

Deconstructing threat in picture processing: An event-related potential

investigation of sex differences in the motivational relevance of highly aversive

images

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Date: _____

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Abstract

Motivational relevance refers to an individual's capacity to prioritise attention allocation towards stimuli with high emotional salience. Sex differences in cognition, perception and behaviour suggest that the motivational relevance of negative stimuli is different for men and women. The evidence is mixed for this form of sexual dimorphism, however, as men and women are also known to vary in their vulnerability to stress-eliciting stimuli, or stress reactivity. This association between stress reactivity and an individual's biological sex may be affected by the specific features of a stimulus which denote threat to an individual. The strength of this relationship in emotional processing has previously been assessed with the use of unpleasant images as negative stimuli in several studies utilising electroencephalography (EEG) measures. The premise that the threat value of aversive images, particularly salient forms of negative stimuli, drives sex-specific variation in event-related potential (ERP) activity was examined across three EEG studies in the present research. Threat value, in this context, refers to the interaction between the stimulus- and individual-level factors that drive attention allocation towards threatening stimuli. In Experiment 1 this was investigated through the selection of specific semantic categories in images shown to participants (i.e., reptiles, firearms, humans) and the measurement of personality traits associated with stress reactivity in men and women (i.e., alexithymia, neuroticism, trait anxiety and worry). The influence of the female ovarian cycle on stress reactivity was also addressed by recruiting women prescribed contraceptive medication for all three EEG studies. In line with predictions, sex differences in stimulus-locked ERP amplitude were moderated by the threat value of images showing snakes, handguns or human injury. The effect of context on responses towards the threat value of aversive stimuli was

targeted in Experiments 2 and 3. Differences between men and women in motivational relevance may depend on the deployment of sex-specific strategies in response to stimuli which represent threats to male or female individuals. This was tested using a modified Flanker paradigm which featured congruent and incongruent arrays constructed from images sourced from specific stimulus categories (i.e., reptiles, firearms, humans), as well as the measurement of the same stress-related personality traits assessed in Experiment 1. Sex differences, and similarities, in response selection were indexed by stimulus-locked ERP activity modulated by reptile and firearm stimuli in Experiment 2, and human stimuli in Experiment 3. Across all three EEG studies levels of neuroticism, trait anxiety and worry contributed to sex-specific variation in ERP activity across the picture processing stream, supporting the notion that differences between male and female individuals in motivational relevance are influenced by both individual- and stimulus-level factors. Moreover, the results of the present research demonstrate that threat value must be considered when investigating the emotional salience of negative stimuli, and that sources of individual variation, such as sex differences, represent a rich avenue of inquiry for psychological research. Furthermore, the present research findings also have implications for the way in which stress reactivity is examined in men and women, particularly in regards to the types of psychopathology associated with being male or female.

Chapter 1 - INTRODUCTION

Pictures which show naturalistic scenes are widely employed to examine the effect of emotion on attentional allocation (Güntekin & Başar, 2014; Okon-Singer, Lichtenstein-Vidne, & Cohen, 2013; Olofsson, Nordin, Sequeira, & Polich, 2008). Men and women are thought to vary in this type of emotional processing in response to unpleasant images, naturalistic scenes that show negative content. To date, however, evidence of this sex-specific variation is mixed (see Chapter 2). The overarching aim of the present thesis is to investigate whether the threat value of highly aversive images elicits sex differences in picture processing. Highly aversive images are unpleasant images which feature content that is particularly negative and high in emotional arousal. These negative scenes also tend to show stimuli that represent a threat in some way, by implying the potential for attack, harm or destruction by the situation depicted in the image (e.g., unsafe environments, injury to humans or animals) or towards the observer of the image itself (e.g., aggressive animals, armed assailant). In the present thesis, threat value will be defined as the interaction between the perception of threat and the individual-level factors that moderate this response.

The association of threat with the content of highly aversive images suggests that these negative stimuli function as small-scale stressors in picture processing, due to the life-threatening nature of these negative scenes for many individuals. Stress refers to a functional, or detrimental, response to a stress-eliciting stimulus (Dedovic, Duchesne, Andrews, Engert, & Pruessner, 2009; Kaltsas & Chrousos, 2007). This dynamic is partially acknowledged in picture processing research, as attention allocation towards negative stimuli is associated with defensive behaviours such as attack, withdrawal, and self-protection (Lang & Bradley, 2013). More broadly, emotional salience can be defined as the perceptual, semantic or physical qualities that distinguish a negative or

positive stimulus from more neutral stimuli in emotion-related processing. In the case of negative stimuli, however, the emotional salience of these stimuli is also affected by an individual's perception of how stress-eliciting the stimulus is. At times individuals can become more sensitised to the stress-eliciting properties of a stimulus, such that in normal, everyday situations even benign stimuli could be viewed as stressors (Aron, Aron, & Jagiellowicz, 2012; Burke, Davis, Otte, & Mohr, 2005; Lahey, 2009).

The individual-level factors that influence the motivational relevance of negative stimuli remain to be fully characterised. In this context, motivational relevance refers to the prioritisation of stimuli with high emotional salience in attention allocation (Bradley, Sabatinelli, & Lang, 2014; Brosch, Pourtois, & Sander, 2010). In the present thesis, the effect of an individual's biological sex on motivational relevance will be targeted. Male and female individuals are known to vary in stress reactivity, or their sensitivity towards stress-eliciting stimuli (Bale & Epperson, 2015; Bangasser & Valentino, 2014; Bangasser & Wicks, 2017; Ordaz & Luna, 2012). Several electroencephalography (EEG) studies have also shown that unpleasant images evoke sex differences in ERP activity (see Chapter 2 for review). However, to date the specific contribution of threat value to this dynamic has not been investigated. The emotional salience of threat is often linked to evolutionary significance, or the shaping of attentional mechanisms by environmental pressures. The present thesis will test the premise that the threat value of aversive images is influenced by evolutionary significance, and this dynamic will be evidenced by sex differences in event-related potential (ERP) activity.

Sex differences in the motivational relevance of unpleasant images will be reviewed in Chapter 2, along with a discussion of the use of ERP measures to index emotional salience. Sex-specific ERP modulation evoked by unpleasant images has

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been associated with sex differences in biases towards negative stimuli and social relevance, as well as sex hormone fluctuation in females. In the present thesis, social relevance is defined as emotional salience with a basis in human socialisation, such as empathy and the learning of culturally-appropriate behaviours. A common element between the EEG studies that have investigated sex-specific variation is the linking of pre-attentive processing to the expression of defensive motivation in male and female individuals. Sex differences have been identified in early, middle and late latency ERP activity for unpleasant images, suggesting that men and women differ in the timing of attention allocation towards negative stimuli. The specific stimulus-level factors that moderate sex differences in picture processing, however, are yet to be determined.

In Chapter 3 the focus on the threat value of aversive images in the investigation of sex differences in ERP activity will be justified. The potential for danger and harm implied by these negative stimuli influences the emotional salience of highly aversive images. It is possible that attention allocation towards unpleasant images differs between men and women due to the deployment of sex-specific strategies in encounters with stimuli that are potential threats. In terms of evolutionary significance, there are two major stimulus properties that may influence sex differences in the processing of threat. Firstly, stimuli with high biological relevance, or emotional salience with a biological basis, often feature in highly aversive images. The threat value of aversive images to men or women could depend on the biological relevance of the stimulus (e.g., snakes vs. handguns). Secondly, the intent to attack is often associated with potential threat, indicating that the action disposition of a stimulus could moderate the emotional salience of aversive images. In the present thesis, action disposition will be defined as the implied tendency towards a specific action. Given that not all content featured in highly aversive images necessarily denote the potential for attack, determining whether

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attack intent leads to sex differences in picture processing is prudent.

Chapters 4, 5 and 6 will describe the three EEG studies in which the contribution of threat value to sex differences in the processing of highly aversive images will be investigated. In each EEG study, men and women will respond to images that differ in terms of biological relevance and action disposition. To accomplish this, image content will be confined to the depiction of three prototypical stimuli with clearly discernible biological relevance and action disposition. It was hypothesised that by systematically varying these two stimulus-level factors, sex differences in response to the threat value of these negative stimuli will manifest, if present. In Experiment 1, scenes of reptiles, firearms and humans will be presented to male and female participants to examine the contribution of action disposition to sex differences in picture processing. This will be accomplished by comparing snakes and handguns, two stimuli readily associated with the intent to attack, with images of severely injured humans (e.g., medical procedures, murder or accident victims, life-threatening mutilation or disfigurement). In Experiments 2 and 3 the effect of contextual cues will be investigated using congruent and incongruent arrays comprised of aversive and neutral versions of these same prototypical stimuli.

To discern the individual-level factors that could moderate the threat value of aversive images, four personality traits associated with sex-specific variation, stress reactivity, and the modulation of ERP activity in picture processing will be measured in male and female participants in each EEG study: trait anxiety; neuroticism; worry; and alexithymia. Sex hormone fluctuation during the female menstrual cycle is shown to impact brain-based measures during picture processing in women (Andreano & Cahill, 2009; Goldstein, Jerram, Abbs, Whitfield-Gabrieli, & Makris, 2010; Lischke et al., 2012; Lusk, Carr, Ranson, Bryant, & Felmingham, 2015; Ossewaarde et al., 2010,

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2013; Wu et al., 2014). For this reason, in each EEG study women taking some form of hormonal conceptive were recruited as participants. The influence of these medications on picture processing in women has rarely been investigated, excluding a few key exceptions (Becker, Creutzfeldt, Schwibbe, & Wuttke, 1982; Petersen & Cahill, 2015; Wuttke et al., 1975). It was hypothesised in the present research that hormonal contraceptive use would attenuate the influence of progesterone and oestrogen fluctuation on picture processing in women, allowing a more direct comparison of responses to the threat value of images by male and female individuals.

Throughout this thesis, it will be shown that the threat value of highly aversive images influences sex differences, and similarities, in ERP activity. It is hypothesised that stimulus- and individual-level factors implicated in threat value will contribute to ERP modulation in men and women in each of the three EEG studies included in this thesis. In Chapter 7 major findings regarding sex-specific variation will be summarised and discussed considering prior research. Though tempting, the purpose of Chapter 7 is not to draw conclusions on the real-world implications of differences observed between men and women in the present research. Rather, Chapter 7 will focus on contextualising the research findings considering relevant theory on the reasons why sex differences manifest in picture processing. The reason being, sex differences in picture processing are likely not isolated to the presentation of highly aversive images. Instead, the findings from the present thesis indicate that the threat-related qualities of an image lead to the selection of appropriate responses by male and female individuals towards negative stimuli. A recurring issue in the previous investigation of differences between men and women in picture processing has been the assumption that this sex-specific variation occurs in isolation from other factors that affect attention allocation towards unpleasant images. As demonstrated by the following thesis though, it is more likely

that men and women engage in sex-specific strategies in encounters with stimuli that signal threat, harm or danger, a dynamic that could correspond to sex differences in the expression of defensive behaviour.

Chapter 2 - SEX DIFFERENCES IN THE MOTIVATIONAL RELEVANCE OF UNPLEASANT IMAGES

Unpleasant images depict a broad range of harmful, off-putting, or despondent content which function as proxies for negative real-world stimuli. A wide range of behavioural, physiological, and brain-based evidence indicates the emotional salience of these stimuli is different for men and for women (Bradley, Codispoti, Sabatinelli, & Lang, 2001; Gomez, von Gunten, & Danuser, 2013; Stevens & Hamann, 2012; Whittle, Yücel, Yap, & Allen, 2011). In the present chapter, the use of EEG measures to investigate sex-specific variation in response to unpleasant images will be reviewed. The intermixing of semantic categories among naturalistic scenes employed as unpleasant images will also be highlighted. In this context, sematic categories refer to the grouping of stimuli based on their inherent meaning to individuals, whether through cultural, social or biological associations. Examples include hazardous environments, humans in pain or distress, contamination, and the display of aggression by animals or humans. The processing of unpleasant images reflects the preparatory stages of defensive responses towards real-world negative stimuli. Examining sex-specific variation in ERP activity towards unpleasant images will help delineate how men and women do, and do not, differ in the behavioural expression of defensive motivation.

The chapter will begin with an overview of motivational relevance in unpleasant images. The focus of the review will then shift to the discussion of relevant EEG studies, starting with those that have reported sex differences in N2 modulation. Next sex-specific variation in early ERP modulation will be detailed, followed by differences between men and women in late ERP positivity. This arrangement will highlight the relationship of early and middle ERP modulation to the attentional processes indexed by the late positive potential (LPP) and related positive activity. For brevity, certain types

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of EEG studies will not be featured in the current review. Sex differences in memoryrelated processing of negative stimuli, including unpleasant images, are considered in depth elsewhere (see Andreano & Cahill, 2009; Cahill, 2003, 2006; Hamann & Canli, 2004). EEG studies that solely employ faces as stimuli will also not feature in the current chapter. Faces are highly salient for humans as these stimuli are important for interpersonal communication (Eimer & Holmes, 2007; Palermo & Rhodes, 2007). The processing of faces and naturalistic scenes overlap, however, these two types of stimuli are not always equivalent in terms of brain activation (Sabatinelli et al., 2011).

The motivational relevance of unpleasant images

Sex differences in motivational relevance are linked to the relationship between attention allocation and subsequent behaviour. Approach and avoidance tendencies are closely tied to picture processing, as viewing an image is thought to mimic a real-life encounter with the content of the scene (Lang, 1979; Lang, Greenwald, Bradley, & Hamm, 1993). Differences between men and women in temperament, physiology, and outward behaviour have driven the investigation of sex differences in picture processing. The theoretical focus of EEG studies that investigate sex-specific variation for unpleasant images either emphasise the greater emotional salience of negative stimuli to women compared to men (Gasbarri et al., 2007; Li, Yuan, & Lin, 2008; Lusk et al., 2015; Yuan et al., 2009) or the influence of social relevance on sex differences in empathy, emotional regulation, and the perception of pain in other humans (Gardener, Carr, MacGregor, & Felmingham, 2013; Gonzalez-Liencres, Breidenstein, Wolf, & Brüne, 2016; Groen, Wijers, Tucha, & Althaus, 2013; Han, Fan, & Mao, 2008; Luo et al., 2014; Proverbio, Adorni, Zani, & Trestianu, 2009). In both cases, the evolutionary significance of negative stimuli to male and female individuals plays a central role.

Stimuli with high levels of motivational relevance are those essential for an
individual's continued survival. Appetitive, or more positive, stimuli traditionally denote opportunities to approach, whereas aversive, or more negative, stimuli signal threat and trigger avoidance behaviours (Elliot, Eder, & Harmon-Jones, 2013). Appetitive cues include stimuli related to food intake, sexual reproduction, or caregiving, while more aversive examples consist of potential danger, contamination, and other stimuli associated with self-preservation. The emotional salience of highly aversive or appetitive stimuli is often framed as a prehistoric remnant from the evolutionary past, despite these stimuli continuing to be important for modern-day humans. For instance, three appetitive stimuli that continue to dominate the popular media of today are scenes of attractive people, delicious food, and cute babies. The emotional salience of aversive stimuli is more ambiguous in the modern-day context, however, as approach and avoidance tendencies are not necessarily tied to the pleasantness of a stimulus in all circumstances. There are situations when approach-type behaviours towards highly aversive stimuli are needed in response to potential threats, such as self-protection or in defence of loved ones.

Defensive motivation. The emotional salience of unpleasant images is related to the specific features of the scene. Motivational relevance is most often conceptualised in terms of valence and arousal in picture processing. These two affective dimensions are thought to describe most forms of emotional experience (Konorski, 1967; Russell, 1980; Watson & Tellegen, 1985). Valence denotes the pleasantness of an image while arousal signals the intensity of the valence attribution. Greater levels of arousal are associated with increasing levels of pleasantness or unpleasantness. Biphasic affect has proven useful in characterising the motivational relevance of unpleasant images; however, the

type of content featured in these negative scenes is diverse. Dysphoric¹ images consist of scenes that evoke uncomfortable or distressing feelings, including sad or fearful faces, grief, war-zones, pain, or exploitation. More aversive images such as angry faces, artificial weaponry, aggressive animals, and severely injured humans (i.e., mutilation, death, severe disfigurement) denote more overt forms of danger or potential harm towards an individual. In comparison to dysphoric images, aversive images are more explicitly linked to defensive motivation in picture processing.

A negativity bias is thought to occur in picture processing due to the greater emotional salience of unpleasant images compared to more pleasant or neutral images (Carretié, Albert, López-Martín, & Tapia, 2009; Norris, Gollan, Berntson, & Cacioppo, 2010). Negative and aversive stimuli are typically equated in terms of approach and avoidance tendencies. The physical properties of an image, such as colour scheme, cropping, and resolution, also determine whether a negative is more dysphoric or aversive in nature. Neuberg, Kenrick, and Schaller (2011) propose that responses towards potential threats, including negative stimuli, can be categorised as either selfprotective or disease-avoidant. This aligns with the dysphoric/aversive distinction, while also indicating how observing the content of a negative scene may affect an individual. Bradley, Codispoti, Sabatinelli and Lang (2001) have proposed that defensive motivation is largely consistent across men and women, and that sex-specific variation may represent the influence of evolutionary significance on picture processing. Biological relevance, or emotional salience with a biological basis, could affect how a male or female individual responds to a negative stimulus.

Defensive motivation is linked the orienting reflex, an immediate response to an

¹ I would like to acknowledge Burkhouse, Woody, Owens and Gibbs (2015) for the label of "dysphoric" to describe these types of unpleasant images.

abrupt change in a person's environment. The early stages of the defensive response have been termed the defence cascade in picture processing (Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang, Bradley, & Cuthbert, 1997). Immediately following an encounter with a negative stimulus momentary immobilisation or "freezing" occurs, a physical state associated with an increase in attentiveness (Obrist, 1981). Physiologically this state is indexed by an initial deceleration in heart rate, a steady increase in galvanic skin response, and potentiation of the startle blink reflex (Figure 2.1). Following this overt action towards or away from the eliciting stimulus occurs (e.g., fight or flight). Picture processing is thought to correspond with the postencounter stage of the defence cascade (Lang et al., 1997). Brain-based measures have



Figure 2.1. A theoretical representation of the defence cascade from Bradley, Codispoti, Cuthbert, et al., Emotion and motivation I: Defensive and appetitive reactions in picture processing, *Emotion*, 1(3), 276–298, 2001. Copyright 2001 by American Psychological Association. Reprinted with permission.

increasingly been utilised to examine this aspect of defensive motivation in recent years (Bradley, Keil, & Lang, 2012; Bradley et al., 2014). The amplitude modulation of several ERP components is shown to index motivational relevance in picture processing, most notably the LPP (a.k.a. the late positive component, P300, P3b).

Brain-based measures of emotional salience

The two most common brain-based methods employed to investigate sex differences in picture processing are functional magnetic resonance imaging (fMRI) and EEG. Both measures index neural activation and physiological arousal associated with the viewing of an unpleasant image. Studies utilising fMRI typically employ paradigms in which men and women actively engage with an image via emotional regulation, imagery, or memory-based strategies. To date sex-specific variation in blood-oxygenlevel-dependent (BOLD) activation due to unpleasant images has been shown to occur in the amygdala, the anterior cingulate cortex, the fusiform gyrus, and regions of the prefrontal cortex (Stevens & Hamann, 2012; Whittle et al., 2011). Despite having excellent spatial properties, fMRI is not ideal for examining sex differences in defensive motivation. The tasks used in fMRI studies are often too slow-paced to examine preattentive processing, and the timing of brain activation immediately following image presentation is not well-represented by this method.

Sex-specific variation in sensation, perception, and behaviour must be considered in the investigation of differences between male and female individuals in motivational relevance. The use of EEG measures to examine sex-specific variation reflects the timing of these other influential factors, as well as the timing of attention allocation. It is well-established that ERP activity during the early, middle and late latencies signal attention allocation to visual stimuli (Kok, 1997; Luck, Woodman, & Vogel, 2000). ERP modulation also reflects the summation of all activity instigated by

viewing an image, particularly physiological arousal. This physical state is thought to denote the level of activation, or alertness, that the individual experiences in response to a stimulus (Blascovich, 1992). For picture processing, ERP activity indexes the distribution of attentional resources after stimulus onset. EEG measures are inferior to fMRI in terms of spatial resolution, although the former measure more accurately captures the fluctuation in brain activity that follows image presentation. ERP activity derived from EEG data also offers insight into the timing of motivational relevance across the picture processing stream.

Sex differences in ERP modulation are often reported in EEG studies that present unpleasant images as part of a passive viewing or oddball task. The participant simply observes an image during passive viewing, while in the oddball paradigm, participants respond to the presence of a deviant, or target, among a stream of frequent stimuli. The LPP is most often associated with sex-specific variation in ERP modulation. Activity for the LPP begins approximately 300ms after image presentation and results from a combination of P3b and slow positive wave (SPW) activity (Foti, Hajcak, & Dien, 2009; Matsuda & Nittono, 2015; Olofsson et al., 2008). The P3b and related SPWs denote task relevance and the allocation of attentional resources (Kok, 1997; Ritter & Ruchkin, 1992). Sex differences are also reported to occur in ERP activity that precedes the LPP. These ERP components include the N2, the N1 and the P1. Early-occurring modulation of the N1 and the P1 are moderated by the physical attributes of an image (Olofsson et al., 2008). It is possible that levels of N1 and P1 activity also reflect broader differences between men and women in sensory and perceptual processing (Schroeder, 2010).

