Seal	1140	8.19 (1.53)	4.61 (2.54)
Kitten	1460	8.21 (1.21)	4.31 (2.63)
Kitten	1463	7.45 (1.76)	4.79 (2.19)
Cat	1540	7.15 (1.96)	4.54 (2.35)
Horse	1600	7.37 (1.56)	4.05 (2.37)
Butterfly	1603	6.90 (1.48)	3.37 (2.20)
Puppies	1710	8.34 (1.12)	5.41 (2.34)
Dolphins	1920	7.9 (1.48)	4.27 (2.53)
Flower	5010	7.14 (1.50)	3.00 (2.25)

Flower	5200	7.36 (1.52)	3.20 (2.16)
Nature	5201	7.06 (1.71)	3.83 (2.49)
Nature	5220	7.01 (1.50)	3.91 (2.27)
Waterfall	5260	7.34 (1.74)	5.71 (2.53)
Boat	5390	6.91 (1.80)	4.36 (2.62)
Nature	5760	8.05 (1.23)	3.22 (2.39)
Pleasant Social			
Adult	2000	6.51 (1.83)	3.32 (2.07)
Baby	2040	8.17 (1.60)	4.64 (2.54)
Baby	2058	7.91 (1.26)	5.09 (2.48)
Baby	2070	8.17 (1.46)	4.51 (2.74)
Babies	2080	8.90 (1.47)	4.70 (2.59)
Girls	2091	7.68 (1.43)	4.51 (2.28)
Baby	2150	7.92 (1.59)	5.00 (2.63)
Father	2165	7.63 (1.48)	4.55 (2.55)
Children	2303	6.83 (2.07)	5.53 (2.10)
Mother	2311	7.54 (1.37)	4.42 (2.28)
Family	2360	7.70 (1.76)	3.66 (2.32)
Couple	2501	6.89 (1.78)	3.09 (2.21)
Couple	2530	7.80 (1.55)	3.99 (2.11)
Couple	2550	7.77 (1.43)	4.68 (2.43)
Unpleasant Non-Social			
Electric Chair	6020	3.41 (1.98)	5.58 (2.01)
Exhaust	9090	3.56 (1.50)	3.97 (2.12)
Puddle	9110	3.76 (1.41)	3.98 (2.23)
Cow	9140	2.91 (1.37)	5.38 (2.19)
Seal	9180	2.99 (1.61)	5.02 (2.09)
Dead Cows	9181	2.26 (1.85)	5.39 (2.41)
Horses	9182	3.52 (2.04)	4.98 (2.07)
Smoke	9280	2.80 (1.54)	4.34 (2.09)
Garbage	9290	2.88 (1.52)	4.40 (2.11)
Garbage	9330	2.98 (1.74)	4.35 (2.07)
Garbage	9340	2.41 (1.48)	5.16 (2.35)
Duck in Oil	9560	2.12 (1.93)	5.50 (2.52)
Sick Kitty	9561	2.68 (1.92)	4.79 (2.29)
Dog	9570	1.68 (1.23)	6.14 (2.31)
Cigarettes	9830	2.54 (1.75)	6.62 (2.26)
Unpleasant Social			
Baby	2661	3.90 (2.49)	5.76 (2.13)
Riot	2691	3.04 (1.73)	5.85 (2.03)
Drug Addict	2710	2.52 (1.69)	5.46 (2.29)
Bum	2750	2.56 (1.32)	4.31 (1.81)
Crying Boy	2900	2.45 (1.42)	5.09 (2.15)
Battered Female	3180	1.92 (1.13)	5.77 (2.21)
Disabled Child	3300	2.74 (1.56)	4.55 (2.06)
Injured Child	3301	1.80 (1.28)	5.21 (2.26)
Infant	3350	1.88 (1.67)	5.72 (2.23)
Scared Child	9041	2.98 (1.58)	4.64 (2.26)
War Victim	9250	2.57 (1.39)	6.60 (1.87)
Soldier	9400	2.50 (1.61)	5.99 (2.15)

Soldier	9421	2.21 (1.45)	5.04 (2.15)
Kids	9520	2.46 (1.61)	5.41 (2.27)
Boys	9530	2.93 (1.84)	5.20 (2.26)

Note: Neutral facial stimuli were selected from the Ekman and Friesen (1976) picture set based on the subjective neutrality of the facial expression, therefore no rating data is presented.

APPENDIX D

PICTORIAL STIMULI PRESENTED IN EXPERIMENTS 4 & 5

Table 3d

Mean Valence and Arousal Ratings for IAPS Stimuli Presented in Experiments 4 & 5

Description	Slide No.	Valence Mean (SD)	Arousal Mean (SD)
Neutral			
Rolling Pin	7000	5.00 (0.84)	2.42 (1.79)
Towel	7002	4.97 (0.97)	3.16 (2.00)
Spoon	7004	5.04 (0.620)	2.00 (1.67)
Bowel	7006	4.88 (0.99)	2.33 (1.67)
Cup	7009	4.93 (1.00)	3.01 (1.97)
Fan	7020	4.97 (1.04)	2.17 (1.71)
Stool	7025	4.63 (1.17)	2.71 (2.20)
Iron	7030	4.69 (1.04)	2.99 (2.09)
Dust Pan	7040	4.69 (1.09)	2.39 (1.93)
Hair Dryer	7050	4.93 (0.81)	2.75 (1.80)
Rubbish Bin	7060	4.43 (1.16)	2.55 (1.77)
Fork	7080	5.27 (1.09)	2.32 (1.84)
Book	7090	5.19 (1.46)	2.61 (2.03)
Fire Hydrant	7100	5.24 (1.20)	2.89 (1.70)
Basket	7101	4.94 (1.07)	1.76 (1.48)
Sexual			
Erotic Couple	4651	6.32 (2.18)	6.34 (2.05)
Erotic Couple	4652	6.79 (2.02)	6.62 (2.04)
Erotic Couple	4656	6.73 (1.94)	6.41 (2.19)
Erotic Couple	4658	6.62 (1.89)	6.47 (2.14)
Erotic Couple	4659	6.87 (1.99)	6.93 (2.07)
Erotic Couple	4664	6.61 (2.23)	6.72 (2.08)
Erotic Couple	4666	6.24 (1.78)	6.10 (2.20)
Erotic Couple	4669	5.97 (2.13)	6.11 (2.42)
Erotic Couple	4670	6.99 (1.73)	6.74 (2.03)
Erotic Couple	4672	6.00 (2.04)	6.29 (2.37)
Erotic Couple	4680	7.25 (1.83)	6.02 (2.27)
Erotic Couple	4687	6.87 (1.51)	6.51 (2.10)
Erotic Couple	4690	6.83 (1.94)	6.06 (2.12)
Erotic Couple	4800	6.44 (2.22)	7.07 (1.78)
Erotic Couple	4810	6.56 (2.09)	6.66 (2.14)
Mutilation			
Mutilation	3000	1.45 (1.20)	7.26 (2.10)
Accident	3015	1.52 (0.95)	5.90 (2.82)
Mutilation	3060	1.79 (1.56)	7.12 (2.09)
Mutilation	3063	1.49 (0.96)	6.35 (2.60)
Mutilation	3064	1.45 (0.97)	6.41 (2.62)
Mutilation	3080	1.48 (0.95)	7.22 (1.97)
Burn Victim	3110	1.79 (1.30)	6.70 (2.16)
Mutilation	3150	2.26 (1.57)	6.55 (2.20)
Mutilation	3168	1.56 (1.06)	6.00 (2.46)

Injury	3266	1.56 (0.98)	6.79 (2.09)
Severed Hand	3400	2.35 (1.90)	6.91 (2.22)
Mutilation	9253	2.00 (1.19)	5.53 (2.40)
Sliced Hand	9405	1.83 (1.17)	6.08 (2.40)
Soldier	9410	1.51 (1.15)	7.07 (2.06)
Soldier	9420	2.31 (1.59)	5.69 (2.28)
Human Threat			
Riot	2691	3.04 (1.73)	5.85 (2.03)
Attack	3500	2.21 (1.34)	6.99 (2.19)
Attack	3530	1.80 (1.32)	6.82 (2.09)
Attack	6211	3.62 (2.07)	5.90 (2.22)
Soldier	6212	2.19 (1.49)	6.01 (2.44)
Terrorist	6213	2.91 (1.52)	5.86 (2.06)
Aimed Gun	6243	2.33 (1.49)	5.99 (2.33)
Attack	6305	1.90 (1.29)	7.29 (1.87)
Abduction	6312	2.48 (1.52)	6.37 (2.30)
Attack	6313	1.98 (1.38)	6.94 (2.23)
Attack	6550	2.73 (2.38)	7.09 (1.98)
Attack	6560	2.16 (1.41)	6.53 (2.42)
Car Theft	6571	2.85 (2.05)	5.59 (2.50)
Gang	6821	2.38 (1.78)	6.29 (2.02)
Police	6831	2.59 (1.50)	5.55 (2.16)