Sex-specific variation in N2 activity

The modulation of middle latency ERPs, including the N2, are associated with

stimulus discrimination and response selection (Folstein & Van Petten, 2008; Näätänen & Gaillard, 1983). In addition to picture processing, middle latency ERPs are typically examined in response to auditory or simple visual stimuli (Hajcak, Weinberg, MacNamara, & Foti, 2012; Olofsson et al., 2008). This includes the early posterior negativity (EPN), temporal-occipital ERP modulation shown to index the emotional salience of images (Schupp, Flaisch, Stockburger, & Junghöfer, 2006). Another type of middle latency ERP activity observed during picture processing is termed the N2, an ERP component with a distribution localised to frontal-central or central sites. Emotionally salient scenes are shown to moderate N2 amplitude, although it is unclear whether the magnitude of this effect is equivalent to that elicited by pleasant and unpleasant images (Hajcak et al., 2012). It is this centrally-distributed N2, rather than the EPN, which is consistently linked to sex differences in picture processing. Modulation of N2 activity is associated with a female bias towards unpleasant images and the presence of humans in emotionally salient scenes.

The female negativity bias. Two EEG studies have investigated whether the unpleasantness of negative stimuli is separable from arousal level in sex-specific variation (Li et al., 2008; Yuan et al., 2009). In both cases, images from the Chinese Affective Picture System (CAPS; Bai, Ma, & Huang, 2005) were employed as stimuli in an oddball task. Frequent stimuli were images of cups whereas deviant stimuli consisted of neutral, moderately unpleasant, or highly unpleasant CAPS images. The arousal level of all deviants, including neutral images, was also matched. Li et al. (2008) and Yuan et al. (2009) found that for women the amplitude of an anterior N2 (230-290ms) was most negative for highly unpleasant deviants, followed by moderate unpleasant deviants, and then neutral deviants (Li et al., 2008; Yuan et al., 2009). For men N2 activity was more negative for highly unpleasant deviants compared to both

neutral and moderately unpleasant deviants. These sex differences in N2 modulation may indicate women are more sensitised to the valence of moderately unpleasant images than men.

To confirm the effects observed by Li et al. (2008) and Yuan et al. (2009) were specific to negative stimuli Yuan et al. replicated the oddball task with neutral, moderately pleasant, and highly pleasant CAPS images, again with matched levels of arousal. Participant sex did not interact with the pleasantness of deviant stimuli in ERP modulation. Neither Li et al. nor Yuan et al. described the content of unpleasant and neutral CAPS images shown as deviants, a practice that is not unusual in picture processing research if the valence and arousal ratings of the stimuli are provided. A more recent study involving the same researchers suggests deviant stimuli consisted of unpleasant and neutral CAPS images featuring animals, landscapes, or humans. Following the same methodology, Yuan et al. (2014) examined differences between pre-pubescent and pubescent girl and boys in gamma-band activity (81-87Hz). Though beyond the scope of the current review, the researchers found that participant sex and pubertal status moderated gamma-band activity elicited by highly unpleasant CAPS images shown as deviants.

Gonadal steroids are associated with sex-specific variation in stress reactivity and physiological arousal (Goel, Workman, Lee, Innala, & Viau, 2011; Ordaz & Luna, 2012). Therefore it is conceivable these sex differences extend to picture processing. The influence of female sex hormones on ERP activity was investigated by Wu et al. (2014). Women completed a similar oddball task to that employed by Li et al. (2008) and Yuan et al. (2009) twice, once during the follicular phase of their menstrual cycle and once during the luteal phase. Wu et al. found that highly unpleasant deviants elicited more negative frontal N2 (150-300ms) activity during the luteal phase

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compared to the follicular phase in these women. This effect was specific to the left hemisphere; moreover, different CAPS images were used as deviants during the follicular and luteal phase of female participants. Similar to Li et al. and Yuan et al. unpleasant and neutral deviants were also matched on arousal. The women also did not differ significantly in terms of negative mood, depressive symptoms, or state anxiety at the two stages of their ovarian cycle (Wu et al., 2014). These results suggest factors apart from dimensional arousal drive sex-specific ERP modulation in response to unpleasant images.

To date, the premise that sex hormones affect picture processing has been investigated primarily in women rather than men. For women the early stage of their ovarian cycle is termed the follicular phase, beginning with menstruation. During the follicular phase, progesterone levels are low compared to the luteal phase that follows ovulation (Farage, Neill, & MacLean, 2009). Oestrogen levels peak in the late follicular phase immediately before ovulation and again midway through the luteal phase. These fluctuations in progesterone and oestrogen during the female ovarian cycle may influence picture processing in women. Due to their involvement in stress reactivity, gonadal steroids potentially moderate defensive motivation in men and women. Androgens, oestrogens, and progestogens moderate activation of the hypothalamic– pituitary–adrenal (HPA) axis in animals and humans (Goel et al., 2011; Kudielka & Kirschbaum, 2005; Panagiotakopoulos & Neigh, 2014) and also influence immune system function in humans (Pennell, Galligan, & Fish, 2012; Plotnikoff & Faith, 2006).

Human stimuli. Linking ERP modulation directly to sex hormone fluctuation is tempting, however, this approach discounts the effect of specific image content on sex differences in picture processing. For instance, the CAPS images employed by Li et al. (2008), Yuan et al. (2009), and Wu et al. (2014) may have intermixed aversive and

dysphoric stimuli among their unpleasant CAPS images. Other EEG studies that have examined sex-specific variation have emphasised the motivational relevance of human stimuli to men and women, rather than unpleasant images specifically (Groen et al., 2013; Han et al., 2008; Luo et al., 2014; Proverbio et al., 2009). Though the emotional salience of human stimuli is high for men and women, the social and biological relevance of these images may differ between the sexes. The N2 modulation observed by Li et al., Yuan et al. and Wu et al. could be related not only to the unpleasantness of deviant stimuli but also to the presence of humans in these negative scenes. To date, two EEG studies have found that human stimuli evoke sex-specific variation in N2 activity (Groen et al., 2013; Proverbio et al., 2009).

Proverbio et al. (2009) included unpleasant and pleasant images from the International Affective Picture System (IAPS; Bradley & Lang, 2007; Lang, Bradley, & Cuthbert, 2008) as frequent stimuli in an oddball task. Images of abstract paintings served as deviants, and the arousal level of frequent stimuli was matched. Within each valence category, half of the IAPS images featured humans, and the other half did not. Groen et al. (2013) replicated the design of Proverbio et al. and included neutral IAPS images along with other frequent stimuli. Proverbio et al. found that for women images of pleasant humans elicited more negative frontal-central N2 (210-270ms) activity than those showing unpleasant humans, a difference not observed for men. The researchers suggest this N2 modulation reflects the greater salience of positive socially-relevant stimuli for women compared to men. In contrast, Groen et al. reported that the amplitude of the N2 (210-270ms) was more negative for human than non-human scenes for women, but not for men. This effect was clearest in the left hemisphere and not unique to pleasant or unpleasant images.

Differences between the stimuli employed by Proverbio et al. (2009) and Groen

et al. (2013) may have contributed to ERP modulation observed in female participants. First, Proverbio et al. showed abstract paintings as deviants, whereas Groen et al. utilised a red-and-white mosaic. Second, the ratio of aversive and dysphoric content featured in unpleasant images varied between the two studies. Human images included scenes of carnage, gore, torture, discomfort, pain, and terror for Proverbio et al., while those without humans consisted of natural disasters, war zones, and animals that were suffering, dead, or tortured. In contrast, Groen et al. did not include IAPS images judged to be particularly disgusting; specifically, scenes of injured humans. Human images were primarily dysphoric and showed people who were in pain or upset. For images without humans Groen et al. intermixed scenes of aggressive animals among others showing natural disasters and unhygienic environments (e.g., dirty bathroom).

Sex-specific variation in early ERP activity

Broad physiological differences between male and female individuals in sensation and perception are another possible source of sex differences in motivational relevance. Two examples of individual-level factors that could influence picture processing in men and women are sex hormone fluctuation and brain asymmetry (Schroeder, 2010). Oestrogen and progesterone changes during the female menstrual cycle are also shown to moderate visual sensitivity in women (Eisner, Burke, & Toomey, 2004; Newlands & Bates, 2001; Ward, Stone, & Sandman, 1978). Sex differences in sensation and perception are most likely indexed by N1 and P1 modulation due to the physical qualities of a stimulus affecting the amplitude of these two ERP components. To date, sex differences in early-occurring ERP amplitude are less reliably observed compared to the N2 and late positivity. Characterising the nature of this sex-specific variation is important for identifying how early sex differences in picture processing occur in relation to the unpleasantness of an image and other

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stimulus-level factors.

Lithari et al. (2010) recorded EEG activity from men and women during a rapid serial viewing passive (RSVP) paradigm, in which a stream of images was shown to participants at a fast pace. Stimuli were shown for one second each and consisted of high and low-arousing IAPS images that were pleasant or unpleasant. High-arousing images evoked more negative posterior N1 (90-170ms) activity than low-arousing images at anterior and posterior regions, and this effect was noticeably larger for women than men at frontal sites. The amplitude of N1 amplitude elicited by unpleasant images was also larger for women compared to men. In addition, posterior N1 activity was more negative for unpleasant images than pleasant images for women, but not for men. These results suggest valence and arousal are processed differently by men and women during early picture processing, however, Lithari et al. also presented different sets of images to male and female individuals. The proportion of aversive and dysphoric stimuli varied between the male and female image-sets, despite some overlap in some of the unpleasant images shown to men and women,

Lusk et al. (2015) addressed this limitation by showing the same set of images to men and women, and by also including low-arousing neutral IAPS images alongside other stimuli. The researchers also grouped women according to the follicular or midluteal phase of their ovarian cycle, groupings that were confirmed with salivary progesterone. An occipital P1 (60-120ms) was analysed in place of the posterior N1. No sex-specific effects were evident for unpleasant images in the frontal N1 (50-150ms), occipital P1, posterior P3, or LPP. When image categories were collapsed, amplitudes for the P1 and the N1 were largest for mid-luteal phase women, followed by follicular phase women, and then men. Differences between mid-luteal women and the two other groupings reached significance for the N1. For the P1, however, only the difference

between mid-luteal women and men was significant. The results of the Lusk et al. study support the idea that visual sensitivity is moderated by the female menstrual cycle in women. Unlike Lithari et al. (2010) though, no difference was found between men and women in early ERP activity for unpleasant images.

The major discrepancy between Lusk et al. (2015) and Lithari et al. (2010) was the types of unpleasant images selected for presentation. For Lithari et al. high-arousing images included human injury, aimed handguns, and war scenes for both sexes; however, images of destruction and aggressive humans were only shown to men. Lowarousing images consisted of cemeteries, criminality, everyday household objects, and poverty for women and for men. Naked members of the same sex were also included in the male and female image-sets for low-arousing unpleasant images. Lusk et al. did not include erotic images among pleasant or low-arousing unpleasant stimuli. Unpleasant images that were low-arousing were primarily dysphoric and consisted of cemeteries, distressed humans, poverty, garbage, and pollution. Images of severely injured humans dominated high-arousing stimuli in the same valence category. The lack of erotic scenes included by Lusk et al., as well as the different proportion of aversive and dysphoric content in unpleasant images in each study, likely contributed to the discrepant findings.

Aside from Lithari et al. (2010) and Lusk et al. (2015), two other EEG studies have reported sex-specific variation in early ERP modulation. First, Groen et al. (2013) found temporal-occipital P1 (90–150ms) activity was larger for women than men in response to human images in the left hemisphere. In the right hemisphere, the amplitude of the P1 for unpleasant images was more positive for women than for men. Second, Gardener et al. (2013) recorded EEG as men and women completed an emotional regulation task. When participants were instructed to up-regulate their response towards high-arousing, unpleasant IAPS images, anterior N1 (50–150ms) and N2 (150–270ms) amplitudes were more negative for women compared to men. These results, along with those from Lithari et al. and Lusk et al., highlight inconsistencies in the types of sex differences observed during early picture processing. Whether these discrepancies are unique to the intermixing of aversive and dysphoric stimuli, or other stimulus-level factors, is presently unclear.

Sex-specific variation in late-occurring positivity

So far EEG evidence for sex-specific variation in early ERP and N2 activity have been reviewed. N2 modulation indicates the emotional salience of unpleasant images is moderated by an individual's biological sex, albeit in terms of stimulus-level qualities. Regarding early ERP activity, it is possible the amplitude of the N1 and P1 index female responsivity towards emotionally-salient visual stimuli in general, not solely to unpleasant images. Generalising the implications of N2, N1 and P1 modulation to sex-specific variation in motivational relevance requires an awareness of how these processes integrate during the time course of the LPP. In line with this, differences between male and female individuals in ERP modulation are most often found for the LPP and related positive activity. Sex-specific variation in late positivity reportedly occurs at anterior and posterior locations. In EEG studies where LPP activity is localised to frontal electrodes, this would suggest a relationship with the anterior P3a associated with stimulus novelty (Polich, 2007). The latency of sex-specific variation in this anterior late positivity is typically more consistent with the time frame of the posterior P3b.

Several EEG studies that found sex differences in N2 modulation also reported differences between male and female individuals in late positivity. Li et al. (2008) and Yuan et al. (2009) found patterns of parietal P3 (350-450ms) activity mirrored that observed for the anterior N2, while Proverbio et al. (2009) and Groen et al. (2013)

reported sex differences in LPP modulation. For Li et al. and Yuan et al., neutral deviants elicited the most positive P3 (350-450ms) amplitude for women, followed by moderately unpleasant, and then highly unpleasant deviants. For men, P3 activity for highly unpleasant deviants was reduced compared to moderately unpleasant and neutral deviants. Proverbio et al. found unpleasant images elicited more positive LPP (500-700ms) activity than pleasant images for women in parietal regions, a difference that was negligible for men. Unpleasant images of humans also evoked larger LPP amplitude in women than men. For Groen et al. parietal LPP (400-800ms) activity in the right hemisphere was more positive for unpleasant images than pleasant images, and this effect was noticeably larger for women compared to men. LPP (500-800ms) activity was also larger in women compared to men for unpleasant images included as frequent stimuli.

Across the four aforementioned EEG studies N2, P3 and LPP modulation were driven by the ERP activity of women. In each case the arousal level of unpleasant, pleasant and neutral images was matched, suggesting the observed effects were not simply due to more intense attributions of pleasantness or unpleasantness. It is possible the arousal level induced by unpleasant images also plays a role in sex-specific variation. Proverbio et al. (2009) attributed the sex differences in LPP activity to the empathy and arousal induced by frequent stimuli in their oddball task. That sex-specific variation was evident for frequent, rather than deviant, stimuli also indicates attention does not need to be directed towards the emotionally salient stimulus to moderate late positivity. Other EEG studies that have reported sex differences in LPP and related ERP modulation by unpleasant images have either focused on the arousal level of these negative stimuli or on sex-specific variation in empathy. Evidence has also been found for the asymmetry of late positivity in male and female individuals.

Asymmetry and the arousal level of unpleasant images. Two EEG studies have reported sex differences in the lateralisation of P3 and state-steady ERP activity elicited by unpleasant images (Gasbarri et al., 2007; Kemp, Silberstein, Armstrong, & Nathan, 2004). In both studies, men and women were shown neutral, unpleasant and pleasant IAPS images during a passive viewing task. First, for women, Gasbarri et al. (2007) found unpleasant images evoked larger frontal and parietal P3 (300-500ms) activity in the left compared to the right hemisphere. The opposite pattern of activity was elicited for men by unpleasant images. Unpleasant images also elicited more positive P3 amplitude than pleasant and neutral stimuli for women, but not men. Second, Kemp et al. (2004) measured steady-state ERPs during a similar time frame as SPW activity following image onset. For women, unpleasant images elicited larger steady-state ERPs (2-6 seconds) in the right compared to the left hemisphere, but this effect did not occur for male participants. The time frame of late positive activity in the two passive viewing tasks likely contributed to the discrepant results of the two EEG studies. There were also clear differences in the types of unpleasant images presented in each EEG study.

The arousal level of pleasant, neutral and unpleasant images was matched by Kemp et al. (2004), but not by Gasbarri et al. (2007). In both EEG studies, low-arousing IAPS stimuli were employed as pleasant and neutral images. The latter stimuli consisted of common, everyday objects (e.g., light-bulb, dust-pan, books), non-emotional faces, and average landscapes (e.g., building, motorway). For pleasant images both EEG studies showed benign stimuli such as babies, beautiful landscapes, baby animals, flowers, or ice cream. Gasbarri et al., however, did not match the arousal level of unpleasant images to the selected low-arousing neutral or positive stimuli. Instead unpleasant images featured a combination of aversive and dysphoric content, including

severe human injury, cemeteries, aimed handguns, and sickness. Kemp et al. utilised low-arousing unpleasant images that were primarily dysphoric, such as garbage, dead animals, and cemeteries. It is possible the pattern of P3 modulation observed by Gasbarri et al. was related to the intermixing of different negative stimuli.

Rozenkrants & Polich (2008) also investigated sex-specific variation in picture processing by matching the arousal level of unpleasant images to those employed as positive stimuli. During an oddball task men and women were shown deviant stimuli that were unpleasant or pleasant IAPS images with high or low levels of arousal. Frequent stimuli consisted of red and white checkerboards. Unpleasant deviants elicited larger P3 (300-450ms) and late SPW (700-850ms) activity than pleasant deviants in parietal regions. The amplitude of the early SPW (550-700ms) was also more positive for high-arousing compared to low-arousing images in the same location, and this difference was noticeably larger for women than men. Although this result suggests the arousal level of images drives sex-specific variation, the effect may have been motivated by the negative stimuli featured in unpleasant images. High-arousing stimuli were primarily aversive and included scenes of human injury, aimed weapons, and destruction while low-arousing scenes were more dysphoric in nature, showing sickness, famine, grief, poverty, and pollution.

The presence of humans in many pleasant and unpleasant scenes employed as deviant stimuli was another limitation of the study conducted by Rozenkrants and Polich (2008). Pleasant images that were high-arousing consisted of scenes showing erotica and active sports, while low-arousing examples depicted food, babies, pets, happy people, and natural landscapes (Rozenkrants & Polich, 2008). Human injury and erotica are particularly salient forms of motivationally relevant image content (Bradley et al., 2014; Weinberg & Hajcak, 2010). The high-arousing human images included as

deviants by Rozenkrants and Polich may have driven the arousal-related effects observed in male and female individuals. This criticism could also be applied to Gasbarri et al. (2007), who included human injury among their unpleasant images. Unlike several of the EEG studies reviewed so far, Rozenkrants and Polich did not present neutral images alongside more pleasant and unpleasant stimuli. The lack of sexspecific variation towards unpleasant images could be due to this absence, as the relative valence of an image may not be evident without a neutral counterpart present.

Social relevance. The types of stimuli that are often featured in unpleasant, neutral, and pleasant images indicate that certain naturalistic scenes are more often associated with positive or negative valence. Humans are one such stimulus thought to elicit sex-specific variation in picture processing, a finding linked to sex differences in empathy (Groen et al., 2013; Proverbio et al., 2009). Empathy refers to the ability to identify with the thoughts, feelings, and mood of another person (Zaki & Ochsner, 2012; Zillman, 2013). It is not clear, however, whether sex differences in empathy and motivational relevance are strictly interchangeable in the processing of human images. Action tendencies are heavily implicated in current theories of emotional processing; however, the focus of this relationship has often been on emotions as feelings rather than as action dispositions (Frijda, 2010; Lowe & Ziemke, 2011). The association of empathy with sex-specific variation may be related to the way in which men and women respond to stimuli with high social relevance, such as humans, rather than the ability of male or female individuals to empathise with the content of an image.

Aside from Proverbio et al. (2009) and Groen et al. (2013), three other EEG studies have examined the relationship between social relevance, empathy and sex differences in late positivity (Gonzalez-Liencres et al., 2016; Han et al., 2008; Luo et al., 2014). The earliest of these four studies examined sex differences in ERP activity

towards the perception of pain. Han et al. (2008) presented scenes of hands shown in painful situations, such as a hand being jammed in a doorframe or cut by a pair of scissors, during a passive viewing task. For women frontal-central LPP (500-660ms) was more positive for painful images than for equivalent neutral stimuli. Each neutral stimulus was matched to one of the unpleasant images, but the hand was not shown in the painful situation. When women were asked to judge the pain level of hands in painful situations, these stimuli elicited larger frontal-central P3 (340-540ms) activity than neutral images. Neither of the two effects observed in late positivity was found in male individuals.