APPENDX E

PICTORIAL STIMULI PRESENTED IN EXPERIMENT 6

Table 3e

Mean Valence and Arousal Ratings for IAPS Stimuli Presented in Experiment 6

Description	Slide No.	Valence Mean (SD)	Arousal Mean (SD)
Neutral			
Rolling Pin	7000	5.00 (0.84)	2.42 (1.79)
Towel	7002	4.97 (0.97)	3.16 (2.00)
Spoon	7004	5.04 (0.620)	2.00 (1.67)
Bowel	7006	4.88 (0.99)	2.33 (1.67)
Cup	7009	4.93 (1.00)	3.01 (1.97)
Fan	7020	4.97 (1.04)	2.17 (1.71)
Stool	7025	4.63 (1.17)	2.71 (2.20)
Iron	7030	4.69 (1.04)	2.99 (2.09)
Dust Pan	7040	4.69 (1.09)	2.39 (1.93)
Hair Dryer	7050	4.93 (0.81)	2.75 (1.80)
Rubbish Bin	7060	4.43 (1.16)	2.55 (1.77)
Fork	7080	5.27 (1.09)	2.32 (1.84)
Book	7090	5.19 (1.46)	2.61 (2.03)
Fire Hydrant	7100	5.24 (1.20)	2.89 (1.70)
Basket	7101	4.94 (1.07)	1.76 (1.48)
Human Threat			
Riot	2691	3.04 (1.73)	5.85 (2.03)
Attack	3500	2.21 (1.34)	6.99 (2.19)
Attack	3530	1.80 (1.32)	6.82 (2.09)
Attack	6211	3.62 (2.07)	5.90 (2.22)
Soldier	6212	2.19 (1.49)	6.01 (2.44)
Terrorist	6213	2.91 (1.52)	5.86 (2.06)
Aimed Gun	6243	2.33 (1.49)	5.99 (2.33)
Attack	6305	1.90 (1.29)	7.29 (1.87)
Abduction	6312	2.48 (1.52)	6.37 (2.30)
Attack	6313	1.98 (1.38)	6.94 (2.23)
Attack	6550	2.73 (2.38)	7.09 (1.98)
Attack	6560	2.16 (1.41)	6.53 (2.42)
Car Theft	6571	2.85 (2.05)	5.59 (2.50)
Gang	6821	2.38 (1.78)	6.29 (2.02)
Police	6831	2.59 (1.50)	5.55 (2.16)
Animal Threat			
Snake	1050	3.46 (2.15)	6.87 (1.68)
Snake	1052	3.50 (1.87)	6.52 (2.23)
Snake	1090	3.70 (1.90)	5.88 (2.15)
Snake	1120	3.79 (1.93)	6.93 (1.68)
Pit Bull	1300	3.55 (1.78)	6.79 (1.84)
Dog	1301	3.70 (1.66)	5.77 (2.18)
Dog	1302	4.68 (2.11)	5.70 (2.04)
Bear	1321	4.32 (1.87)	6.64 (1.89)
Shark	1930	3.79 (1.92)	6.42 (2.07)
Shark	1931	4.00 (2.28)	6.80 (2.02)

APPENDIX F

INFORMATION SHEET, CONSENT FORM, AND MEDICAL QUESTIONNAIRE

UNIVERSITY OF TASMANIA

Information Sheet for Participation in a Research Project

'Cognitive Processing of Visual, Semantic Information"

Kate Briggs (PhD Student), Dr Frances Martin (Senior Lecturer, School of Psychology

You are invited to participate in a research project investigating the effect of semantic category on the cognitive processing of visual imagery. The study is being undertaken as part of the requirements for a PhD in Psychology and will be conducted in the Cognitive Psychophysiology Laboratory, University of Tasmania (Hobart). If you decide to participate in this research in this study you will gain experience in research procedures and a knowledge of the cognitive processes involved in the processing of visual imagery. Kate Briggs can be contacted at the School of Psychology (phone: 6226 7458, email: kbriggs@utas.edu.au).

The experiment will be conducted in one session of approximately two hours. The session will involve a simple attention task and ratings of visual images both presented on a computer monitor, and a pencil and paper questionnaire. Brain activity and eye movements will be recorded while participants perform the tasks. While the equipment used to measure EEG activity may feel a little uncomfortable, it is not painful in any way, however if you have sensitive skin, you should inform the researcher. If you have any serious medical or psychological conditions, you should not volunteer to participate in this study. Participants must be right handed and will be excluded is they have a history of neurological illness or injury, or are on any forms of medication.

All participants will be required to fill in a medical questionnaire to ensure that there are no pre existing conditions that might cause them to be excluded from the experiment.

All information collected will be kept entirely confidential and contained in a locked storage for at least five years at the School of Psychology at the University of Tasmania. If the study is published, no participant will be personally identifiable. A summary of the results will be available on the University of Tasmania School of Psychology web page, at www.scieng.utas.au/psychol or will be available by contacting the researcher.

Participation is entirely voluntary and if you decide to take part you can withdraw at any stage without academic or other prejudice. Participants will be given copies on this information sheet and the statement of informed consent to keep. If you would like more information regarding this study, please contact Kate Briggs on (03) 6226 7458 or Dr Frances Martin on (03) 6226 2262.

This project has been approved by the Human Research Human Ethics Committee (Tasmania) network. If you have any concerns of an ethical nature or complaints about the manner in which the project has been conducted, you may contact the Chair or Executive Officer of the University of Tasmania, Tasmania Ethics Committee, the Chair is Professor Roger Fay (6324 3576), and the Executive Officer if Ms Amanda McAully (Phone: 6226 2763; fax: 6226 7148; email: Human.Ethics@utas.edu.au

Alternatively, students of the University of Tasmania may prefer to discuss any concerns confidentially with a University Student Counsellor.

Kate Briggs **Dr Frances Martin**

UNIVERSITY OF TASMANIA

Statement of Informed Consent

'Cognitive Processing of Visual, Semantic Information'

Kate Briggs (PhD Student), Dr Frances Martin (Senior Lecturer, School of Psychology)

For the Participant

1. I have read and understood the 'Information Sheet' for this study.
2. The nature and the possible effects of this study have been explained to me.
3. I understand that the study involves the recording of brain activity and eye movements while performing a simple attention task, to rate visual imagery, and to fill out a pencil and paper questionnaire.
4. I understand that while the equipment used to measure EEG activity may feel a little uncomfortable, it is not painful in any way and there are no foreseeable risks associated with this study.
5. I understand that all research data will be securely stored on the University of Tasmania premises at the School of Psychology for a period of five years. I also understand that the data will be securely stored on password protected computers and locked cabinets on the University of Tasmania premises until no longer required, at which time it will be destroyed.
6. Any questions that I have asked have been answered to my satisfaction.
7. I agree that research data for the study may be published and that I cannot be identified as a participant.
8. I understand that my identity will be kept confidential and that any information I supply to the researchers will be used only for the purposes of the research.
9. I agree to participate in this investigation and understand that I may withdraw at anytime without academic or other prejudice, and if I so wish, may request that any personal data gathered be withdrawn from the research.

Name of Participant_____

Signature of Participant_____Date_____

_____

For the Investigator

I have explained this project and the implications of participation in it to this volunteer and believe that the consent is informed and that he/she understands the implications of participation.

UNIVERSITY OF TASMANIA

General Medical Questionnaire for all studies.

Medical and History Questionnaire[1]

University of Tasmania
School of Psychology

Participant Code..... Date...../...../.....

Age…….

Handedness: Left / Right

Medical History

Are you currently suffering from anxiety or depression?.....

Do you have a heart condition or any other serious physical condition?

.....

Are you currently taking any prescription medication? If so, what medication?

.....

Have in the past taken any medications for psychological condition(s)? If so, what medications?

.....

Is there any possibility that you could be pregnant?

.....

Have you ever had or are you now suffering from any of the following (please circle):

Fits or convulsions	*Yes*	*No*
Epilepsy	*Yes*	*No*
Giddiness	*Yes*	*No*
Concussion	*Yes*	*No*
Severe Head Injury	*Yes*	*No*
Loss of Consciousness	*Yes*	*No*

Have you ever been or are you now phobic? *Yes* *No*
If yes, please specify:
……

Drinking and Smoking History

On how many days last week did you drink alcohol?