Similar to Han et al. (2008), Gonzalez-Liencres et al. (2016) employed scenes of hands in painful or non-painful situations which participants also rated for unpleasantness. Before EEG testing half of the participants were subjected to a modified version of the Trier Social Stress Test (Kirschbaum, Pirke, & Hellhammer, 1993). Painful images evoked more positive centromedial P3 (350–410ms) activity than neutral stimuli for stressed men and non-stressed women, but not for non-stressed men and stressed women (Gonzalez-Liencres et al., 2016). A very strong and positive correlation was also found between the amplitude of the centromedial P3 and the cortisol levels of stressed men, but the same relationship was not found for stressed women. Like Han et al., Gonzalez-Liencres et al. did not include painful images that showed blood, mutilation, or gore. This suggests sex-specific effects observed in the two EEG studies were due to the depiction of pain in the unpleasant images. Arousal ratings for painful or non-painful images were not collected by Han et al. or Gonzalez-Liencres et al., making a comparison with other EEG studies that have found sex-specific variation in response to unpleasant images difficult.

In several EEG studies reviewed so far scenes of humans in clear distress have

been employed as unpleasant stimuli. The addition of cues that denote potential threat or harm in these images may explain the high emotional salience of human injury as a stimulus (Sarlo, Buodo, Poli, & Palomba, 2005; Schienle et al., 2006; Wright, He, Shapira, Goodman, & Liu, 2004). Moreover, women are shown to be more sensitive than men to the perception of physical pain in themselves and other people (Craft, 2007; Fillingim, King, Ribeiro-Dasilva, Rahim-Williams, & Riley III, 2009; Hashmi & Davis, 2014; Unruh, 1996). This premise is supported by the results of the two remaining EEG studies. As previously mentioned, Gardener et al. (2013) compared emotional regulation between men and women in response to unpleasant images, specifically the use of cognitive reappraisal strategies. This form of emotional regulation occurs largely outside conscious awareness. Conversely, Luo et al. (2014) focused on sex differences in ERP activity elicited by negative or neutral scenes of humans.

Similar to Li et al. (2008) and Yuan et al. (2009), Luo et al. (2014) presented images with varying levels of unpleasantness. These highly unpleasant, moderately unpleasant, and neutral IAPS images were shown to participants during a passive viewing task. To ensure participant attendance to the stimuli judgement trials were randomly interspersed throughout the task. Highly unpleasant images evoked the most positive parietal LPP (350–750ms) activity for women, followed by moderately unpleasant, and then neutral, stimuli. For men LPP amplitude was larger for highly unpleasant images compared to other images, with little difference between LPP activity for moderately unpleasant and neutral images. The pattern of these results corresponds to those observed by Li et al. and Yuan et al. in N2 and P3 modulation. More striking is that the highly unpleasant images presented by Luo et al. were clearly aversive and the moderately unpleasant images primarily dysphoric. The former stimuli showed humans who were deceased, in danger, or obviously suffering, while the latter stimuli consisted

of humans in pain or emotional turmoil.

In contrast Gardener et al. (2013) employed IAPS images that were either higharousing and unpleasant or neutral and low-arousing. Negative stimuli consisted of humans or animals that were threatening, injured or disfigured. Participants were instructed to maintain, increase, or decrease their response to images as they were shown. In the maintain condition participants simply viewed the image, while the other two conditions involved reappraising the image as either more (i.e., increase) or less (i.e., decrease) salient. Similar to activity observed for the N1 and the N2, the increase condition led to significantly greater frontal LPP (400-800ms) activity than the maintain condition for women, but not men, in response to negative scenes. Participant sex also predicted LPP and peak P3 (approx. 300ms) amplitudes in the increase and maintain conditions for unpleasant images. The negative scenes employed by Gardener et al. stimuli were primarily aversive. However as observed in several EEG studies the aversiveness or dysphoria of an image does not always correspond to the level of arousal associated with the stimulus.

Summary of sex differences in ERP activity for unpleasant images

The findings of the EEG studies reviewed in the current chapter indicate the motivational relevance of unpleasant images differs between men and women, and that the mismatch between arousal level and the semantic category of unpleasant images is a potential confound in the investigation of this sex-specific variation. Unpleasant images were chosen on the basis of valence and arousal ratings in several EEG studies. Unpleasant images either consisted of intermixed dysphoric and aversive stimuli (Groen et al., 2013; Proverbio et al., 2009; Rozenkrants & Polich, 2008), or were primarily dysphoric or aversive in nature (Gardener et al., 2013; Gasbarri et al., 2007; Kemp et al., 2004; Lithari et al., 2010; Lusk et al., 2015). Humans were also featured in

unpleasant images employed as negative stimuli in many of the reviewed EEG studies (e.g., severe injury, grief, physical assault). However, only three studies examined whether the presence of humans specifically moderated sex differences in ERP activity (Groen et al., 2013; Luo et al., 2014; Proverbio et al., 2009).

The types of paradigms utilised in picture processing research may have contributed to sex-specific variation in ERP activity. For passive viewing tasks sex differences in LPP modulation were reported when images were presented for two or more seconds (Gasbarri et al., 2007; Kemp et al., 2004) or required a response of some kind to the image (Gardener et al., 2013; Gonzalez-Liencres et al., 2016; Han et al., 2008; Luo et al., 2014). These results suggest that some form of response selection is necessary to elicit most forms of sex-specific variation for unpleasant images. Amplitude modulation for the N2, late positivity, or for early ERP components was more often observed in women than men (Groen et al., 2013; Han et al., 2008; Proverbio et al., 2009; Rozenkrants & Polich, 2008; Yuan et al., 2009). Other EEG studies reported different patterns of late positivity for male and female individuals in response to unpleasant images (Gasbarri et al., 2007; Kemp et al., 2004; Luo et al., 2014).

The location of N2 modulation across different EEG studies was relatively stable compared to earlier- or later-occurring ERP activity. Early anterior N1 and posterior P1 activity in response to unpleasant and pleasant images were influenced by participant sex in select instances (Gardener et al., 2013; Groen et al., 2013; Lithari et al., 2010; Lusk et al., 2015). It is unclear whether these results were due to the emotional salience of the images or sex differences in sensory and perceptual processing. Activity for the LPP and related ERP components was observed in frontal regions (Gardener et al., 2013; Gasbarri et al., 2007; Han et al., 2008), parietal regions

(Groen et al., 2013; Luo et al., 2014; Proverbio et al., 2009; Rozenkrants & Polich, 2008), or a combination of both (Li et al., 2008; Yuan et al., 2009). Late positivity in anterior regions may be associated with sex differences in social relevance and empathy, while more posterior instances of this activity could be specific to the motivational relevance of images for male and female individuals.

The distribution of early ERP activity and late positivity in relation to sexspecific variation is clearly an issue that requires further investigation, particularly in regards to hemispheric asymmetry. Another area of concern is the influence of sex hormone fluctuation on picture processing in women, with only two EEG studies addressing this dilemma in the current review (Lusk et al., 2015; Wu et al., 2014). The timing of stimulus presentation may also affect sex-specific variation in ERP activity for unpleasant images. Two studies that employed the RSVP paradigm either did not find sex differences related to unpleasant images (Lusk et al., 2015) or reported sexspecific variation in the N1 for high-arousing images (Lithari et al., 2010). As mentioned, some form of response selection may also be needed to elicit sex differences in ERP activity, as most of the reviewed EEG studies included direct responses to unpleasant images by way of the oddball task (Li et al., 2008; Rozenkrants & Polich, 2008; Yuan et al., 2009) or attendance was required to some aspect of images presented within the oddball or passive viewing task (Gardener et al., 2014; Proverbio et al., 2009).

Implications for sex differences in defensive motivation

The most pressing outcome of the present review is that females were not the sole source of sex-specific variation. In several EEG studies, ERP modulation was either absent or different in men compared to women. Women and men naturally vary in brain-based measures simply due to differences in physical characteristics such as the

size and density of specific brain regions (Ingalhalikar et al., 2014; Ruigrok et al., 2014). It is important to differentiate whether or not this normal physiological variation drives sex differences in picture processing. Response selection may also contribute to sex-specific variation in ERP activity towards unpleasant images. Sex differences in N2 and P3 modulation were evident even when unpleasant images were frequent rather than deviant stimuli in two oddball tasks (Groen et al., 2013; Proverbio et al., 2009). Requiring participants to respond to the presented images may ensure the attention of male and female individuals is engaged in the task at hand.

Most importantly, it has been demonstrated throughout the current review that the semantic category of an unpleasant image must be considered in the investigation of picture processing in men and women. The intermixing of dysphoric with aversive stimuli throughout many of the reviewed EEG studies obscures whether this sexspecific variation is due to the motivational relevance of specific image content, the arousal level of emotionally salient scenes, or unpleasant images in general. Differences between men and women in defensive motivation also likely contribute to the observed modulation of early ERP, N2 and LPP activity. More broadly, these findings indicate dissimilar attenuation of attentional resources towards negative stimuli in men compared to women. Biases to negative or socially-relevant stimuli do not appear to be specific to women, but rather reflect the moderating influence of motivational relevance on attention allocation. Characterising the nature of this divergence between male and female individuals would clarify the role of defensive motivation in picture processing.

Chapter 3 - THESIS RATIONALE

Sex differences in defensive motivation contribute to how men and women respond to highly aversive stimuli during picture processing. The background to this assertion was considered in the previous chapter with a review of several EEG studies that have reported sex-specific variation in ERP activity for unpleasant images. These findings indicate that the motivational relevance of these negative stimuli is different for male and female individuals. Several concerns were also raised about the influence of stimulus-level and individual-level factors on the investigation of sex differences in picture processing. The current chapter will describe the theoretical basis for examining ERP activity towards the threat value of highly aversive images in men and women. The attribution of threat, or the presence of implied or real danger, is a recurring feature of unpleasant images employed in picture processing research. The individual-level factors that have been linked to attention allocation towards threat could influence the processing of highly aversive images, a dynamic that should be reflected by sex differences in ERP modulation.

To begin with, the role of threat in picture processing will be discussed, followed by a consideration of the relationship between threat value and sex differences in stress reactivity. An overview of three EEG studies intended to address sex-specific variation in ERP activity elicited by highly aversive images will then be provided. Highly aversive images are typically rated with higher levels of unpleasantness and arousal than other unpleasant images due to the presence of life threatening content in these negative scenes. Often these images are also characterised as extremely distressing, intimidating, or disgusting. Depending on the physical properties of the stimulus aversive images can also include dysphoric elements (see Chapter 2). In the present research, highly aversive images with clear connotations of threat will be

targeted. These scenes can range from tangible hazards that pose a clear risk to one's safety to threats that are more abstract in nature. Prototypical threats constitute negative stimuli with a recurrent association with the attribution of threat. In the present research, semantic categories will be selected based on social and biological relevance, as well as the use of the prototypical stimulus in prior research to denote threat, negativity or aversiveness in picture processing research.

The attribution of threat is dependent on both the actual danger represented by a stimulus and the perceptual biases that affect how an individual allocates attention to the stimulus. Threat-related responses result from the interaction between internal states and external cues, in that individual-level factors influence attendance towards threats and vice versa. External cues include the specific image features that denote threat, while internal states refer to the individual differences that moderate motivational relevance. As mentioned in Chapter 1, the interaction between external cues and internal states in attention allocation towards threat will be defined as threat value in the present research concept. Unpleasant images are typically categorised as such based on the affective dimensions of valence and arousal; however, the specific content of the negative scene is not always considered during image selection. Given the range of EEG evidence that indicates the motivational relevance of unpleasant images differs between men and women (see Chapter 2), characterising sex-specific variation in ERP activity evoked specifically by highly aversive images is prudent.

The depiction of threat in aversive images has typically been studied in one of two ways; either in terms of evolutionary significance for non-clinical populations (LoBue & Rakison, 2013; Öhman, 2009; Quinlan, 2013), or as a foil for disgusteliciting stimuli (Carretié, Ruiz-Padial, López-Martín, & Albert, 2011; Lu et al., 2015; Schienle et al., 2006; Wheaton et al., 2013). In research such as this images of threat have been selected on the basis of potential danger (e.g., snakes, spiders, artificial weapons) or the display of aggression by humans or animals. Several types of anxious psychopathology and related personality traits have also been shown to moderate attention allocation when aversive images are employed as threat cues (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Cisler & Koster, 2010; MacNamara, Kappenman, Black, Bress, & Hajcak, 2013). The types of aversive images employed as threat stimuli for anxious and non-anxious populations often feature humans, the most common examples being scenes showing angry faces or injured people. There is overall a lack of consistency in the types of specific image content selected to denote threat in picture processing.

In the present research, this limitation will be addressed by testing the contribution of stimulus-level and individual-level factors to sex differences in ERP modulation. Prior EEG investigations of sex-specific variation indicate the semantic category of unpleasant images moderate ERP activity differently for male and female individuals (see Chapter 2). However other sources of individual variation that impact the threat value of negative stimuli were not considered in many of these studies. One instance is the greater prevalence of anxiety and mood disorders in women compared to men worldwide (Baxter, Scott, Vos, & Whiteford, 2013; Ferrari et al., 2013; Steel et al., 2014). To date, sex differences in ERP activity evoked by the threat-related qualities of highly aversive images have rarely been examined. The intermixing of these stress-eliciting stimuli with other unpleasant images in several EEG studies has contributed to this lack of characterisation (see Chapter 2). The aim of the present research is to investigate the external cues and internal states that influence the motivational relevance of highly aversive images for men and for women.

The individual-level factors that moderate sex differences in stress reactivity will

be addressed in two ways. First, women currently prescribed hormonal contraceptives will be recruited for each EEG study². Hormone fluctuation during the menstrual and ovarian cycle is shown to moderate picture processing in women (Andreano & Cahill, 2009; Goldstein et al., 2010; Lischke et al., 2012; Lusk et al., 2015; Ossewaarde et al., 2010, 2013; Wu et al., 2014). Yet the effect of hormonal contraceptives on picture processing has rarely been investigated, excluding a few key exceptions (Becker, Creutzfeldt, Schwibbe, & Wuttke, 1982; Petersen & Cahill, 2015; Wuttke et al., 1975). Second, personality traits linked to sex differences in negative emotionality and individual variation in picture processing were measured in male and female individuals. These four personality traits were trait anxiety (Spielberger, 2010); worry (Newman, Llera, Erickson, Przeworski, & Castonguay, 2013; Startup & Erickson, 2006); neuroticism (Ormel, Jeronimus, et al., 2013); and alexithymia (Sifneos, 1973; G. J. Taylor & Bagby, 2012). The relationship between ERP modulation and these four personality traits will be modelled via linear mixed effects analysis³.

Sex differences in the threat value of unpleasant images will be examined in Experiment 1. High threat, moderate threat, and neutral images will be shown to men and women during a passive viewing task as EEG is recorded. Scenes of severely injured humans are considered highly motivationally-relevant and are widely employed as negative stimuli in picture processing research (e.g., Bublatzky & Schupp, 2012; Leite et al., 2012; Weinberg & Hajcak, 2010). The danger represented by these stimuli constitutes a more passive hazard compared to other types of highly aversive images, as the scene represents the aftermath of an attack or dangerous situation. Images of human injury will be contrasted with snake and handgun images; these latter two stimuli are

² An additional sample of women not prescribed hormonal contraceptives were recruited in Experiment 1.

³ For examples of the use of this analysis method in psychological research see Baayen, Davidson, & Bates (2008), Judd, Westfall, & Kenny (2012), Kahn (2011) and Tremblay & Newman (2015).

readily associated with attack intent, or the willingness to inflict harm. Reptiles and firearms are hypothesised to be inversely related in terms of evolutionary significance (Blanchette, 2006; Brosch & Sharma, 2005; C. Brown, El-Deredy, & Blanchette, 2010; Carlson, Fee, & Reinke, 2009; Faucher & Blanchette, 2011; Fox, Griggs, & Mouchlianitis, 2007). The question remains whether the threat value of handguns and snakes is influenced by the biological relevance of these stimuli. An encounter with an aimed handgun is also more socially-relevant than a reptile stimulus as these scenes imply that the weapon is held by a human assailant, whereas the display of aggression by a snake is not dependent on the presence of another person.

In Experiments 2 and 3 sex differences in response selection towards the threat value of aversive images will be examined. Sex-specific variation in ERP activity is often reported in EEG studies that employ the oddball task, a paradigm that requires direct responses to a deviant stimulus (see Chapter 2). This evidence indicates the performance of men and women on the oddball task is influenced by the unpleasant images selected as deviant stimuli and the frequent stimuli employed as distractors in the paradigm. The context in which a highly aversive image is viewed may contribute to sex differences in the threat value of the stimulus. The congruency of highly aversive and neutral images will be systematically varied using a modified Flanker paradigm to characterise this sex-specific variation. In Experiment 2 the biological relevance of attack intent will be examined with reptile and firearm images. The effect of action disposition on the threat value of socially-relevant images will be investigated in Experiment 3 using scenes featuring humans who are severely injured or explicitly armed with aimed handguns.

Chapter 4 - EXPERIMENT 1

Sex differences in ERP activity are moderated by the threat value of reptile, firearm and human images

The threat value of highly aversive images may contribute to sex differences in the motivational relevance of these stimuli. In the previous chapter, the focus on the threat value in the present thesis was justified. Biological relevance is implicated in the emotional salience of many unpleasant images, especially those that show prototypical threats. It is presently unclear, however, how the action disposition of a stimulus interacts with biological relevance in the processing of these unpleasant images, particularly in relation to individual-level factors. The current chapter will describe an EEG investigation of sex differences in ERP activity elicited by images of three prototypical stimuli: reptiles, firearms and humans. The influence of biological relevance on the emotional salience of unpleasant images will be discussed first. Discrepancies in the association of action disposition with prototypical stimuli will also be highlighted. Next, the approach taken in the investigation of sex-specific variation in Experiment 1 by way of stimulus-locked ERP activity will be detailed.

Stimuli with high levels of biological relevance are purportedly prioritised over other stimuli (LoBue & Rakison, 2013; Öhman, Soares, Juth, Lindström, & Esteves, 2012). This would suggest that prototypical stimuli found in natural environments, such as snakes, spiders, and animals prone to aggression, are more likely to capture attention than other prototypical stimuli that are artificial (e.g., handguns, knives, syringes). To date, the distinction between high and low biological relevance in threat-related attention has not been supported by behavioural and ERP evidence (Blanchette, 2006; Brosch & Sharma, 2005; C. Brown et al., 2010; Carlson et al., 2009; Fox et al., 2007). Moreover, the high/low distinction of biological relevance is also moderated by the social relevance of an unpleasant image. Scenes of human injury are high in social and biological relevance due to the presence of a human in the image and the contaminative threat represented by the stimulus. Injured humans are also shown to differ in motivational relevance compared to other types of unpleasant images, including other types of prototypical threats (Sarlo et al., 2005; Schäfer, Scharmüller, Leutgeb, Köchel, & Schienle, 2010; Schienle et al., 2006; Wright et al., 2004).

The effect of evolutionary significance on sex differences in picture processing was investigated in a two-part study by Bradley and colleagues (Bradley, Codispoti, Cuthbert, et al., 2001; Bradley, Codispoti, Sabatinelli, et al., 2001). Men and women were shown unpleasant, pleasant, and neutral IAPS images as heart-rate, skin conductance, and startle blink modulation indices were recorded. Unpleasant images led to higher ratings of arousal and a trend of greater cardiac deceleration for women compared to men. Sex differences were also observed in startle blink modulation towards specific image content. For women scenes of contamination, human injury, dangerous animals, and attacking humans led to larger startle-blink responses than more neutral stimuli. The opposite pattern of startle blink modulation was reported for men in relation to images featuring pollution and disease. These findings support sex-specific variation in the threat value of unpleasant images, as cardiac deceleration and potentiation of the startle blink reflex both correspond to the post-encounter stage of the defence cascade (Lang et al., 1997).

By separating out specific types of content in unpleasant images, Bradley, Codispoti, Sabatinelli et al. (2001) showed that sex differences in response to unpleasant images are influenced by stimulus-level factors other than valence. These results have not been consistently mirrored in EEG measures, despite the wide use of ERP modulation as an index of picture processing. Bradley, Codispoti, Sabatinelli et al. concede that defensive motivation could be largely consistent across men and women; instead, sex-specific variation reflects the influence of social relevance and biological relevance on picture processing. The findings of several EEG studies have confirmed men and women vary in ERP activity elicited by unpleasant images at the stage of the N2, the LPP and related late positivity (Gardener et al., 2013; Gasbarri et al., 2007; Gonzalez-Liencres et al., 2016; Groen et al., 2013; Li et al., 2008; Luo et al., 2014; Proverbio et al., 2009; Yuan et al., 2009). Evidence for sex-specific variation in the motivational relevance of highly aversive images specifically, however, is lacking.

The current EEG study was expected to show whether ERP modulation in male and female individuals is influenced by the biological relevance of stimuli featured in highly aversive images. This was accomplished by selecting stimuli with distinct evolutionary significance and the types of action dispositions most commonly observed in highly aversive examples of these stimuli. Men and women were shown images of snakes, handguns, and human injury as EEG was recorded. These three stimuli were selected due to the association of these negative scenes with threat-related attention. High and moderate threat versions of snakes, handguns, and human injury were matched by low-arousing, neutral images of turtles, water pistols or non-injured humans. As reviewed in Chapter 2, sex differences for unpleasant images have been reported for early ERP, N2, and LPP activity. It was hypothesised that ERP modulation corresponding to the same latencies would index the influence of stimulus-level and individual-level factors on picture processing for male and female individuals.

Threat is typically linked to the depiction of attack intent in picture processing. This assumption is subverted by scenes showing human injury, particularly in studies examining the link between anxious traits and threat-related attention (e.g., Koster, Verschuere, Crombez, & Van Damme, 2005; Mocaiber et al., 2009; Mogg, Bradley,

Miles, & Dixon, 2004; Yiend & Mathews, 2001). For this reason, ERP activity evoked by attacking snakes and aimed handguns were compared to that elicited by severely injured humans who were dead or unconscious. It was predicted that ERP modulation due to highly aversive stimuli would be influenced by known sources of individual variation in men and women. Individual variation in stress reactivity was indexed by measuring the trait anxiety, worry, alexithymia, and neuroticism levels of male and female individuals before data collection. Two groups of women were recruited; those currently prescribed some form of hormonal contraceptive and those with a normallyfluctuating ovarian cycle. Sex hormone levels are closely linked to stress reactivity in men and women (Goel et al., 2011; Ordaz & Luna, 2012), as well as picture processing in women (Andreano & Cahill, 2009; Goldstein et al., 2010; Lischke et al., 2012; Lusk et al., 2015; Ossewaarde et al., 2010, 2013; Wu et al., 2014). In contrast, the influence of hormonal contraceptives on ERP measures is largely unknown in picture processing.

Method

Participants

EEG data were collected from 76 individuals (21 male) who were either undergraduate students from the University of Newcastle, Australia, or volunteers who responded to word-of-mouth, social media, or online advertising. Students received course credit for research participation, while other individuals were reimbursed with a \$25 Coles-Myer gift card. All volunteers completed a questionnaire requesting information on their medical history, any phobias related to negative stimuli, prior drug use, and vision issues before EEG testing (Appendix A). Women provided details about their menstrual cycle and use of hormonal contraceptives. Individuals were excluded from EEG testing based on a history of psychiatric or neurological disorders, epilepsy, severe head trauma, concussions, giddiness or loss of consciousness (Keil et al., 2014; Picton, Lins, & Scherg, 1995). Other exclusion criteria included recent or chronic usage of alcohol, cigarettes, illicit drugs and psychoactive medication. Participants were also excluded if a history of phobia was reported in the general medical history questionnaire. Due to poor quality EEG recordings two females were omitted from behavioural and EEG datasets. The age of participants ranged from 17 to 33 years old $(M = 23.16 \pm 0.54)$. All participants reported normal or corrected-to-normal vision and most were right-handed (seven left-handed). Informed consent was obtained from all participants before EEG testing. Ethics approval was granted by the Human Research Ethics Committee at the University of Newcastle, Australia (see Digital Appendix A).

Female participants. Twenty-two women were currently prescribed some form of hormone-based contraceptive. Oral contraceptives, the most common form, prevent pregnancy by interfering with normal sex hormone fluctuation during the female ovarian cycle by way of synthetic oestrogen and/or progesterone (Warren, Gurvich, Worsley, & Kulkarni, 2014). Nineteen women recruited for Experiment 1 were prescribed combined oral contraceptives (Table 4.1). Two women were implanted with a progestogen-only rod (Implanon, 68mg etonogestrel) and another received regular Depo-Provera injections. The remaining 31 women reported signs of a normal menstrual cycle (i.e., 25-31 days). These women were split into one of two groupings based on the estimated stage of their ovarian cycle. The early stage was defined as one to ten days after onset of menses, during which progesterone levels are relatively low compared to the luteal phase (Farage et al., 2009). This grouping, here-on referred to as the follicular phase grouping, consisted of 15 women who were currently menstruating or in the mid-follicular phase of their cycle. The remaining 16 women were one week or less from the onset of their next menses, during which progesterone levels peak and slowly start to decline. These women comprised the luteal phase grouping.

Table 4.1. Combined oral contraceptives prescribed to 19 women recruited for Experiment 1. Information is categorised by the brand name most often provided by participants. Alternative brand names, the number of females and the active hormone-based ingredients are also provided.

Pill brand	Alternative names	No. of females	Active ingredients
Levlen ED	Micronelle-20ED, Trifeme	7	Levonorgestrel (synthetic progesterone) and ethinyloestradiol (synthetic oestrogen)
Diane-35ED	Brenda-35ED, Laila-35ED	6	Cyproterone acetate (synthetic progesterone) and ethinyloestradiol
Yasmin	Yaz	6	Drospirenone (synthetic progesterone) and ethinyloestradiol
Zoely	N/A	1	Nomegestrol acetate (synthetic progesterone) and oestradiol (natural oestrogen)

Questionnaires

Prior to EEG recording participants completed the PSWQ, the TAS-20, a questionnaire indexing the five Goldberg markers of the Big-Five Factor model (hereon referred to as IPIP5F-100; Goldberg, 1992), and the STAI. Questionnaire scores were expected to overlap as trait anxiety, worry, neuroticism, and alexithymia are each indicative of behaviours related to negative emotionality (Eysenck & Eysenck, 1985; Watson & Clark, 1984). Although not optimal, the order of questionnaires was used for each participant to ensure consistency in patterns of responses to each personality measure.

The PSWQ. An overt tendency to worry is a defining trait of generalised anxiety disorder and a common feature of anxious psychopathology. The PSWQ was designed to "...capture the generality, excessiveness, and uncontrollability of [this] pathological worry" (Fresco, Mennin, Heimberg, & Turk, 2003, p. 284). Worry is also associated with anxious apprehension, or the cognition-based aspects of anxious
pathology (Nitschke, Heller, Palmieri, & Miller, 1999). The 16-item PSWQ is shown to be a valid and reliable measure of pathological worry in normal and clinical populations (Meyer, Miller, Metzger, & Borkovec, 1990; Startup & Erickson, 2006). Items consist of 16 statements that respondents rate from 1 ("not at all typical of me") to 5 ("very typical of me") including five reverse-scored items. PSWQ scores range from 16 to 80, with a higher score denoting a greater tendency towards pathological worry. Cronbach alpha coefficients for the PSWQ range from .88 to .95 in normal and clinical populations (Davey, 1993; Startup & Erickson, 2006; Stöber, 1998). On average women tend to score more highly on the PSWQ than men (Meyer et al., 1990; Robichaud, Dugas, & Conway, 2003; Stöber, 1998).

The TAS-20. Alexithymia indicates an individual's vulnerability to psychopathology, particularly psychosomatic symptoms (De Gucht & Heiser, 2003; G. J. Taylor & Bagby, 2004). The TAS-20 is a valid and reliable index of alexithymic traits (Bagby, Parker, & Taylor, 1994; Bagby, Taylor, & Parker, 1994; Parker, Taylor, & Bagby, 2003; G. J. Taylor, Bagby, & Parker, 2003). The questionnaire consists of 20 statements which respondents rate from 1 ("strongly disagree") to 5 ("strongly agree"). Each TAS-20 subscale indexes a core feature of alexithymia: difficulty identifying feelings; difficulty describing feelings; or externally-oriented thinking (Bagby, Parker, et al., 1994; Loas et al., 2001). Scores on the TAS-20 range between 20 and 100, with a higher score indicating greater levels of alexithymic traits. Internal reliability for the English version of the TAS-20 ranges between .8 and .85 in clinical and non-clinical samples (Bagby, Parker, et al., 1994; Leising, Grande, & Faber, 2009; Parker et al., 2003). Only scores for the full TAS-20 were utilised in the present research.

The IPIP5F-100. The five Goldberg markers were developed to index the dimensions of the Five-Factor Model of Personality (Goldberg, 1992; McCrae & John,

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1992). These markers are extraversion, agreeableness, conscientiousness, emotional stability and imagination. Scores from the Emotional stability marker represented neuroticism in the present research. Neuroticism is defined as an individual's tendency towards emotional reactivity and negative thinking styles (Canli, 2008; Matthews, 2004; Ormel, Bastiaansen, et al., 2013). Emotional stability scores were reverse-scored and relabelled neuroticism, such that higher scores on this questionnaire denoted lower levels of emotional stability.

The International Personality Item Pool (IPIP). The IPIP is a public-domain repository of items used to develop questionnaires that parallel the results of copyright restricted measures (Goldberg, 1992; Goldberg et al., 2006). The IPIP5F-100 contained the same items in the same order as those provided in the sample 100-item questionnaire (IPIP, 2015b). Twenty items are included for each Goldberg marker in the IPIP5F-100. Items consist of statements the respondent rates from 1 ("very inaccurate") to 5 ("very accurate"). Scores range from 20 to 100 for each Goldberg marker, with higher scores denoting the more positive extreme of each dimension. No norms are provided for IPIP items to encourage researchers to develop local norms specific to their own sample (Goldberg et al., 2006). Cronbach alpha coefficients for the five Goldberg markers range from .88 to .91 for the IPIP5F-100, with an average value of .9 (IPIP, 2015a). Descriptive statistics and analysis of the five IPIP5F-100 dimensions are reported in Appendix B.

The STAI. The STAI is a reliable, valid, and well-known questionnaire that measures state and trait anxiety as separate constructs (Spielberger, 2010; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). Respondents rate a series of statements for each 20-item subscale. On state anxiety items respondents indicate their current feelings by rating each item from 1 ("not at all") to 4 ("very much so"). Respondents then rate

items for trait anxiety from 1 ("almost never") to 4 ("almost always") in relation to the relevance of the statements to themselves. Scores for the state anxiety (STAI-S) or trait anxiety (STAI-T) subscale range from 20 to 80, with total STAI scores varying between 40 and 160. In a sample of approximately 10,000 participants, the most recent version of the STAI received internal reliability scores between .86 and .95 (Julian, 2011; Spielberger et al., 1983).

Stimuli and materials

Rating scales. Four visual six-point scales were created to collect valence, arousal, threat, and disgust ratings (Appendix C). Common words associated with each extreme of the affective dimension were included to aid participant interpretation. Pictures from the original Self-Assessment Manikin were included in the scales for valence and arousal (Lang et al., 2008). Valence and arousal ratings were collected during the first block of Experiment 1. Ratings of threat and disgust were recorded for each image in the second and third blocks. All ratings were made with a Presentation Cedrus RB-830 response pad.

Images. Ninety stimuli were chosen from a larger pool of 260 full-colour images sourced from the IAPS (Lang et al., 2008) or downloaded from the Internet (Australian Copyright Council, 2014). All images were resized to 800x600 pixels and converted to .jpeg format. All 260 stimuli were validated for an Australian sample by collecting valence, arousal and threat ratings from seven male ($M_{Age} = 26$, SD = 0.60) and seven female ($M_{Age} = 30$, SD = 3) consenting volunteers. Ratings were made using a seven-point scale similar to those created for Experiment 1 (Appendix C). Volunteers were seated in a quiet room with a computer screen positioned at eye level. Images were shown for 1500ms each and ratings were made using a computer keyboard. Ratings were collected in the order of valence, arousal, and then threat, for each image. Thirty

reptile, 30 firearm and 30 human images were selected for Experiment 1⁴ (Appendix D). Ten images from each stimulus category were classified as either high threat, moderate threat, or neutral (Figure 4.1). Full non-parametric analysis of initial valence, arousal and threat ratings are reported in Appendix E.

Firearm and reptile images. High threat firearms consisted of handguns aimed towards the observer of the scene. The presence of the human holding the handgun was minimised, such that only the hand aiming the weapon was visible in each image. Moderate threat images of firearms depicted unarmed handguns laid side-on on a flat surface. Five of the unarmed handgun images were pointed left and five towards the right. Water pistols were aimed away from the observer on a white or light grey background. High threat images of reptiles featured attacking snakes with bared fangs and an open mouth. Moderate threat and neutral images of reptiles showed placid



Figure 4.1. Examples of firearm, reptile and human images presented during the passive viewing task. Shown images are sourced from the Internet.

⁴Snakes: 1040, 1101, 1050, 1051, 1052, 1070, 1114, 1120; Non-injured humans:2026, 2036, 2102, 2359, 2381, 2382, 2383, 2390, 2593, 2594; Human injury: 3017, 3102, 3120, 3130, 3140, 3181, 3400; Handguns: 6230, 6260, 6263

snakes or turtles with closed mouths. Aimed handguns were rated as the most unpleasant, arousing, and threatening firearm, followed by unarmed handguns, and then water pistols (Bonferroni-corrected, all ps < .002; Appendix E). Attacking snakes were also judged as the most unpleasant, arousing and threatening reptile, followed by non-attacking snakes, and then turtles (Bonferroni-corrected, all ps < .002).

Human stimuli. Scenes of severe injury featured a range of disfigured, maimed or mutilated humans who were deceased or unconscious (Figure 4.1). Moderate threat images included scenes of injured humans who were visibly alive or conscious (e.g., a boxing match, a severely burned foot, and a dazed person with a head wound). Neutral images showed normal, non-injured humans in everyday situations (e.g., grocery shopping, walking). Both types of injury stimuli were rated as significantly more unpleasant, arousing and threatening than scenes of non-injured humans (Bonferronicorrected, both ps < .002; Appendix E).

Human injury. Four types of human injury were shown to volunteers during the initial rating task; sports injuries, conscious people with obvious injuries, injury to specific body parts, and severely injured people who were dead or unconscious (see Appendix E for full analyses of initial affective ratings). Dead or unconscious humans with severe injuries were rated as significantly more unpleasant and arousing than the other three injury categories (all ps < .001). Given that the threat value of human injury may not be reflected by conventional ratings of threat, the images of severe injury were selected as the high threat stimulus. The attribute that distinguished these scenes from the other injury scenes was the presence of a human who was clearly not conscious. The affective ratings of moderate threat injury were matched as closely as possible to those for severe injury to ensure the arousal, valence, and threat level of injury stimuli was consistent. Disgust ratings were also collected during Experiment 1 to determine

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whether this affective dimension would distinguish severe injury from other types of human injury.

EEG recording and processing

Data collection. EEG was recorded with impedances of $10 \text{ k}\Omega$ or less, using a 64-channel Quik-cap featuring sintered Ag/Ag Cl passive electrodes. All data were continuously sampled at 1000Hz with Neuroscan SynAmps2/RT amplifiers using Curry 7 software. EEG data were collected from 64 channels per the international 10-20 system of electrode placement (Jasper, 1958; Tavakoli & Campbell, 2015a). The active reference electrode was positioned halfway between Cz and CPz, and the ground electrode was immediately posterior to FPz. To assess horizontal (HEOG) and vertical electro-oculographic (VEOG) movement, VEOG and HEOG electrodes were placed at outer canthi sites and above and below the left eye.

Data reduction and scoring. EEG data were saved as continuous files and exported from Curry 7 to BESA 6 to derive ERP activity. The original average reference and a pre-stimulus baseline of 200ms were applied during off-line processing. Eye blinks (-100 to 400μ V) were removed, and data were filtered with a high pass of 0.16Hz and a low pass of 30Hz. Epochs were time-locked to stimulus onset for 1200ms from -200ms pre-stimulus to 1000ms post-stimulus. For each participant, no less than 80% of trials ($n \ge 40$) were accepted for each image condition.

Procedure

Participants were seated in a sound-proofed room with dimmed lighting. Images were presented centrally on a dark grey background at eye-level on a 28 inch BenQ monitor positioned 70cm away from the participant. Instructions for the task were explained by the supervising researcher and shown on-screen. Participants were reminded to remain still and relaxed during EEG recording. Across three blocks, 90 images were shown five times each, producing a total of 450 trials. For each trial a white fixation cross was shown first for 1000ms, followed by an image presented for 1000ms (Figure 4.2). Then a rating scale appeared and remained onscreen until the participant responded. The next trial began after an inter-stimulus interval of 500ms. Ninety images appeared in a random order in the first block of the passive viewing task. Following the presentation of each image, participants rated valence, and then arousal, with the appropriate rating remaining on-screen until the participant responded. During the second and third blocks, the 90 images were randomly presented four times each. Participants rated either how threatening or how disgusting they found the image shown on each trial. The order of threat and disgust ratings was randomised and shown an equal number of times across the second and third blocks. The task took approximately 40 minutes to complete.

Design and data analysis

A 4[Participant sex: male, birth control female, follicular phase female, luteal phase female] x 3(Stimulus type: firearm, reptile, human) x 3(Threat level: high, moderate, neutral) mixed design was followed for statistical analysis. Behavioural and





Figure 4.2. The trial procedures for block one, two and three showing the timings of each stage of the passive viewing task.

ERP data were prepared with Microsoft Excel and Statistica 13. The same software was used to analyse behavioural data, while ERP data were analysed with R 3.2.2 (R Core Team, 2016) through the RStudio (2016) interface using the linear mixed-effects model regression (lmer) function (lme4; Bates, Maechler, Bolker, & Walker, 2014). All data were checked for equal variance and normal distribution. Graphs of behavioural and ERP data were plotted with Graphpad Prism 7. Descriptive statistics and Spearman rank correlation coefficients were calculated with Statistica 13. The level of significance was set at $\alpha = .05$, and all values were rounded to two decimal places.

Behavioural data. Questionnaire data were manually entered and scored with Microsoft Excel. Cronbach alpha coefficients were also calculated to confirm internal reliability. The arousal, threat, and disgust dimensions were reverse-scored such that higher ratings indicated more extreme ratings of these three affective ratings. Valence ratings were not modified as higher levels of this rating indicated greater unpleasantness. Questionnaire and affective rating datasets were analysed with separate parametric ANOVAs. Geisser-Greenhouse or Huynh-Feldt corrections were employed as necessary. Post hoc comparisons were conducted using Tukey's HSD with Bonferroni corrections applied as needed. Non-parametric analyses were utilised in cases where assumptions of normality or equal variance were not met.

ERP data. Average waveforms for overall, male and female groupings were computed from 64 channels (Appendix F). Scoring of ERP activity was based on visual inspection of average waveforms. Average waveforms were down-sampled from 1000Hz to 500Hz and exported from BESA 6 to Graphpad Prism 7. Mean amplitudes were derived from individual ERP waveforms (Luck, 2005; Tavakoli & Campbell, 2015b). Timeframes were determined based on visual inspection of overall, grouped and individual waveforms, as well as reports from previous EEG studies and review

articles (e.g., Hajcak et al., 2012; Olofsson et al., 2008). Electrode sites from which mean amplitudes were derived are detailed in the description of average waveforms for each ERP component. The 30Hz low-pass filter was switched off before mean amplitudes were computed to minimise inclusion of voltage from outside the selected time frame (Luck, 2005).

Linear mixed effects analysis. Each ERP dataset was exported as a .csv file from Microsoft Excel and imported into RStudio (2016). For more details on the application of linear mixed effects analysis in the present research see Appendix G. PSWQ, TAS-20, Neuroticism, STAI-S and STAI-T scores were grand-mean centred before inclusion in ERP datasets (Peugh, 2010). A combination of Satterthwaite and Kenward-Roger approximations were utilised during model estimation. A base model with a random Participant intercept and a fixed intercept of one was generated first. Residuals from the base model were checked for normality and equal variance with basic R functions and the sip.lmer function (siPlot; Lüdecke, 2016). These assumption checks were also used to identify outliers in each ERP data set. Participants were excluded in cases where an individual's data led to skewing of random effects. The base model, the null model and assumption checks were then recomputed to confirm normality and equal variance without the excluded participant. The necessity of the random Participant intercept in the base model was then tested with the rand function (ImerTest; Kuznetsova, Brockhoff, & Christensen, 2016). The fit of the base and final models were significantly better than the null for each ERP dataset, supporting the inclusion of the random Participant intercept (Appendix I, also see Digital Appendix B).

Model estimation. During model estimation, maximum likelihood was employed to calculate loglikelihood ratios between models. The Akaike information criterion (AIC) and the Bayesian information criterion (BIC) were also employed for model

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comparison (Appendix I). Loglikelihood ratios were tested using a chi-square statistic calculated with the anova function (R Core Team, 2016). The KRmodcomp function (pbkrtest; Halekoh & Højsgaard, 2014), which provides an *F*-statistic for the difference between model variations using the Kenward-Roger approximation, was also employed during model estimation. Fixed factors for Participant sex, Stimulus type, Threat level, Coronal site and Sagittal location were added to the base model first. Backwards elimination was then applied to the full model to identify non-significant effects and reduce model complexity using the step function (ImerTest; Kuznetsova et al., 2016). Separate versions of full and reduced models with each questionnaire score as a fixed predictor were then tested. Questionnaire scores with no meaningful correlation with ERP mean amplitudes were not analysed further. No more than two trait score predictors were included in any one final model.

Final model. The final model for each dataset was re-estimated with restricted maximum likelihood (REML). A description of average waveforms grouped by participant sex will be provided for each ERP dataset. Following this, a short overview of model estimation for the ERP dataset will then be detailed. Fit statistics for each final model were computed with the sjt.lmer function (sjPlot; Lüdecke, 2016). Omega-squared (Ω^2) provided an estimate of variance explained by the final model for each dataset, similar to the R² value in regression analysis (Xu, 2003). The intraclass correlation coefficient (ICC) indicated the amount of variance due to the random Participant intercept (Hox, Moerbeek, & van de Schoot, 2010). Methods for presenting the results of linear mixed effects models are an ongoing subject of debate in the relevant literature. For this reason, results for each final model will be reported in a similar manner to mixed design ANOVAs using a combination of parameter information and inferential statistics calculated with Kenward-Roger approximations.