None
One or two days
Three or four days

	Five or six days Every day
Do you usually drink...	Never During weekdays Friday night Weekends
How many drinks would you usually have at one time?	One or two Three to five Five to eight Eight to twelve More than twelve
Do you get drunk?	Never Rarely Once a month Once a week More frequently
How often do you smoke a cigarette?	Never Less than 5 per week Less than 5 per day 5 to 9 per day 10 to 19 per day 20 to 39 per day Over 40 per day

Do you or have you in the past used marijuana? (please circle)	*Yes*	*No*
a) Have you used marijuana in the last two weeks?	*Yes*	*No*
b) Have you used any other form of illicit drug in the last 6 months?	*Yes*	*No*

Vision

Do you have any difficulties with vision? (please specify)

.....

If yes, are these difficulties corrected (i.e. glasses/contacts)

.....

Hearing

Do you have any difficulties with hearing? (please specify)

.....

If yes, are these difficulties corrected (i.e. hearing aid)

.....

Heterosexual: Yes/No

Note: It is a formal requirement of the Human Research Ethics Committee (Tasmania) Network that the information provided on this questionnaire be held under security to comply with confidentiality regulations and to protect your privacy. You can be assured that information will be available only to the principal researcher and not to any other party. The questionnaire will be destroyed following completion of the project.

Thank you for your Participation

APPENDIX G

STAI AND FSS III QUESTIONNAIRES

STAI: Form Y-1 (STAIT ANXIETY)

Please provide the following information:

Age…… **Gender** *(circle)* M / F

Directions:

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate value to the right of the statement to indicate how you feel *right* now, that is, *at this moment.* There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best. 1=not at all so; 2=somewhat; 3=moderately so; 4=very much so.

1. I feel calm…….	**1**	**2**	**3**	**4**
2. I feel secure……...	**1**	**2**	**3**	**4**
3. I am tense……..	**1**	**2**	**3**	**4**
4. I feel strained……	**1**	**2**	**3**	**4**
5. I feel at ease……..	**1**	**2**	**3**	**4**
6. I feel upset……	**1**	**2**	**3**	**4**
7. I am presently worrying over possible misfortunes…..	**1**	**2**	**3**	**4**
8. I feel satisfied……	**1**	**2**	**3**	**4**
9. I feel frightened……	**1**	**2**	**3**	**4**
10. I feel comfortable……..	**1**	**2**	**3**	**4**
11. I feel self-confident……	**1**	**2**	**3**	**4**
12. I feel nervous…….	**1**	**2**	**3**	**4**
13. I am jittery…….	**1**	**2**	**3**	**4**
14. I feel indecisive……..	**1**	**2**	**3**	**4**
15. I am relaxed……...	**1**	**2**	**3**	**4**
16. I feel content……..	**1**	**2**	**3**	**4**
17. I am worried……..	**1**	**2**	**3**	**4**
18. I feel confused……...	**1**	**2**	**3**	**4**
19. I feel steady……	**1**	**2**	**3**	**4**
20. I feel pleasant…….	**1**	**2**	**3**	**4**

STAI form Y-2 (TRAIT ANXIETY)

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate value to the right of the statement to indicate how you feel *right* now, that is, *at this moment.* There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best. 1=not at all so; 2=somewhat; 3=moderately so; 4=very much so.

21. I feel pleasant……..	**1**	**2**	**3**	**4**
22. I feel nervous and restless……	**1**	**2**	**3**	**4**
23. I feel satisfied with myself……..	**1**	**2**	**3**	**4**
24. I wish I could be as happy as others seem to be……..	**1**	**2**	**3**	**4**
25. I feel like a failure……...…….	**1**	**2**	**2**	**3**
26. I feel rested……..	**1**	**2**	**3**	**4**
27. I am "calm, cool, and collected"……..	**1**	**2**	**3**	**4**
28. I feel that difficulties are piling up so that I cannot overcome them...	**1**	**2**	**3**	**4**
29. I worry too much over something that really doesn't matter……...	**1**	**2**	**3**	**4**
30. I am happy……...	**1**	**2**	**3**	**4**
31. I have disturbing thoughts……	**1**	**2**	**3**	**4**
32. I lack self-confidence……	**1**	**2**	**3**	**4**
33. I feel secure……...	**1**	**2**	**3**	**4**
34. I make decisions easily……	**1**	**2**	**3**	**4**
35. I feel inadequate……...	**1**	**2**	**3**	**4**
36. I am content……..	**1**	**2**	**3**	**4**
37. Some unimportant thoughts run through my mind and it bothers me..	**1**	**2**	**3**	**4**
38. I take disappointments so keenly that I can't put them out on my mind……	**1**	**2**	**3**	**4**
39. I am a steady person……...	**1**	**2**	**3**	**4**
40. I get in a state of tension or turmoil as I think over my recent concerns and interests….…….……..	**1**	**2**	**3**	**4**