For brevity, parameter information for significant main effects and interactions will be restricted to those generated by lmer output. Main effects and interactions involving the Coronal site or Sagittal location factors will not be described either unless these interact with image-related factors. Breakdown analyses were performed on datasets separated by the three levels of stimulus type for four ERP datasets due to the complexity of the four final models. Least-square means and pair-wise comparisons were calculated with Satterthwaite approximations to report significant main effects and interactions (Ismeans; Lenth, 2016). Pearson correlations with Bonferroni corrections applied were computed to characterise the influence of PSWQ, TAS-20, Neuroticism or STAI-T scores on ERP modulation. For ease of interpretation, the polarity of correlations between traits scores and ERP mean amplitudes with a negative maximum was reversed.

Results

Behavioural data

Questionnaire scores. PSWQ, TAS-20 and neuroticism scores were normally distributed with equal variance (Digital Appendix B). STAI-S and STAI-T scores were analysed with non-parametric methods due to unequal variance and non-normal distribution. PSWQ, TAS-20 and neuroticism scores were analysed with three separate 4[Participant sex: male, birth control female, follicular phase female, luteal phase female] one-way ANOVAs. STAI-S and STAI-T scores were analysed with separate 4[Participant sex: male, birth control female, follicular phase female, luteal phase female] one-way ANOVAs. STAI-S and STAI-T scores were analysed with separate 4[Participant sex: male, birth control female, follicular phase female, luteal phase female] Kruskal-Wallis one-way ANOVAs. The effect size for the Kruskal-Wallis ANOVA was indexed by the epsilon-squared estimate (Tomczak & Tomczak, 2014). Post hoc comparisons were performed using Mann-Whitney U tests with continuity and Bonferroni corrections applied ($\alpha = .008$).

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The PSWQ. The mean PSWQ score was 46.3 (*SE* = 1.38), and internal reliability was strong for this questionnaire (α = .92). Positive and significant correlations occurred between the PSWQ and scores for neuroticism and the STAI-T (Table 4.2). Women (*M* = 49.38±1.42) scored more highly on the PSWQ than male participants. This difference was driven by the scores of follicular phase women and women taking birth control medication (Table 4.3). Statistical testing confirmed the Sex main effect was significant, *F*(3, 70) = 8.85, *p* < .001, $\eta\rho^2$ = .28. The PSWQ scores of follicular phase females were significantly higher than that for males (Tukey's HSD, *p* < .001) and luteal phase females (*p* = .02). This difference occurred for birth control females compared to the other groupings as well, but only reached significance for male participants (*p* = .001).

The TAS-20. The TAS-20 possessed very good internal reliability ($\alpha = .86$) and the average TAS-20 score was 44.33 (*SE* = 1.27). TAS-20 scores were positively associated with those for neuroticism, the STAI-S and the STAI-T (Table 4.2). The correlations involving the two STAI subscales were very strong, but the relationship between TAS-20 and neuroticism scores was weak. TAS-20 scores for men and women were comparable, and this similarity was confirmed by statistical analysis, *F*(3, 70) = 0.52, *p* = .67, $\eta \rho^2 = .02$ (Table 4.3).

Neuroticism. Internal reliability was very strong for scores from the IPIP5F-100 dimension of Emotional stability ($\alpha = .92$). The average score for neuroticism was 33.31 (*SE* = 1.61). Neuroticism scores were positively related to those from the two STAI subscales (Table 4.2). This relationship was moderate for the STAI-S and strong for the STAI-T. Women ($M = 36.04 \pm 1.88$) tended to report higher levels of neuroticism than men (Table 4.3). This difference was supported by the main effect of Participant sex reaching significance, F(3, 70) = 2.93, p = .04, $\eta \rho^2 = .11$.

Table 4.2. Spearman rank correlation coefficients between scores from the PSWQ, the TAS-20, neuroticism and the two subscales of the STAI. P-value significance is located at the bottom left of the table.

	DSWO	TAS 20	Neuroticism	STAI	
	PSWQ	TAS-20		STAI-S	STAI-T
PSWQ	1				
TAS-20	.16	1			
Neuroticism	.64***	.29*	1		
STAI					
STAI-S	.22	.5***	.4***	1	
STAI-T	.45***	.53***	.61***	.7***	1

p < .05*, p < .01 **, p < .001***

Table 4.3. Mean scores (\pm standard error) for PSWQ, TAS-20, neuroticism and the two STAI subscales, grouped by male and female groupings. Median values for state and trait anxiety scores are also shown with their relevant interquartile range.

			Females	
	Males	Birth control	Follicular phase	Luteal phase
PSWQ	38.52 (±2.37)	50.73 (±2.03)	54.2 (±2.63)	43 (±2.18)
TAS-20	44.71 (±2.28)	42.18 (±2.08)	46.67 (±2.55)	44.63 (±3.31)
Neuroticism	26.43 (±2.6)	38.18 (± 2.87)	34.6 (±4.15)	34.44 (±3)
$STAI - M (\pm SE)$				
STAI-S	31.86 (±1.67)	32.46 (±1.67)	35.93 (±2.75)	33.06 (±2.09)
STAI-T	38 (±1.84)	38.68 (±1.71)	41.53 (±2.63)	37.38 (±2.16)
STAI – Mdn (IQR)				
STAI-S	33 (25-37)	31.5 (27-39)	36 (26.5-39)	32.5 (26-44)
STAI-T	37 (30-44)	40.5 (32-45)	38 (33-44)	38 (34-51)

The STAI. The mean score for the STAI-S was 33.12 (*SE* = 0.99; *Mdn* = 32,*IQR* = 26-39), and the average STAI-T score was 38.78 (*SE* =1.01; *Mdn* = 37, *IQR* = 33-45). The internal reliability of the overall STAI (α = .94), the STAI-S (α = .9), and the STAI-T (α = .9) was very strong. A strong, positive and significant association was also found between STAI-S and STAI-T scores (Table 4.2). The scores of males and females for the STAI-S (*H*(3, *N* = 74) = 1.36, *p* = .71, *E*_R² = .02) and the STAI-T (*H* (3, *N* = 74) = 1.04, *p* = .79, *E*_R² = .01) were of similar magnitude (Table 4.3).

Affective ratings. Strong, positive and significant relationships were found between valence, arousal, threat, and disgust ratings (Table 4.4). Correlations between threat and disgust ratings, as well as correlations between valence and these two affective ratings, were particularly strong. Assumption checks indicated the four types of affective ratings were not normally distributed and possessed unequal variance (Digital Appendix B). Four separate 3(Stimulus type: firearm, reptile, human) x 3(Threat level: high threat, moderate threat, neutral] Friedman one-way ANOVAs were performed on ratings of valence, arousal, threat, and disgust. Kendall's Coefficient of Concordance (*W*) indexed the effect size of the relevant test, and Bonferroni-corrected Wilcoxon signed-rank tests ($\alpha = .002$) were used for posthoc comparisons. For comparison, average ratings for valence, arousal, threat and disgust were calculated for the male and three female groupings (Appendix J). The Friedman ANOVAs for valence (χ^2 (8, N = 74) = 490.28, p < .001, W = .83), arousal (χ^2 (8, N = 74) = 270.01, p < .001, W = .46), threat (χ^2 (8, N = 74) = 481.57, p < .001, W = .81) and disgust (χ^2 (8, N = 74) = 495.53, p < .001, W = .84) each reached statistical significance.

The highest ratings of unpleasantness, arousal, threat, and disgust were recorded for high threat images, followed by moderate threat images, and then neutral images (Figure 4.3). All differences between the median ratings of neutral, moderate threat and high threat images were significant (all ps < 0.01). Images of human injury were rated with higher levels of unpleasantness, arousal, threat, and disgust than those showing non-injured humans. For reptile and firearm stimuli, the patterns of arousal ratings varied for moderate and high threat stimuli. Aimed handguns were rated with much higher levels of arousal than unarmed handguns and water pistols. This discrepancy was consistent across the male and female groupings (Table 4.5). The magnitude of the difference between images of non-attacking snakes or turtles in arousal ratings was smaller compared to the three other affective ratings. This result was driven by lower ratings of arousal for non-attacking snakes in males compared to females (Table 4.5).

ERP data

Activity for the N1 and the N2 was maximal at anterior and centromedial electrodes close to the midline (Figure 4.4). Timings for these two components were consistent with previous research (Gardener et al., 2013; Lithari et al., 2010; Lusk et al., 2015; Yuan et al., 2009). Mean amplitudes for the N1 were derived from 100 to 150ms post-stimulus, while those for the N2 were computed from 200 to 350ms. Amplitude

Table 4.4. Spearman rank correlation coefficients between ratings of valence, arousal, threat and disgust for Experiment 1. Greater ratings of arousal, threat and disgust indicate higher levels of these affective dimensions (1 = low, 6 = high). For valence higher ratings denote increasing levels of unpleasantness (1 = pleasant, 6 = unpleasant). P-value significance is located at the bottom left of the table.

	Valence	Arousal	Threat	Disgust
Valence	1			
Arousal	.66***	1		
Threat	.86***	.65***	1	
Disgust	.89***	.65***	.95***	1

 $p < .05^*, p < .01^{**}, p < .001^{***}$



Figure 4.3. Average ratings of valence, arousal, threat and disgust for firearm, reptile and human stimuli. Significance values are based on median ratings for each image condition. Colourings for high threat, moderate threat and neutral images are shown to the right. Vertical bars denote 95% confidence intervals.

		Females		
	Males	Birth control	Follicular phase	Luteal phase
Firearms				
Aimed handguns	4.31 (±0.22)	4.35 (±0.18)	4.19 (±0.21)	4.19 (±0.19)
Unarmed handguns	3.08 (±0.17)	3.64 (±0.14)	3.41 (±0.27)	3.35 (±0.22)
Water pistols	2.45 (±0.22)	3.12 (±0.21)	3.06 (±0.26)	3.26 (±0.26)
Reptiles				
Attacking snakes	3.94 (±0.25)	4.25 (±0.17)	4.31 (±0.22)	3.89 (±0.28)
Non-attacking snakes	3.05 (±0.25)	3.7 (±0.13)	3.82 (±0.26)	3.54 (±0.24)
Turtles	2.63 (±0.32)	2.87 (±0.25)	2.88 (±0.26)	2.96 (±0.25)

Table 4.5. Arousal ratings of firearm and reptile images by the male and three female groupings. All descriptive statistics for males and females in ratings of valence, arousal, threat and disgust are provided in Appendix J.



Figure 4.4. Approximate locations of ERP activity elicited by the passive viewing task on a 64-channel Neuroscan Quik-cap. Activity for the P3b (purple area), the N2 (dark grey area) and the EPN (green areas) are shown to the left, while activity for the LPP (yellow area) and the N1 (blue area) are shown to the right.

modulation for a lateralised temporal-occipital EPN was also observed 150 to 300ms following image presentation (Figure 4.4). This ERP modulation occurred primarily in the positive range of average waveforms, an effect that has been noted in previous EEG

studies (Hajcak et al., 2012; Schupp et al., 2006). Mean amplitudes for the EPN were derived from 150-250ms post-stimulus. Two sources of late positivity were identified at posterior electrodes following image onset, both of which were centred on the midline (Figure 4.4). The LPP was most prominent at central-parietal and parietal electrodes between 450 and 700ms. For most participants, a distinct peak was evident between 300-400ms; this ERP activity was labelled the P3b. Mean amplitudes for the LPP were derived from 500 to 650ms post-stimulus, and for the P3b from 300 to 380ms.

The N1 (100-150ms). Mean activity for the N1 was computed from the frontalcentral sites FC1, FCz and FC2, and the central sites C1, Cz and C2. Human stimuli did not modulate N1 activity for males, birth control females or luteal phase females (Figure 4.5, Figure 4.6). Images of non-severe injury led to more negative N1 amplitude than observed for severe injury and non-injured humans for follicular phase females (top, Figure 4.6). N1 modulation by way of firearm stimuli was not evident for luteal phase females. For birth control females, images of unarmed handguns elicited larger amounts of N1 activity than aimed handguns and water pistols (top, Figure 4.5). This same difference occurred for follicular phase females at midline and right hemisphere sites (top, Figure 4.6). Images of unarmed handguns and water pistols led to more negative N1 amplitude than aimed handguns for males at the midline and in the right hemisphere (bottom, Figure 4.5). Non-attacking snakes also evoked larger amounts of N1 activity than images of attacking snakes and turtles for the male grouping.

Linear mixed effects analysis. One luteal phase female was excluded from the analysis of N1 mean amplitudes due to 87% of her data being below the lower 95% confidence interval ($M = -2.75 \mu V$ [1.22, -6.71]). This left 22 birth control females, 21 males, 15 follicular phase females and 15 luteal phase females for estimation of the N1 model. Scores for neuroticism (Kenward-Roger: F(216, 3359) = 1.18, p = .04), the



BIRTH CONTROL FEMALES





Figure 4.5. Grand average N1 waveforms for males (top) and birth control females (bottom), averaged across frontal-central and central electrodes close to the midline. Images of firearms, reptiles and humans are categorised by threat level (i.e., high threat, moderate threat, neutral).



FOLLICULAR PHASE FEMALES



Handguns

Water-pistols

Reptiles

Attacking snakes

Snakes

Turtles

Humans

Severe injury

Non-severe injury

Non-injured humans

LUTEAL PHASE FEMALES



Figure 4.6. Grand average N1 waveforms for follicular phase (top) and luteal phase (bottom) females, averaged across frontal-central and central electrodes close to the midline. Images of firearms, reptiles and humans are categorised by threat level (i.e., high threat, moderate threat, neutral).

TAS-20 (F(216, 3359) = 1.25, p = .009) and the STAI-S (F(216, 3359) = 1.33, p = .001) were significantly related to N1 modulation. Further model variations were tested with TAS-20 or STAI-S scores included, and both trait scores were retained as predictors in the final model (Table 4.6). The clustering of N1 mean amplitudes was very strong between participants (ICC_{Participants} = .8) and 82% of the total variance was explained by the final model ($\sigma^2 = 0.7, \tau_{00}$ for participants = 2.78). All main effects and lower order interactions were qualified by four three-way interactions and one four-way interaction that were significant in the N1 final model (Appendix K). The clustering between participants in the reptile and human models was stronger compared to that for the firearm model (Table 4.7). To characterise N1 modulation related to TAS-20 scores in each breakdown model participants were grouped based on the mean TAS-20 score

 Table 4.6. R notation for the final and breakdown model estimated for N1 mean

 amplitudes. Abbreviations for factors are provided at the bottom of the table.

			R-notation	
Final model	lmer(N1~ Se Stim*Sex*T	x*Sag*STAI-S + Sex AS-20 + Stim*Thr*S	x*Cor*STAI-S + S ex*STAI-S + (~1)	Stim*TAS-20*STAI-S + Participant), Ex1_N1)
Breakdown mode	lmer(N1~ TA Sex*Cor*ST	lmer(N1~ TAS-20*STAI-S + Sex*TAS-20 + Sex*Sag*STAI-S + Sex*Cor*STAI-S + Thr*Sex*STAI-S + (~1 Participant), Ex1_N1)		
Stim = Stimulus type	Thr = Threat level	Sag = Sagittal location	Cor = Coronal site	STAI-S = state anxiety scores TAS-20 = alexithymia scores

Table 4.7. *Fit statistics for the firearm, reptile and human models estimated to break down the N1 final model.*

	ICC (Participants)	Total variance (Ω^2)	Within-subject variance (σ ²)	Between-subject variance (τ 00)
Firearms	.79	.82	0.63	2.31
Reptiles	.84	.86	0.61	3.08
Humans	.86	.87	0.56	3.3

 $(M = 44.33 \pm 1.27)$. Twelve male and 28 females (eight follicular phase, seven luteal phase) were included in the low TAS-20 grouping, while the high TAS-20 grouping consisted of nine males and 24 females (seven follicular phase, eight luteal phase).

Firearms. The main effects of Threat level (F(2, 1201) = 71.94, p < .001, β_{MOD} = -0.38 [-0.18, -0.57], β_{NEU} = 0.37 [0.56, 0.18]) and TAS-20 scores (*F*(1, 60) = 4.85, $p = .03, \beta = 0.04$ [0.15, -0.06]) reached significance. A weak, negative and significant correlation occurred between N1 amplitude and TAS-20 scores (r = -.23, p < .001), and N1 activity for firearm stimuli was more negative for the low TAS-20 grouping (M = -3.2 [-3.05, -3.34]) compared to the high TAS-20 grouping (M = -2.43 [-2.31, -2.55]). The Threat level main effect was moderated by two significant two-way interactions, one involving Participant sex and the other STAI-S scores (Table 4.8). These two-way interactions were further moderated by a significant three-way interaction between Threat level, Participant sex and STAI-S scores. The magnitude of N1 activity was comparable between the male and the three female groupings for water pistol images (Figure 4.7). For images of handguns, however, the N1 amplitude of birth control females were more negative than that of males, follicular phase females and luteal phase females (all ps > .05). Unarmed handguns evoked significantly larger amounts of N1 activity than aimed handguns and water pistols for males, birth control females, and follicular phase females. There was also a moderate, significant and negative relationship between STAI-S levels and N1 amplitude for birth control females in response to images of unarmed handguns (Bonferroni-corrected $\alpha = .004$, r = -.43, p < .004.001). For luteal phase females, only the difference in N1 amplitude between aimed or unarmed handgun stimuli reached significance (Figure 4.7). Aimed handguns and water pistols were not differentiated in N1 modulation for follicular phase and luteal phase females. For birth control females, N1 activity for water pistols was significantly

Table 4.8. Parameter information for significant two-way and three-way interactions in the N1 firearm model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Thr*Sex	$F(6, 1201) = 8.2^{***}$	
ref. High threat: BC female	Moderate: Male	-0.44 [-0.17, -0.72]**
	Moderate: Follicular	-0.14 [0.16, -0.45]
	Moderate: Luteal	-0.23 [0.07, -0.53]
	Neutral: Male	-0.77 [-0.49, -1.05]***
	Neutral: Follicular	-0.03 [0.27, -0.34]
	Neutral: Luteal	-0.72 [-0.41, -1.02]***
Thr*STAI-S	F(2, 1201) = 4.35*	
ref. High threat	Moderate threat	0.05 [0.08, 0.03]***
	Neutral	-0.003 [0.02, -0.03]
Thr*Sex*STAI-S	F(6, 1201) = 3.1 **	
ref. High threat: BC female	Moderate: Male	-0.05 [-0.01, -0.08]
	Moderate: Follicular	-0.05 [-0.02, -0.08]**
	Moderate: Luteal	-0.04 [-0.005, -0.08]*
	Neutral: Male	-0.001 [0.04, -0.04]
	Neutral: Follicular	0.01 [0.04, -0.03]
	Neutral: Luteal	0.02 [0.06, -0.01]
.1 , $p < .05$, $p < .01$ **, $p < .001$ *** Thr: Threat level STAI-S = state anxiety scores		

reduced compared to aimed handguns. In contrast, the N1 amplitude of males towards water pistol stimuli was significantly larger than that observed for aimed handguns.

Reptiles. The Threat level main effect was significant in the reptile model, F(2, 1201) = 25.58, p < .001, $\beta_{MOD} = -0.2$ [-0.01, -0.39], $\beta_{NEU} = -0.55$ [-0.36, -0.73], and a trend occurred for the TAS-20 predictor, F(1, 60) = 3.43, p = .07, $\beta = -0.01$ [0.11, -0.13]. Again, there was a weak, negative and significant association between N1 amplitude and TAS-20 scores, r = -.2, p < .001, indicating that N1 activity for the low TAS-20 grouping (M = -2.92 [-2.77, -3.06]) was more negative than observed for the high TAS-20 grouping (M = -2.16 [-2.02, -2.3]). The main effect of Threat level was qualified by a



Figure 4.7. LS means for N1 mean amplitudes in the firearm model categorised by threat level and participant sex ($M_{\text{STAI-S}} = 33.03$). Parameter estimates for LS differences are shown for males and the three female groupings between each threat level (bottom). Vertical and horizontal bars denote 95% confidence intervals.

significant two-way interaction between this factor and Participant sex, as well as a significant three-way interaction between Threat level, Participant sex and STAI-S scores (Table 4.9). The N1 activity of birth control females was more negative than that of males and other female participants for reptile images (Figure 4.8). The magnitude of this difference was larger for turtles than for images of snakes. For males, N1 activity

Table 4.9. Parameter information for one two-way and one three-way interaction that reached significance in the N1 reptile model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Thr*Sex	$F(6, 1201) = 3.09^{**}$	
ref. High threat: Left	Moderate: Male	-0.2 [0.07, -0.47]
	Moderate: Follicular	-0.13 [0.17, -0.43]
	Moderate: Luteal	0.003 [0.3, -0.29]
	Neutral: Male	0.22 [0.49, -0.05]
	Neutral: Follicular	0.4 [0.7, 0.1]**
	Neutral: Luteal	0.07 [0.37, -0.23]
Thr*Sex*STAI-S	$F(6, 1201) = 3.33^{**}$	
ref. High threat: BC female	Moderate: Male	-0.04 [-0.01, -0.08]*
	Moderate: Follicular	0.004 [0.04, -0.03]
	Moderate: Luteal	0.01 [0.05, -0.03]
	Neutral: Male	-0.05 [-0.01, -0.08]**
	Neutral: Follicular	-0.04 [-0.01, -0.08]**
	Neutral: Luteal	-0.02 [0.01, -0.06]
.1 < p < .05., p < .05*, p < .01 **, p	<.001*** Thr: Threat level	STAI-S = state anxiety scores

for attacking snakes was reduced compared to other reptile images, with only the difference between turtles and attacking snakes being significant. Despite this, there was a weak, significant and positive relationship between N1 amplitude and STAI-S scores for non-attacking snakes in the male grouping (Bonferroni-corrected $\alpha = .004$, r = .26, p = .003). Turtles evoked more negative N1 activity than snake images for birth control and luteal phase females. This N1 modulation was significant for birth control females, but not for luteal phase females. However, there were moderate, negative and significant relationships between the N1 amplitude and the state anxiety levels of luteal phase females for images of non-attacking snakes (r = .38, p < .001) and turtles



Figure 4.8. LS means for N1 mean amplitudes in the reptile model categorised by threat level and participant sex ($M_{STAI-S} = 33.03$). Parameter estimates for LS differences are shown for males and the three female groupings between each threat level (bottom). Vertical and horizontal bars denote 95% confidence intervals.

(r = -.36, p < .001). The threat level of reptile images did not moderate the N1 amplitude of follicular phase females.

Humans. The main effect of Threat level was significant for human stimuli, F(2, 1201) = 17.98, p < .001, $\beta_{MOD} = -0.02$ [0.16, -0.2], $\beta_{NEU} = 0.09$ [0.28, -0.09]. Once again a trend was found for the TAS-20 main effect, F(1, 60) = 3.79, p = .06, $\beta = -0.002$ [0.12,

-0.13]. Similar to reptile and firearm images, there was a weak, negative and significant relationship between TAS-20 scores and N1 amplitude (r = -.19, p < .001), and human stimuli evoked more negative N1 activity in the low TAS-20 grouping (M = -3.05 [-2.9, -3.21]) than the high TAS-20 grouping (M = -2.33 [-2.18, -2.47]). The Threat level main effect was qualified by a significant two-way interaction between this factor and STAI-S scores, and a significant three-way interaction between these two factors and Participant sex (Table 4.10). N1 activity for birth control females was again more negative than that of males, follicular phase females, and luteal phase females (Figure 4.9). Images of injury elicited larger N1 amplitude than those showing non-injured humans for males and follicular phase females. This difference reached significance for severe injury in males and for non-severe injury in follicular phase females. Human stimuli did not appear to moderate the N1 activity of birth control and luteal phase females. However, a significant, negative and moderate correlation between STAI-S

Table 4.10. Parameter information for one two-way and one three-way interaction that reached significance in the N1 human model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Thr*STAI-S	$F(2, 1201) = 11.32^{***}$	
ref. High threat	Moderate threat	0.01 [0.03, -0.02]
	Neutral	0.005 [0.03, -0.02]
Thr*Sex*STAI-S	<i>F</i> (6, 1201) = 11.83***	
ref. High threat: BC female	Moderate: Male	-0.06 [-0.02, -0.09]**
	Moderate: Follicular	0.01 [0.04, -0.02]
	Moderate: Luteal	-0.09 [-0.05, -0.12]***
	Neutral: Male	-0.05 [-0.01, -0.08]**
	Neutral: Follicular	0.05 [0.09, 0.02]***
	Neutral: Luteal	-0.06 [-0.02, -0.09]***



Figure 4.9. LS means for N1 mean amplitudes in the human model categorised by threat level and participant sex ($M_{\text{STAI-S}} = 33.03$). Parameter estimates for LS differences are shown for males and the three female groupings between each threat level (bottom). Vertical and horizontal bars denote 95% confidence intervals.

scores and N1 amplitude was found for luteal phase females in response to images of severe injury (Bonferroni-corrected $\alpha = .004$, r = .37, p < .001).

The EPN (150-250ms). Mean amplitudes for the EPN were computed from the left hemisphere electrodes P7 and PO7 and the right hemisphere electrodes P8 and PO8. In the right hemisphere, unarmed handguns elicited more negative EPN activity

compared to images of aimed handguns and water pistols (Figure 4.10, Figure 4.11). This same difference between unarmed handguns and other firearm images also occurred in the left hemisphere for birth control and follicular phase females. For luteal phase females, handgun images led to more negative EPN amplitude than images of water pistols in the left hemisphere (bottom, Figure 4.11). For males in the left hemisphere unarmed handguns evoked the most negative EPN activity, followed by aimed handguns, and then water pistols (bottom, Figure 4.10). Regarding reptile stimuli, modulation of EPN amplitude by the threat level of these images was not apparent for male or female participants. The threat level of human images did not moderate EPN activity for birth control or follicular phase females either (top, Figure 4.10; top, Figure 4.11). In contrast images of human injury evoked more negative EPN amplitude than non-injured humans for males in the left and right hemisphere (bottom, Figure 4.10). The same difference between injury and non-injured humans also occurred for luteal phase females, but only in the left hemisphere (bottom, Figure 4.11).

Linear mixed effects analysis. One birth control female was excluded from the analysis of EPN mean amplitudes. Assumption checks showed this female's data led to a positive skew in the Participant random effect, despite only 44% of her data being above the upper 95% confidence limit ($M = -3.83\mu$ V [13.24, -5.58]). The final model for the EPN was estimated with the data of 21 males, 21 birth control females, 16 luteal phase females and 15 follicular phase females. Scores from the PSWQ (Kenward-Roger: F(144, 2229) = 1.34, p = .005), the STAI-S (F(144, 2229) = 1.38, p = .003) and the STAI-T (F(144, 2229) = 1.31, p = .009) were significantly related to EPN modulation. Scores from the STAI-S (AIC = 11807, BIC = 12065) led to better model fit than the addition of scores from the PSWQ (AIC = 11817, BIC = 12076). Based on these results STAI-S scores were retained in



Figure 4.10. Grand average EPN waveforms for birth control females (top) and males (bottom), averaged across the most lateral parietal and parietal-occipital electrodes. Images of firearms, reptiles and humans are categorised by threat level (i.e., high threat, moderate threat, neutral).



Figure 4.11. Grand average EPN waveforms for follicular phase (top) and luteal phase (bottom) females, averaged across the most lateral parietal and parietal-occipital electrodes. Images of firearms, reptiles and humans are categorised by threat level (i.e., high threat, moderate threat, neutral).

the EPN final model (Table 4.11).

EPN activity was strongly clustered across participants (ICC_{Participants} = .66) and approximately 80% of total variance was explained by the final model (σ^2 = 4.57, τ_{00} for participants = 8.87). Main effects for Stimulus type (*F*(2, 2521) = 434.02, *p* < .001, β_{HUM} = 2.07 [2.6, 1.54], β_{REP} = 0.47 [1, -0.06]), Threat level (*F*(2, 2521) = 46.01, *p* < .001, β_{MOD} = -0.46 [0.03, -0.95], β_{NEU} = 0.8 [1.29, 0.31]) and Participant sex (*F*(3, 65) = 6.5, *p* < .001, β_{MALE} = -2.33 [-0.48, -4.19], β_{FOLL} = -1.71 [0.35, -3.78], β_{LUT} = -1.23 [0.75, -3.21]) were significant. The Stimulus type main effect was qualified by a significant interaction between this factor and Sagittal location, *F*(2, 2521) = 5.81, *p* = .003, β_{HUM} = 0.68 [1.08, 0.28], β_{REP} = 0.2 [0.6, -0.2]. At both sagittal locations EPN activity was most negative for firearms (M_P = 0.71 [1.45, -0.03], M_{PO} = 4.01 [4.76, 3.27]), followed by reptiles (M_P = 1.4 [2.15, 0.66], M_{PO} = 4.91 [5.65, 4.16]), and then humans (M_P = 3.28 [4.02, 2.54], M_{PO} = 7.26 [8.01, 6.52], all *ps* < .001). For each stimulus type EPN amplitude was more negative at parietal electrodes than parietaloccipital electrodes (all *ps* < .001). This latter difference for firearms was smaller in magnitude than observed for reptile and human stimuli.

Stimulus type and Threat level were further moderated by a significant threeway interaction between these two factors and Coronal site (Table 4.12, Figure 4.12). The threat level of reptile images did not moderate EPN activity in the left or the right

Table 4.11. *R* notation for the final model estimated for the EPN. Abbreviations for factors included in analyses are provided at the bottom of the table.

	R-notation			
Final model Imer(EPN~ Stim*Sag + Stim*Cor + Thr*Cor + Stim*Thr*Cor +				
Stim = Stimulus type	e Thr = Threat level Sag = Sagittal location Cor = Coronal site STAI-S = state anxiety scor			

Table 4.12. Parameter information for significant higher-order interactions in the final model for EPN mean amplitudes, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Stim*Thr*Cor	$F(4, 2521) = 3.36^{**}$	
ref. Firearm: High threat: Left	Reptile: Moderate: Right	0.85 [1.83, -0.14].
	Reptile: Neutral: Right	1.14 [2.12, 0.16]*
	Human: Moderate: Right	1.62 [2.6, 0.64]**
	Human: Neutral: Right	1.33 [2.31, 0.35]**

.1 , <math>p < .05*, p < .01**, p < .001*** Thr: Threat level Stim: Stimulus type STAI-S = state anxiety scores ST

hemisphere. EPN modulation observed for firearm images in average waveforms were partially confirmed. In the right hemisphere, unarmed handguns elicited significantly more negative EPN amplitude than water pistols and aimed handguns. In the left hemisphere handgun images led to larger amounts of EPN activity than water pistol stimuli, although only the difference between unarmed handguns and water pistols reached significance. EPN activity for images of human injury was also significantly more negative than that evoked by non-injured humans.

The N2 (200-350ms). Mean amplitudes for the N2 were derived from the central electrodes C1, Cz and C2, and the central-parietal electrodes CP1, CPz and CP2. Aimed handgun and water pistol stimuli evoked more negative N2 amplitude than images of unarmed handguns for birth control and follicular phase females (top; Figure 4.13, Figure 4.14). For luteal phase females, larger amounts of N2 activity were elicited by handgun images than by water pistol stimuli (bottom, Figure 4.14). This same difference between handgun and water pistol images occurred for males at midline and right hemisphere sites (bottom, Figure 4.13). In the left hemisphere, however, the



Figure 4.12. LS means for EPN mean amplitudes categorised by stimulus type, threat level and coronal site. Parameter estimates for LS differences between threat levels for firearm and human stimuli in the left and right hemisphere sites are shown (bottom). Vertical and horizontal bars denote 95% confidence intervals.

amplitude of the N2 for images of water pistols and unarmed handguns was more negative compared to that observed for aimed handgun images in the male grouping. Turtles and non-attacking snakes evoked more negative N2 activity than images of



Figure 4.13. Grand average N2 waveforms for birth control females (top) and males (bottom), averaged across central and central-parietal electrodes close to the midline. Images of firearms, reptiles and humans are categorised by threat level (i.e., high threat, moderate threat, neutral).



FOLLICULAR PHASE FEMALES

Figure 4.14. Grand average N2 waveforms for follicular phase (top) and luteal phase (bottom) females, averaged across central and central-parietal electrodes close to the midline. Images of firearms, reptiles and humans are categorised by threat level (i.e., high threat, moderate threat, neutral).
attacking snakes for male and female participants, particularly at midline and right hemisphere sites (Figure 4.13, Figure 4.14). Finally, images of non-injured humans led to more negative N2 activity than observed for injured humans at left hemisphere, midline and right hemisphere sites.

Linear mixed effects analysis. A trend was found for the relationship between neuroticism scores and N2 modulation (Kenward-Roger: F(216, 3412) = 1.17, p = .05), and this predictor was included in the N2 final model (Table 4.13). N2 activity was very strongly clustered between participants (ICC_{Participants} = .77) and the final model explained 87% of total variance ($\sigma^2 = 1.61, \tau_{00}$ for participants = 5.43). All significant main effects and lower-order interactions were moderated by two or more high-order interactions that reached significance (Appendix K). Fit statistics for the firearm, reptile and human models were equivalent to those found for the N2 final model (Table 4.14).

Firearms. Main effects for Threat level ($F(2, 1202) = 62.62, p < .001, \beta_{MOD} = 0.98$ [1.28, 0.68], $\beta_{NEU} = -0.09$ [0.21, -0.39]) and Participant sex ($F(1 3, 66) = 3.93, p = .01, \beta_{MALE} = 3.48$ [4.97, 2], $\beta_{FOLL} = 1.47$ [2.99, -0.04], $\beta_{LUT} = 2$ [3.49, 0.51]) were significant. These two main effects were qualified by a significant two-way interaction between these factors, and a significant three-way interaction between the same two factors and neuroticism scores (Table 4.15, Figure 4.15). Aimed handguns elicited the most negative N2 activity for birth control females, followed by follicular phase and

Table 4.13. R notation for the final and breakdown model estimated for N2 meanamplitudes. Abbreviations for factors are provided at the bottom of the table.

	R-notation		
Final model	lmer(N2~ Stim*Sag+ Stim*Cor + Stim*Thr*Sex*Neur + Sex*Sag*Cor*Neur (~1 Participant), Ex1_N2)		
Breakdown mode	lmer(N2~ Thr*Sex*Neur + Sex*Sag*Cor*Neur + (~1 Participant), Ex1_N2)		
Stim = Stimulus type	Thr = Threat level Sag = Sagittal location Cor = Coronal site Neur = neuroticism scores		

	ICC (Participants)	Total variance (Ω^2)	Within-subject variance (σ^2)	Between-subject variance (τοο)
Firearms	.76	.85	1.37	4.37
Reptiles	.81	.88	1.34	5.82
Humans	.82	.89	1.49	6.87

Table 4.14. Fit statistics for the firearm, reptile and human models estimated to break down the N2 final model.

Table 4.15. Parameter information for one two-way and one three-way interaction that reached significance in the N2 firearm model, with the reference parameter and estimates (β) provided for each interaction. *F*-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom *left of the table.*

	Parameter	β [95% CI]
Thr*Sex	$F(6, 1202) = 8.37^{***}$	
ref. High threat: Left	Moderate: Male	-1.46 [-1.01, -1.9]***
	Moderate: Follicular	-0.08 [0.38, -0.54]
	Moderate: Luteal	-0.37 [0.08, -0.82]
	Neutral: Male	-0.96 [-0.51, -1.41]***
	Neutral: Follicular	-0.06 [0.4, -0.52]
	Neutral: Luteal	-0.35 [0.1, -0.8]
Thr*Sex*Neur	$F(6, 1202) = 2.86^{**}$	
ref. High threat: BC female	Moderate: Male	-0.05 [-0.02, -0.09]**
	Moderate: Follicular	-0.02 [0.01, -0.05]
	Moderate: Luteal	-0.01 [0.02, -0.05]
	Neutral: Male	-0.05 [-0.01, -0.08]**
	Neutral: Follicular	-0.01 [0.02, -0.04]
	Neutral: Luteal	0.02 [0.05, -0.02]
$1 < n < 05$ $n < 05^*$ $n < 01^{**}$ n	< 001*** Thr: Threat level	Neur = neuroticism scores

Thr: Threat level .1 , <math>p < .05, p < .01 **, p < .001

luteal phase females, and then male participants. The difference between N2 amplitude for males and females was significant for birth control females ($\beta = -3.23$ [-1.8, -4.66], p = .002), but not for follicular phase (β = -1.15 [-0.3, -2.6]) or luteal phase (β = -1.82



Figure 4.15. LS means for N2 mean amplitudes in the firearm model, categorised by threat level and participant sex ($M_{\text{NEUR}} = 33.31$). Parameter estimates for LS differences between threat level for males, birth control females, follicular phase females and luteal phase females are shown (bottom). Vertical and horizontal bars denote 95% confidence intervals.

[-0.4, -3.25], both ps > .05) females. The N2 amplitude of birth control females was also larger for unarmed handgun or water pistol stimuli compared to that observed for males, follicular phase females and luteal phase females. N2 modulation for birth control females may have been related to weak, positive and significant correlations between Neuroticism scores and N2 amplitude for images of aimed handguns (Bonferronicorrected α = .004, *r* = .28, *p* = .001), unarmed handguns (*r* = .27, *p* = .002) and water pistols (*r* = .27, *p* = .002) in this female grouping. In contrast, trends for negative and weak associations between N2 activity and Neuroticism levels were found for males (*r* = -.25, *p* = .005) and follicular phase females (*r* = -.28, *p* = .007) in response to aimed handgun images. For follicular phase females, N2 amplitude was also negatively related to Neuroticism scores for water pistols (*r* = -.29, *p* = .006) though this correlation was above the Bonferroni-corrected level of significance. Returning to Threat level, within each female grouping the amplitude of the N2 for images of unarmed handguns was significantly reduced compared to aimed handguns and water pistols (Figure 4.15). For males, however, N2 activity was more negative for handgun images compared to those showing water pistols. This difference was significant for aimed handguns and a trend for unarmed handguns.

Reptiles. Similar to the firearm model, main effects for Threat level (F(2, 1202)= 54.01, p < .001, $\beta_{MOD} = -0.24$ [0.06, -0.54], $\beta_{NEU} = -0.77$ [-0.47, -1.07]) and Participant sex (F(3, 66) = 3.45 p = .02, $\beta_{MALE} = 2.83$ [4.51, 1.14], $\beta_{FOLL} = 1.86$ [3.57, 0.14], $\beta_{LUT} = 1.99$ [3.68, 0.3]) reached significance. The two main effects were qualified by a significant interaction between Threat level, Participant sex and neuroticism scores (Table 4.16). N2 activity was most negative for birth control females, followed by follicular and luteal phase females, and then males (Figure 4.16). Moreover, there were moderate, positive and significant relationships between N2 amplitude and Neuroticism scores for birth control females in response to images of attacking snakes (Bonferronicorrected $\alpha = .004$, r = .32), non-attacking snakes (r = .37) and turtles (r = .36, all ps <.001). For males and luteal phase females, images of attacking snakes evoked significantly larger N2 amplitude than those showing non-attacking snakes and turtles (Figure 4.16). Conversely, for birth control females N2 activity elicited by attacking and

Table 4.16. Parameter information for one significant three-way interaction in the N2 reptile model with reference parameters and estimates (β). F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Thr*Sex*Neur	F(6, 1202) = 2.47*	
ref. High threat: BC female	Moderate: Male	0.04 [0.07, 0.01]*
	Moderate: Follicular	0.01 [0.04, -0.02]
	Moderate: Luteal	0.04 [0.08, 0.01]*
	Neutral: Male	0.02 [0.05, -0.02]
	Neutral: Follicular	0.03 [0.06, 0.001]*
	Neutral: Luteal	0.02 [0.06, -0.01]
.1 < p < .05•, p < .05*, p < .01 **, p	<.001*** Thr: Threat	t level Neur = neuroticism scores

non-attacking snakes was significantly more negative than for turtles. This same difference between non-attacking snakes and turtles in N2 modulation was not significant for follicular phase females (both ps > .05).

Humans. Main effects for Threat level ($F(2, 1202) = 233.7, p < .001, \beta_{MOD} = 0.27 [0.59, -0.05], \beta_{NEU} = -1.52 [-1.2, -1.83]) and Participant sex (<math>F(3, 66) = 3.81, p = .01, \beta_{MALE} = 3.07 [4.9, 1.25], \beta_{FOLL} = 1.26 [3.12, -0.61], \beta_{LUT} = 1.8 [3.63, -0.03])$ were significant in the human model. Threat level interacted significantly with Neuroticism scores, and this two-way interaction was qualified by a trend occurring for the three-way interaction between Threat level, Participant sex and neuroticism scores (Table 4.17, Figure 4.17). N2 activity for images of non-injured humans was significantly more negative than elicited by injured humans for male and female participants. Injured and non-injured humans evoked the most negative N2 amplitude for birth control females, followed by follicular and luteal phase females, and then males. A trend also occurred for the difference between birth control females and males in N2 activity towards non-severe injury ($\beta = -3.05$ [-1.27, -4.83], p = .08), but not for



Figure 4.16. LS means for N2 mean amplitudes in the reptile model, categorised by threat level and participant sex ($M_{\text{NEUR}} = 33.31$). Parameter estimates for LS differences between threat level for males, birth control females, follicular phase females and luteal phase females are shown (bottom). Vertical and horizontal bars denote 95% confidence intervals.

images of severe injury (β = -3.01 [-1.23, -4.79], *p* = .1). For birth control females, there were significant and positive relationships between N2 activity and Neuroticism scores for injured human stimuli. These associations were moderate for images of severe injury (Bonferroni-corrected α = .004, *r* = .35, *p* < .001) and weak for scenes of non-severe injury (*r* = .27, *p* = .001). There was some indication that the N2 amplitude of follicular phase females was moderated by neuroticism scores due to the occurrence of negative,

Table 4.17. Parameter information for one two-way and one three-way interaction that reached significance in the N2 human model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Thr*Neur	F(2, 1202) = 6.1 **	
ref. High threat	Moderate threat	0.02 [0.04, -0.003].
	Neutral	0.05 [0.07, 0.02]***
Thr*Sex*Neur	F(6, 1202) = 2.08, p = .05	
ref. High threat: BC female	Moderate: Male	0.003 [0.038, -0.03]
	Moderate: Follicular	0.01 [0.05, -0.02]
	Moderate: Luteal	-0.034 [0, -0.07].
	Neutral: Male	-0.03 [0.004, -0.06].
	Neutral: Follicular	-0.02 [0.01, -0.05]
	Neutral: Luteal	-0.04 [-0.01, -0.081]*
.1 < p < .05., p < .05*, p < .01 **, p <	<.001*** Thr: Threat level	Neur = neuroticism scores

moderate and significant correlations for images of non-severe injury (r = .43) and noninjured humans (r = .41, both ps < .001).