Fear Survey Schedule

The items in this questionnaire refer to things and experiences that may cause fear or other unpleasant feelings. Write down the number of each item in the column that describes how much you are disturbed by it nowadays.

	Not at all	A little	A fair amount	Much	Very much
1. Noise of vacuum cleaners	1	2	3	4	5
2.Open wounds	1	2	3	4	5
3. Being alone	1	2	3	4	5
4. Being in a strange place	1	2	3	4	5
5. Loud voices	1	2	3	4	5
6. Dead people	1	2	3	4	5
7. Speaking in public	1	2	3	4	5
8. Crossing the streets	1	2	3	4	5
9. People who seem insane	1	2	3	4	5
10. Falling	1	2	3	4	5
11. Automobiles	1	2	3	4	5
12. Being teased	1	2	3	4	5
13. Dentists	1	2	3	4	5
14. Thunder	1	2	3	4	5
15. Sirens	1	2	3	4	5
16. Failure	1	2	3	4	5
17. Entering a room where other people are already seated	1	2	3	4	5
18. High places on land	1	2	3	4	5
19. People with deformities	1	2	3	4	5
20. Worms	1	2	3	4	5
21. Imaginary creatures	1	2	3	4	5
22. Receiving injections	1	2	3	4	5
23. Strangers	1	2	3	4	5
24. Bats	1	2	3	4	5
25. Journeys a-train, b-bus, c-car	1	2	3	4	5
26. Feeling angry	1	2	3	4	5
27. People in authority	1	2	3	4	5
28. Flying insects	1	2	3	4	5
29. Seeing other people injected	1	2	3	4	5
30. Sudden noises	1	2	3	4	5
31. Dull weather	1	2	3	4	5
32. Crowds	1	2	3	4	5
33. Large open spaces	1	2	3	4	5
34. Cats	1	2	3	4	5
35. One person bullying another	1	2	3	4	5
36. Tough looking people	1	2	3	4	5
37. Birds	1	2	3	4	5
38. Sight of deep water	1	2	3	4	5

39. Being watched working	1	2	3	4	5
40. Dead animals	1	2	3	4	5
41. Weapons	1	2	3	4	5
42. Dirt	1	2	3	4	5
43. Crawling insects	1	2	3	4	5
44. Sight of fighting	1	2	3	4	5
45. Ugly people	1	2	3	4	5
46. Fire	1	2	3	4	5
47. Sick people	1	2	3	4	5
48. Dogs	1	2	3	4	5
49. Being criticized	1	2	3	4	5
50. Strange shapes	1	2	3	4	5
51. Being in an elevator	1	2	3	4	5
52. Witnessing surgical operations	1	2	3	4	5
53. Angry people	1	2	3	4	5
54. Mice	1	2	3	4	5
55. Blood a- human, b-animal	1	2	3	4	5
56. Parting from friends	1	2	3	4	5
57. Enclosed spaces	1	2	3	4	5
58. Prospect of a surgical operation'	1	2	3	4	5
59. Feeling rejected by others	1	2	3	4	5
60. Airplanes	1	2	3	4	5
61. Medical odors	1	2	3	4	5
62. Feeling disapproved	1	2	3	4	5
63. Harmless snakes	1	2	3	4	5
64. Cemeteries	1	2	3	4	5
65. Being ignored'	1	2	3	4	5
66. Darkness	1	2	3	4	5
67. Premature heart beats (missing a beat)	1	2	3	4	5
68. a) Nude men	1	2	3	4	5
b) Nude women	1	2	3	4	5
69. Lightening	1	2	3	4	5
70. Doctors	1	2	3	4	5
71. Making mistakes	1	2	3	4	5
72. Looking foolish	1	2	3	4	5