The P3b (300-380ms). Mean activity for the P3b was computed from the midline sites Pz and POz, the left hemisphere sites P1, P3 and PO3, and the right hemisphere sites P2, P4 and PO4.

Firearms. Aimed handguns led to more positive P3b amplitude than water pistol images for male and female participants (Figure 4.18, Figure 4.19). For birth control females P3b activity was more positive for aimed handguns compared to unarmed handgun and water pistol stimuli in the left and right hemisphere. At midline sites, P3b amplitude was most positive for aimed handguns, followed by unarmed handguns, and then water pistols. P3b modulation for follicular phase and luteal phase females was the same as observed for birth control females at the midline and in the right hemisphere



Figure 4.17. LS means for N2 mean amplitudes in the human model, categorised by threat level and participant sex ($M_{\text{NEUR}} = 33.31$). Parameter estimates for LS differences between threat level for males, birth control females, follicular phase females and luteal phase females are shown (bottom). Vertical and horizontal bars denote 95% confidence intervals.

(Figure 4.19). For luteal phase females, P3b activity was most positive for aimed handguns, followed by unarmed handguns, and then water pistols in the left hemisphere. This modulation, however, was of lesser magnitude than for the same difference observed at midline sites. For follicular phase females, handgun images led to larger amounts of P3b activity than water pistol images. This same difference between images



Figure 4.18. Grand average P3b waveforms for birth control females (top) and males (bottom), averaged across parietal and parietal-occipital electrodes close to the midline. Images of firearms, reptiles and humans are categorised by threat level (i.e., high threat, moderate threat, neutral).

BIRTH CONTROL FEMALES



Figure 4.19. Grand average P3b waveforms for follicular phase (top) and luteal phase (bottom) females, averaged across parietal and parietal-occipital electrodes close to the midline. Images of firearms, reptiles and humans are categorised by threat level (i.e., high threat, moderate threat, neutral).

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of handguns and water pistols also occurred for males at left hemisphere and midline sites (bottom, Figure 4.18). Finally, P3b amplitude was most positive for aimed handguns, followed by unarmed handguns, and then water pistols, in the right hemisphere for male participants.

Reptiles. The threat level of reptile images did not modulate P3b activity in the left hemisphere for male or female participants (Figure 4.18, Figure 4.19). This lack of P3b modulation also occurred for female participants at midline sites. However, images of attacking snakes and turtle led to more positive P3b amplitude than observed for images of non-attacking snakes at the midline for males (bottom Figure 4.18). This same difference between non-attacking snakes and other reptile images also occurred in the right hemisphere for all participants.

Humans. Images of injured humans led to larger amounts of P3b activity compared to non-injured humans for birth control and follicular phase females (top, Figure 4.18; top, Figure 4.19). This same difference between injured and non-injured humans also occurred for luteal phase females at right hemisphere and midline sites (bottom, Figure 4.19). In the left hemisphere, P3b amplitude was most positive for severe injury, followed by non-severe injury, and then non-injured humans for luteal phase females. For males, images of severe injury elicited larger amounts of P3b activity than non-severe injury and non-injured humans at left hemisphere and midline sites (bottom, Figure 4.18). In the right hemisphere images of human injury also evoked more positive P3b amplitude than images of non-injured humans for males, although this modulation was of lesser magnitude than observed for female participants.

Linear mixed effects analysis. The data of one male and one luteal phase female were excluded from the analysis of P3b mean amplitudes. At parietal-occipital sites the percentage of P3b data over the upper 95% confidence interval limit was above 60% for

both participants ($M_P = 5.51 \mu V$ [13.15, -2.14], $M_{PO} = 7.63 \mu V$ [16.42, -1.16]). Therefore, the P3b final model was estimated with the data of 22 birth control females, 20 males, 15 follicular phase females and 15 luteal phase females. PSWQ scores were significantly related to P3b modulation (Kenward-Roger: F(216, 4559) = 1.24, p = .01), and this predictor was added to the final model (Table 4.18). Mean amplitudes for the P3b were strongly related across participants (ICC_{Participants} = .53), and the final model accounted for 69% of total variance ($\sigma^2 = 4.16, \tau_{00}$ for participants = 4.6). All main effects and two-way interactions that reached significance were qualified by one or more significant three-way interactions (Appendix K). As found in the final model, P3b mean amplitudes were strongly clustered across participants in the firearm, reptile and human models (Table 4.19). The human model (74%) was found to explain slightly more total variance than the models for reptiles (71%) or firearms (69%).

Firearms. Main effects for Threat level ($F(2, 1608) = 48.74, p < .001, \beta_{MOD} = -0.46 [0.07, -0.98], \beta_{NEU} = -1.01 [-0.48, -1.54])$ and Participant sex ($F(13, 64.37) = 3.18, p = .03, \beta_{MALE} = -0.14 [1.42, -1.69], \beta_{FOLL} = -1.36 [0.45, -3.17], \beta_{LUT} = -1.19 [0.41, -2.79])$ reached significance. The Threat level main effect was moderated by two significant two-way interactions (Table 4.20). Both main effects, as well as the two-way

Table 4.18. R notation for the final and breakdown model estimated for P3b meanamplitudes. Abbreviations for factors are provided at the bottom of the table.

	R-notation			
Final model	Imer(P3b~ Sag*Cor + Stim*Cor + Stim*Thr*Cor + Stim*Thr*Sag + Sex*Sag*PSWQ + Sex*Cor*PSWQ + Thr*Sex*PSWQ + Stim*Sex*PSWQ (~1 Participant), Ex1_P3b)			
Breakdown model	ner(P3b~ Sag*Cor + Thr*Sag + Thr*Cor + Sex*Sag*PSWQ + ex*Cor*PSWQ + Thr*Sex*PSWQ + (~1 Participant), Ex1_P3b)			
Stim = Stimulus type T	hr = Threat level Sag = Sagittal location Cor = Coronal site PSWQ = worry scores			

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	ICC (Participants)	Total variance (Ω^2)	Within-subject variance (σ ²)	Between-subject variance (τ 00)
Firearms	.56	.69	3.34	4.29
Reptiles	.58	.71	3.63	4.95
Humans	.55	.74	4.6	5.51

Table 4.19. *Fit statistics for the firearm, reptile and human models estimated to break down the P3b final model.*

interaction between Threat level and PSWQ scores, were further modified by a significant three-way interaction between Threat level, Participant sex and PSWQ scores (Figure 4.20). For males, birth control females and luteal phase females, P3b activity was largest for aimed handguns, followed by unarmed handguns, and then water pistols. These differences were significant for birth control females; for males and luteal phase females, only the difference between water pistols and aimed handguns reached significance (see Figure 4.20). In the luteal phase grouping this P3b modulation was also paralleled by negative, moderate and significant associations between P3b activity and PSWQ scores for images of aimed handguns (Bonferroni-corrected $\alpha =$.004, r = -.38), unarmed handguns (r = -.44) and water pistols (r = -.42, all ps < .001). The same relationships were weak for birth control females in response to aimed handgun (r = -.2, p = .007) and unarmed handgun (r = -.23, p = .002) stimuli. In contrast, images of aimed handguns led to a weak, positive and significant association between P3b amplitude and PSWQ scores for males (r = .24, p = .002). The same relationship was moderate for follicular phase females (r = .39, p < .001), and in this female grouping unarmed handgun stimuli also elicited more positive P3b activity than aimed handguns and water pistols (both ps > .05).

Table 4.20. Parameter information for one two-way and two three-way interactions that reached significance in the P3b firearm model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Thr*Cor	<i>F</i> (4, 1608) = 3.55**	
ref. High threat: Left	Moderate: Midline	-0.41 [0.13, -0.96]
	Moderate: Right	-0.19 [0.3, -0.67]
	Neutral: Midline	-1.05 [-0.5, -1.59]***
	Neutral: Right	-0.49 [-0.002, -0.98]*
Thr*PSWQ	F(2, 1608) = 3.74*	
ref. High threat	Moderate threat	0 [0.04, -0.04]
	Neutral	0.04 [0.08, 0.002]*
Thr*Sex*PSWQ	<i>F</i> (6, 1608) = 3.81***	
ref. High threat: BC female	Moderate: Male	-0.02 [0.03, -0.07]**
	Moderate: Follicular	-0.1 [-0.04, -0.17]***
	Moderate: Luteal	-0.01 [0.06, -0.07]
	Neutral: Male	-0.07 [-0.02, -0.12]**
	Neutral: Follicular	-0.13 [-0.07, -0.19]
	Neutral: Luteal	-0.05 [0.02, -0.12]

.1 , <math>p < .05*, p < .01 **, p < .001 *** Thr: Threat level Cor: Coronal site PSWQ = worry scores PSWQ = worry

Electrode position in the P3b firearm model. The two-way interaction between Threat level and Coronal site indicated that P3b activity was significantly more positive for handgun images compared to water pistol stimuli at midline and right hemisphere sites (Figure 4.21). These same differences also occurred in the left hemisphere, however only reached significance for images of aimed handgun. A trend occurred for more positive P3b amplitude for aimed handguns compared to unarmed handguns at midline sites. In the right hemisphere handguns evoked larger P3b activity than at the midline and in the left hemisphere. For water pistol images, the P3b amplitude was



Figure 4.20. LS means for P3b mean amplitudes in the firearm model, categorised by threat level and participant sex ($M_{PSWQ} = 46.43$). Parameter estimates for LS differences between threat level for males, birth control females, follicular phase females and luteal phase females are shown (bottom). Vertical and horizontal bars denote 95% confidence intervals.

significantly reduced at the midline compared to the left and right hemisphere.

Reptiles. The main effect for Threat level was significant, F(2, 1608) = 10.98, p < .001, $\beta_{MOD} = 3.78$ [4.92, 2.64], $\beta_{NEU} = 0.47$ [1.02, -0.08]. The Threat level main effect was qualified by three significant two-way interactions and a significant three-way interaction between Threat level, Participant sex and PSWQ scores (Table 4.21). In the



Figure 4.21. LS means for P3b mean amplitudes in the firearm model, categorised by threat level and coronal site. Parameter estimates for LS differences are shown at each coronal site between aimed handguns, unarmed handguns and water pistols, as well as between coronal sites for aimed handguns, unarmed handguns and water pistols (bottom). Vertical and horizontal bars denote 95% confidence intervals.

luteal phase grouping negative and significant correlations between PSWQ scores and P3b amplitude ranged from strong to weak for images of attacking snakes (Bonferronicorrected $\alpha = .004$, r = -.48), non-attacking snakes (r = -.4) and turtles (r = -.4, all ps < .001). Images of attacking snakes or turtles evoked more positive P3b amplitude for males and birth control females compared to female participants from the follicular and

Table 4.21. Parameter information for three two-way and one three-way interactions that reached significance in the P3b reptile model, with the reference parameter and estimates (β) provided for each interaction. *F*-statistics are located at the top of the parameter column for each interaction. *P*-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Thr*Sex	F(6, 1608) = 3.51 **	
ref. High threat: BC female	Moderate: Male	-0.42 [0.24, -1.08]
	Moderate: Follicular	1.04 [1.81, 0.27]**
	Moderate: Luteal	0.06 [0.74, -0.62]
	Neutral: Male	-0.47 [0.2, -1.13]
	Neutral: Follicular	-0.42 [0.35, -1.19]
	Neutral: Luteal	-0.16 [0.52, -0.84]
Thr*Sag	<i>F</i> (2, 1608) = 21.45***	
ref. High threat: Parietal	Moderate: Parietal-occipital	-0.02 [0.44, -0.48]
	Neutral: Parietal-occipital	1.32 [1.78, 0.86]***
Thr*Cor	$F(4, 1608) = 10.46^{***}$	
ref. High threat: Left	Moderate: Midline	-1.16 [-0.59, -1.73]***
	Moderate: Right	-1.42 [-0.91, -1.93]***
	Neutral: Midline	-0.88 [-0.31, -1.46]**
	Neutral: Right	-0.28 [0.23, -0.79]
Thr*Sex*PSWQ	<i>F</i> (6, 1608) = 5.19***	
ref. High threat: BC female	Moderate: Male	-0.04 [0.02, -0.09]
	Moderate: Follicular	-0.13 [-0.07, -0.2]***
	Moderate: Luteal	0.03 [0.1, -0.04]
	Neutral: Male	-0.01 [0.05, -0.06]
	Neutral: Follicular	0 [0.07, -0.06]
	Neutral: Luteal	0.08 [0.15, 0.01]*

.1 , <math>p < .05*, p < .01 **, p < .001*** Thr: Threat level Cor: Coronal site PSWQ = Worry scores

luteal phase groupings (Figure 4.22). For non-attacking snakes, P3b activity was largest for birth control females, followed by males and follicular phase females, and then luteal phase females. There were also positive and significant associations between PSWQ scores and P3b amplitude for images of attacking snakes in the male (r = .27)



Figure 4.22. LS means for P3b mean amplitudes in the reptile model, categorised by threat level and participant sex ($M_{PSWQ} = 46.43$). Parameter estimates for LS differences between threat level for males, birth control females, follicular phase females and luteal phase females are shown (bottom). Vertical and horizontal bars denote 95% confidence intervals.

and follicular phase (r = .31, both ps = .001) groupings. For birth control and luteal phase females, turtles evoked more positive P3b amplitude than images of snakes. This same difference, however, was significant only between non-attacking snakes and turtles for birth control females (see Figure 4.22). For males, P3b activity was reduced for non-attacking snakes compared to attacking snakes and turtles, though only the latter

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difference reached significance. Lastly, P3b modulation for follicular phase females was opposite to that observed for males, with non-attacking snakes evoking more positive P3b activity than attacking snakes and turtles (all ps > .05).

Electrode position in the P3b reptile model. The two-way interaction involving Sagittal location and Threat level indicated P3b modulation for reptile images was more evident at the parietal-occipital location than the parietal location (Figure 4.23). At parietal-occipital electrodes P3b activity was significantly more positive for turtles compared to snakes that were attacking (β = -1.07, [-0.68, -1.45]) or non-attacking (β = -1.32, [-0.93, -1.7], both *p*s < .001). The two-way interaction between Coronal site and Threat level indicated that this effect might have been driven by P3 modulation in the right hemisphere (Figure 4.24). P3b amplitude was also significantly larger for attacking snakes and turtles compared to non-attacking snakes at right hemisphere electrodes. No P3b modulation was evident at midline sites, although P3b amplitude for non-attacking snakes in the left hemisphere. For turtles, P3b activity was largest in the right hemisphere, followed by



Figure 4.23. LS means for P3b mean amplitudes in the reptile model, categorised by threat level and sagittal location. Vertical bars denote 95% confidence intervals.



Figure 4.24. LS means for P3b mean amplitudes in the reptile model, categorised by threat level and coronal site. Parameter estimates for LS differences are shown at each coronal site between attacking snakes, non-attacking snakes and turtles (bottom), as well as between coronal sites for attacking snakes, non-attacking snakes and turtles and turtles (right). Vertical and horizontal bars denote 95% confidence intervals.

the left hemisphere, and then the midline (Figure 4.24). In the left and right hemisphere, P3b activity was more positive for non-attacking snakes compared to the midline, while P3b amplitude was larger for attacking snakes in the right hemisphere in comparison to left hemisphere and midline sites.

Humans. The main effect of Threat level reached significance, F(2, 1608) = 38.01, p < .001, $\beta_{MOD} = -0.3$ [0.33, -0.92], $\beta_{NEU} = -1.39$ [-0.77, -2.01], and was moderated by a significant two-way interaction between this factor and Sagittal location

Table 4.22. Parameter information for two significant two-way interactions in the P3b human model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Thr*Sag	<i>F</i> (2, 1608) = 8.15***	
ref. High threat: Parietal	Moderate: Parietal-occipital	-0.53 [-0.01, -1.04]*
	Neutral: Parietal-occipital	0.54 [1.06, 0.02]*
Thr*Cor	F(4, 1608) = 2.28, p = .06	
ref. High threat: Left	Moderate: Midline	0.16 [0.81, -0.48]
	Moderate: Right	0.22 [0.79, -0.35]
	Neutral: Midline	-0.73 [-0.09, -1.38]*
	Neutral: Right	-0.07 [0.51, -0.64]
33b mean amplitude (μV) 93b 94b 94b	H H	Severe injury Non-severe injury
Parietal electrodes	Parietal-occipital electrodes	

Figure 4.25. LS means for P3b mean amplitudes in the human model, categorised by threat level and sagittal location. Vertical bars denote 95% confidence intervals.

(Table 4.22, Figure 4.25), as well as a trend for the two-way interaction between Threat level and Coronal site (Figure 4.26). The three-way interaction between Threat level, Participant sex and PSWQ scores was not significant, F(6, 1608) = 0.79, p = .58. Regarding Sagittal location, P3b amplitude at parietal electrodes was significantly reduced for non-injured humans compared to images of severe injury ($\beta = 1.62$ [1.98,



Figure 4.26. LS means for P3b mean amplitudes in the human model, categorised by threat level and coronal site. Parameter estimates for LS differences are shown at each coronal site between severe injury, non-severe injury and non-injured humans (bottom), as well as between coronal sites for severe injury, non-severe injury and non-injury and non-injury and non-injury humans (right).

1.26]) or non-severe injury ($\beta = 1.32$ [1.68, 0.96], both *ps* < .001, Figure 4.25). At parietal-occipital electrodes scenes of severe injury elicited significantly larger P3b activity than both non-injured humans ($\beta = 1.08$ [1.51, 0.64], *p* < .001) and humans with non-severe injury ($\beta = 0.83$ [1.26, 0.39], *p* = .003). In relation to the Coronal site factor, images of injury evoked larger P3b activity than non-injured humans at midline and right hemisphere sites (Figure 4.26). These differences were significant apart from P3b modulation for non-severe injury in the right hemisphere. In the left hemisphere, the amplitude of the P3b evoked by severe injury was more positive than for non-severe injury and non-injured humans. A trend occurred for the former difference, while the latter difference was significant. For severe injury, non-severe injury and non-injured humans P3b activity was largest at the midline, followed by the left hemisphere, and then the right hemisphere.

The LPP (500-650ms). Mean activity for the LPP was computed from the central-parietal electrodes CP1, CPz and CP2, and the parietal electrodes P1, Pz and P2. Images showing human injury elicited larger amounts of LPP activity than non-injured humans (Figure 4.27, Figure 4.28). High threat versions of reptile and firearm images (i.e., attacking snakes, aimed handguns) also evoked more positive LPP amplitude than moderate threat or neutral versions of these same stimuli. The magnitude of the difference between attacking snakes and other reptile images was of lesser magnitude in the left hemisphere compared to the midline and the right hemisphere for males, birth control females and luteal phase females (Figure 4.27; bottom, Figure 4.28).

Linear mixed effects analysis. Scores from the STAI-T (Kenward-Roger: F(216, 3412) = 1.31, p = .002) and the PSWQ (F(216, 3412) = 1.26, p = .008) were significantly related to LPP modulation. STAI-T scores led to a better-fitting model of LPP activity (AIC = 14052, BIC = 14644) compared to PSWQ scores (AIC = 14059, BIC = 14701). The addition of both STAI-T and PSWQ scores, however, further improved the fit of the full model (Kenward-Roger: F(432, 2880) = 1.28, p < .001), and both predictors were included in the LPP final model (Table 4.23). Mean LPP activity was moderately clustered across participants (ICC_{Participants} = .5), and the final model accounted for 71% of total variance ($\sigma^2 = 1.57, \tau_{00}$ for participants = 1.54). Most significant main effects and lower-order interactions were moderated by the five-way interaction between Stimulus type, Threat level, Participant sex, PSWQ scores and



Figure 4.27. Grand average LPP waveforms for birth control females (top) and males (bottom), averaged across central-parietal and parietal electrodes close to the midline. Images of firearms, reptiles and humans are categorised by threat level (i.e., high threat, moderate threat, neutral).

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Figure 4.28. Grand average LPP waveforms for follicular phase (top) and luteal phase (bottom) females, averaged across central-parietal and parietal electrodes close to the midline. Images of firearms, reptiles and humans are categorised by threat level (i.e., high threat, moderate threat, neutral).

STAI-T scores reaching significance, F(12, 3695) = 2.77, p < .001 (Appendix K). Mean amplitudes were more strongly clustered in the reptile model compared to the firearm and human models (Table 4.24).

Firearms. The main effect of Threat level was significant, F(2, 1165) = 80.86, p < .001, $\beta_{MOD} = -0.92$ [-0.5, -1.35], $\beta_{NEU} = -1.23$ [-0.8, -1.66], and was qualified by significant interactions between Threat level and Participant sex, and between Threat level, STAI-T scores and PSWQ scores (Table 4.25). There were weak, positive and significant correlations between LPP amplitude and scores for the PSWQ and the STAI-T for images of aimed handguns (Bonferroni-corrected $\alpha = .004$; STAI-T: r = .27; PSWQ: r = .18), unarmed handguns (STAI-T: r = .24; PSWQ: r = .15) and water pistols

Table 4.23. R notation for the final and breakdown model estimated for LPP meanamplitudes. Abbreviations for factors are provided at the bottom of the table.

		R-notation		
F' allow del	lmer(LPP~ Sag*Cor + Stin	n*Sag + Cor*Sex*ST	AI-T + Cor*Sex*PSWQ +	
Final model	Cor*STAI-T*PSWQ + Sex*Sag*STAI-T*PSWQ + Stim*Thr*Sex*STAI-			
	T*PSWQ + (~1 Participant	(), Ex1_LPP)		
	*Sex*PSWQ + Cor*STAI-			
Breakdown model	lel T*PSWQ + Sex*Sag*STAI-T*PSWQ + Thr*Sex*STAI-T*PSWQ +			
	(~1 Participant), Ex1_LPP)			
Stim = Stimulus type	Sag = Sagittal location	Cor = Coronal site	PSWQ = worry scores	
Thr = Threat level			STAI-T = trait anxiety scores	

Table 4.24. *Fit statistics for the firearm, reptile and human models estimated to break down the LPP final model.*

	ICC (Participants)	Total variance (Ω^2)	Within-subject variance (σ ²)	Between-subject variance (τοο)
Firearms	.55	.73	1.27	1.55
Reptiles	.61	.76	1.25	1.96
Humans	.54	.76	1.6	1.86

Table 4.25. Parameter information for significant two-way and three-way interaction s involving Threat level in the LPP firearm model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Thr*Sex	<i>F</i> (6, 1165) = 4.21***	
ref. High threat: BC female	Moderate: Male	-0.95 [-0.39, -1.52]***
	Moderate: Follicular	-0.52 [0.1, -1.14]
	Moderate: Luteal	-0.3 [0.37, -0.97]
	Neutral: Male	-0.39 [0.17, -0.95]
	Neutral: Follicular	0.56 [1.18, -0.06].
	Neutral: Luteal	0.49 [1.16, -0.18]
Thr*Sex*STAI-T	<i>F</i> (6, 1165) = 2.21*	
ref. High threat: BC female	Moderate: Male	-0.07 [0.01, -0.15].
	Moderate: Follicular	-0.06 [0.03, -0.15]
	Moderate: Luteal	-0.05 [0.04, -0.14]
	Neutral: Male	-0.1 [-0.02, -0.18]**
	Neutral: Follicular	0.002 [0.09, -0.09]
	Neutral: Luteal	-0.08 [0.01, -0.17].
Thr*STAI-T*PSWQ	$F(2, 1165) = 8.4^{***}$	
ref. High threat	Moderate threat	-0.004 [0.001, -0.01].
	Neutral	-0.002 [0.003, -0.01]

.1

(STAI-T: r = .22; PSWQ: r = .16, all ps < .001). This three-way interaction also confirmed that LPP activity was significantly larger for aimed handguns ($M_{LS} = 3.52$ [3.98, 3.06]) compared to unarmed handguns ($M_{LS} = 2.15$ [2.61, 1.69], $\beta = 1.37$ [1.59, -1.15]) and water pistols ($M_{LS} = 2.46$ [2.92, 2], $\beta = 1.06$ [1.28, 0.84], both ps < .001). The difference between unarmed handguns and water pistols in LPP modulation was also significant ($\beta = -0.31$ [-0.08, -0.53], p = .02).

The two-way interaction between Participant sex and Threat level was further moderated by a significant three-way interaction between these two factors and STAI-T



Figure 4.29. LS means for LPP mean amplitudes in the firearm model, categorised by threat level and participant sex ($M_{\text{STAI-T}} = 38.9$). Parameter estimates for LS differences between threat level for males, birth control females, follicular phase females and luteal phase females are shown (bottom). Vertical and horizontal bars denote 95% confidence intervals.

scores (Figure 4.29). The LPP activity of follicular phase females was reduced compared to that observed for males and the other two female groupings for handgun stimuli. There were also strong, positive and significant relationships between STAI-T scores and LPP amplitude in the follicular phase grouping for images of aimed handguns (Bonferroni-corrected $\alpha = .004$; r = .61), unarmed handguns (r = .56) and water pistols (r = .56, all ps < .001). The same positive relationships were observed in the male grouping; however, these were moderate for aimed handgun stimuli (r = .39, p < .001) and weak for images of unarmed handguns (r = .3, p = .001) and water pistols (r = .27, p = .003). LPP modulation was similar for males and birth control females, with aimed handguns eliciting significantly more positive LPP amplitude than unarmed handguns and water pistols. This same pattern of results occurred for luteal phase females, although the difference between aimed handguns and water pistols did not reach significance (see Figure 4.29). For follicular phase females, LPP activity was significantly reduced for unarmed handguns compared to images of aimed handguns and water pistol stimuli in the birth control female (r = -.26, p = .003) and luteal phase female (r = -.29, p = .005) grouping, though this correlation was only below the Bonferroni-corrected level of significance for birth control females.

Reptiles. The main effect of Threat level reached significance, F(2, 1165) = 40.89, p < .001, $\beta_{MOD} = -0.98$ [-0.55, -1.4], $\beta_{NEU} = -0.73$ [-0.31, -1.16], and was moderated by two significant three-way interactions and a significant four-way interaction between Threat level, Participant sex, STAI-T scores and PSWQ scores (Table 4.26). Attacking snakes evoked larger LPP activity for male compared to female participants, a difference that did not occur for non-attacking snake or turtle stimuli (all ps > .05, Figure 4.30). In the follicular phase grouping, there were strong to very strong positive relationships between LPP amplitude and scores from the PSWQ and the STAI-T for images of attacking snakes (Bonferroni-corrected $\alpha = .004$; STAI-T: r = .66; PSWQ: r = .7), non-attacking snakes (STAI-T: r = .64; PSWQ: r = .5) and turtles

Table 4.26. Parameter information for significant two-way and three-way interactions involving Threat level in the LPP reptile model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Thr*Sex*STAI-T	<i>F</i> (6, 1165) = 6.29***	
ref. High threat: BC female	Moderate: Male	0.01 [0.09, -0.06]
	Moderate: Follicular	0.17 [0.26, 0.08]***
	Moderate: Luteal	0.04 [0.13, -0.05]
	Neutral: Male	-0.09 [-0.01, -0.16]*
	Neutral: Follicular	0.12 [0.21, 0.03]**
	Neutral: Luteal	-0.03 [0.06, -0.12]
Thr*STAI-T*PSWQ	<i>F</i> (2, 1165) = 8***	
ref. High threat	Moderate threat	-0.001 [0, -0.01]
	Neutral	-0.002 [0, -0.01]
Thr*Sex*STAI-T*PSWQ	<i>F</i> (6, 1165) = 5***	
ref. High threat: BC female	Moderate: Male	-0.001 [0.005, -0.01]
	Moderate: Follicular	-0.01 [-0.003, -0.02]**
	Moderate: Luteal	0.0001 [0.01, -0.01]
	Neutral: Male	0.001 [0.01, -0.01]
	Neutral: Follicular	-0.01 [-0.01, -0.02]***
	Neutral: Luteal	-0.0004 [0.01, -0.01]

.1

(STAI-T: r = .47; PSWQ: r = .44, all ps < .001). LPP activity for snake stimuli was also more positive than observed for turtle images in the follicular phase grouping, and only the difference between attacking snakes and turtles reached significance. For males and birth control females, images of attacking snakes evoked significantly more positive LPP activity than those showing non-attacking snakes or turtles. In the male grouping positive, moderate and significant correlations were also found between STAI-T scores and LPP amplitude for snake images (Attack: r = .41; Non-attack: r = .39; both ps >.001). The same pattern of LPP activity observed for males and birth control females



Figure 4.30. LS means for LPP mean amplitudes in the reptile model, categorised by threat level and participant sex ($M_{\text{STAI-T}} = 38.9$, $M_{\text{PSWQ}} = 46.43$). Parameter estimates for LS differences between threat level for males, birth control females, follicular phase females and luteal phase females are shown (bottom). Vertical and horizontal bars denote 95% confidence intervals.

occurred for luteal phase females but was non-significant (see Figure 4.30). There were also moderate to strong negative associations between LPP amplitude and PSWQ scores in the luteal phase female grouping for images of attacking snakes (r = .46), non-attacking snakes (r = .39) and turtles (r = .47, all ps < .001).

Images of attacking snakes. Descriptive statistics were calculated to characterise the influence of STAI-T scores on sex-specific LPP modulation in response to images of attacking snakes. Participants were split into high and low STAI-T groupings based on the median score (Mdn = 37, IQR = 34-45). The high STAI-T group consisted of 36 participants (eight males, 12 birth control females, eight follicular phase females, eight luteal phase females) while the low STAI-T group contained 37 participants (nine males, nine birth control females, four follicular phase females, seven luteal phase females). The LPP amplitude of males (M = 5.72 [6.13, 5.31]) was noticeably larger than that observed for females (M = 4.12 [4.55, 3.69]) for attacking snakes in the high STAI-T grouping. For the low STAI-T grouping, however, the LPP activity of males (M = 3.83 [4.34, 3.32]) and females (M = 4.3 [4.69, 3.91]) was of equivalent magnitude for attacking snake stimuli.

Humans. The main effect of Threat level reached significance, F(2, 1165) = 134.53, p < .001, $\beta_{MOD} = -0.46$ [0.02, -0.94], $\beta_{NEU} = -2.79$ [-2.31, -3.27], and was qualified by a significant two-way interaction and two significant three-way interactions (Table 4.27). These lower-order interactions were further moderated by a significant four-way interaction between Threat level, Participant sex, STAI-T scores and PSWQ scores (Figure 4.31). The LPP activity of follicular phase females was reduced compared to males and the other two female groupings for images of human injury. In the follicular phase grouping, there were also strong and positive relationships between LPP amplitude and scores from the PSWQ and the STAI-T for images of severe injury (Bonferroni-corrected $\alpha = .004$; STAI-T: r = .47; PSWQ: r = .49), non-severe injury (STAI-T: r = .54; PSWQ: r = .58) and non-injured humans (STAI-T: r = .62; PSWQ: r = .55, all ps < .001). Similar relationships were observed for luteal phase females in relation to PSWQ scores, but these were moderate and negative for images of severe

Table 4.27. Parameter information for significant two-way and three-way interactions involving Threat level in the LPP human model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Thr*Sex	<i>F</i> (6, 1165) = 4.13***	
ref. High threat: BC female	Moderate: Male	0.39 [1.02, -0.24]
	Moderate: Follicular	0.23 [0.93, -0.46]
	Moderate: Luteal	0.76 [1.52, 0.004]*
	Neutral: Male	1.11 [1.74, 0.48]***
	Neutral: Follicular	1.47 [2.17, 0.78]***
	Neutral: Luteal	1.14 [1.89, 0.38]**
Thr*Sex*STAI-T	<i>F</i> (6, 1165) = 5.69***	
ref. High threat: BC female	Moderate: Male	0.01 [0.1, -0.07]
	Moderate: Follicular	0.03 [0.13, -0.07]
	Moderate: Luteal	-0.03 [0.07, -0.13]
	Neutral: Male	0.12 [0.21, 0.04]**
	Neutral: Follicular	0.27 [0.37, 0.17]***
	Neutral: Luteal	0.13 [0.23, 0.03]*
Thr*Sex*PSWQ	<i>F</i> (6, 1165) = 3.11**	
ref. High threat: BC female	Moderate: Male	-0.08 [-0.03, -0.13]**
	Moderate: Follicular	-0.02 [0.05, -0.09]
	Moderate: Luteal	-0.01 [0.07, -0.09]
	Neutral: Male	-0.09 [-0.04, -0.14]***
	Neutral: Follicular	-0.02 [0.05, -0.09]
	Neutral: Luteal	-0.07 [0.01, -0.15].
Thr*Sex*STAI-T*PSWQ	<i>F</i> (6, 1165) = 5.11***	
ref. High threat: BC female	Moderate: Male	-0.003 [0.004, -0.01]
	Moderate: Follicular	-0.0001 [0.01, -0.01]
	Moderate: Luteal	0 [0.01, -0.01]
	Neutral: Male	-0.01 [-0.005, -0.02]***
	Neutral: Follicular	-0.02 [-0.01, -0.02]***
	Neutral: Luteal	-0.01 [-0.005, -0.02]**

.1 , <math>p < .05*, p < .01 **, p < .001 *** Thr: Threat level STAI-T: trait anxiety scores PSWQ = Worry scores



Figure 4.31. LS means for LPP mean amplitudes in the human model, categorised by threat level and participant sex ($M_{\text{STAI-T}} = 38.9$, $M_{\text{PSWQ}} = 46.43$). Parameter estimates for LS differences between threat level for males, birth control females, follicular phase females and luteal phase females are shown (bottom). Vertical and horizontal bars denote 95% confidence intervals.

injury (r = -.36, p < .001), non-severe injury (r = -.31, p = .002) and non-injured humans (r = -.35, p = .001). Moderate, negative and significant relationships were also found between STAI-T scores and LPP activity for images of severe injury (r = -.3, p = .003) and non-severe injury (r = -.34, p = .001) in the luteal phase female grouping. Outside of PSWQ and STAI-T scores, the amplitude of the LPP for non-injured human stimuli was of comparable magnitude between the male and the three female groupings (see Figure 4.31). Lastly, scenes of human injury elicited significantly more positive LPP activity than non-injured humans for male and female participants.

Discussion

The aim of Experiment 1 was to characterise sex-specific variation in stimuluslocked ERP activity elicited by the threat value of highly aversive images with distinct biological relevance and action disposition. Sex differences were observed in N1, N2 and LPP modulation, three components of the ERP previously connected to sex-specific variation. Amplitude modulation in the posterior P3b and temporal-occipital EPN were also evident in averaged waveforms. Female groupings and individual variation in trait anxiety, neuroticism, worry and state anxiety were related to sex-specific variation in N1, N2, P3b and LPP activity. Broad differences in ERP modulation were also observed for women prescribed hormonal contraceptives compared to women in the follicular or luteal phase of their ovarian cycle. The N1, the N2, and the P3b amplitude of birth control females were also relatively larger compared to that of men and other female participants. This ERP modulation was mirrored by reduced EPN activity for birth control females compared to other participants. When known sources of individual variation in men and women were allowed for (i.e., personality traits, the female ovarian cycle), the threat level of firearm, reptile and human stimuli contributed to sex differences in ERP modulation.

Sex-specific variation, threat value and evolutionary significance

Sex differences were evident throughout the picture processing stream in Experiment 1, and the biological relevance of firearm, reptile and human images exerted

CHAPTER 4

differential effects on the N1 activity of men and women. These results contrast to those reported by EEG studies that have found sex-specific variation in N1 and P1 activity (Gardener et al., 2013; Groen et al., 2013; Lithari et al., 2010; Lusk et al., 2015). The unexpected relationship between N1 activity and state anxiety levels indicates that sex differences in early picture processing are not specifically moderated by stress reactivity in men and women. Rather, N1 modulation in response to unpleasant and neutral images could reflect sex-specific variation in the transient fluctuation of physiological arousal associated with state anxiety. Findings from Experiment 1 also shed new light on the nature of sex differences in early N1 activity and the connection of this ERP modulation to motivational relevance.

The threat level of firearms, reptiles and humans influenced sex differences in amplitude modulation for the N2, the P3b and the LPP. The link between negative emotionality and sex differences in N2 amplitude was supported as this ERP modulation was related to individual variation in neuroticism. Effects observed in N2 amplitude for firearm images also corresponded to previous research findings, as high threat stimuli (i.e., aimed handguns) were differentiated from moderate threat stimuli (i.e., unarmed handguns) in N2 activity for women but not men (Li et al., 2008; Yuan et al., 2009). A different pattern of N2 modulation was observed for reptile images, as attacking and non-attacking snakes were differentiated in N2 activity for men and luteal phase women but not for birth control or follicular phase women. Sex differences in N2 amplitude were consistent with prior research for images of human injury (Groen et al., 2013; Proverbio et al., 2009), as N2 activity was more negative for women than men for images of severe and non-severe injury. The magnitude of this difference was also noticeably larger for women taking contraceptive medication compared to those women in the follicular or luteal phase of their ovarian cycle.

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Sex differences in late positivity both aligned and contrasted to those observed in previous EEG studies in response to unpleasant images. First, P3b or LPP activity was not localised to anterior locations (Gardener et al., 2013; Gasbarri et al., 2007; Han et al., 2008). Second, two sources of late positivity were observed in averaged waveforms, a finding supported by recent EEG studies (Foti et al., 2009; Gardener et al., 2013; Lusk et al., 2015; Matsuda & Nittono, 2015). Third, individual variation in worry was associated with modulation of the P3b and the LPP, but trait anxiety was uniquely linked to LPP modulation. This result supports a relationship between anxious traits, threat-related attention and participant sex. Fourth, the LPP activity of follicular phase women was reduced compared to men and other women for images of human injury, a result that corresponds to N2 modulation in one previous EEG study (Wu et al., 2014). Fifth, the motivational relevance of reptile, human or firearm images was largely consistent in LPP modulation across the male and three female groupings.

Similarities between men and women in EPN, N2, and P3b modulation were also apparent. Images of human injury and handguns elicited more negative EPN and reduced N2 activity than neutral equivalents in each stimulus category. Reptile stimuli did not moderate EPN amplitude, while N2 activity for attacking snakes was reduced compared to other reptiles. Regarding the EPN, these results contradict other reports on this ERP component indexing the emotional salience of reptile images (Van Strien, Christiaans, Franken, & Huijding, 2016; Van Strien, Eijlers, Franken, & Huijding, 2014). A reduction in N2 amplitude, however, has been associated with increasing levels of emotional salience (Olofsson & Polich, 2007; Palomba, Angrilli, & Mini, 1997). Patterns of P3b activity for the threat level of firearms and humans, two stimuli with high social relevance, were remarkably similar. In contrast P3b modulation for reptiles, a stimulus with low social relevance, was not directly related to the threat value

of reptiles. Patterns of LPP activity were comparable for images of firearms and reptiles; two stimuli whose level of threat is closely associated with attack intent. In contrast, high and moderate threat versions of human injury were not distinguished in LPP modulation.

Biological relevance and threat level in unpleasant images

To date, the threat value of unpleasant images has not been directly tied to P3 or LPP modulation in in non-clinical populations, although the threat-related qualities of images are implicated in the emotional salience of negative scenes (Bradley et al., 2014; Hajcak et al., 2012). Previous EEG investigations of sex-specific variation in late positivity have linked this ERP modulation to social relevance (Gonzalez-Liencres et al., 2016; Groen et al., 2013; Luo et al., 2014; Proverbio et al., 2009) or a female bias towards negative stimuli (Kemp et al., 2004; Li et al., 2008; Yuan et al., 2009). The results of the present EEG study support both perspectives, as threats with low or high biological relevance moderated sex-specific variation in N1, EPN, N2, P3b and LPP activity. These findings also highlight the need to characterise sources of emotional salience in unpleasant images aside from dimensional valence and arousal. In addition, the present findings support the contribution of threat value to the motivational relevance of highly aversive images for men and for women. These results also provide guidance for the future investigation of sex differences in picture processing, by showing that stimulus-level factors must be considered during image selection when examine individual-level factors such as an individual's biological sex.

The inclusion of participants as a random factor in analyses of ERP data succeeded in reducing sex-specific variation unrelated to the processing of aversive and neutral images. As predicted, participant sex was associated with individual variation in the four measured personality traits; alexithymia for the N1, neuroticism for the N2, worry for the P3b and the LPP, and trait anxiety for the LPP. These findings reiterate the importance of internal states to the threat value of highly aversive images. In contrast to predictions, however, individual variation in state anxiety was strongly related to N1 and EPN modulation. Though an unexpected finding, state anxiety has previously been implicated in attention allocation towards threat (Bishop, Duncan, & Lawrence, 2004; Fox, Russo, Bowles, & Dutton, 2001; Mogg, Holmes, Garner, & Bradley, 2008). Given that levels of state anxiety are thought to be context-dependant rather than stable (Bishop, 2007; Endler & Parker, 1990), the association between state anxiety and modulation of the N1 and the EPN could be driven primarily by physiological arousal rather than picture processing. Alternatively, personality traits more closely related to stress reactivity, such as neuroticism, worry and trait anxiety, could be more instrumental in endogenous rather than exogenous ERP activity.

The influence of the female ovarian cycle on picture processing has been investigated in many EEG and fMRI studies. However, the effect of hormonal contraceptives on this process has rarely been examined⁵. In the present study, it was unclear whether the broad differences between birth control women and the other female groupings in ERP activity were directly related to picture processing. For instance, the use of hormone-based contraceptives by women is associated with below average levels of testosterone, in addition to altered progesterone and oestrogen levels (Zimmerman, Eijkemans, Coelingh-Bennink, Blankenstein, & Fauser, 2014). Future research should be directed to replicate the effects related to hormonal contraceptive use. In relation to picture processing, these hormone-based medications may also indirectly affect attention allocation towards aversive images. Utilising an experimental

⁵ Notable exceptions include Petersen and Cahill (2015), Becker, Creutzfeldt, Schwibbe and Wuttke (1982) and Wuttke et al. (1975).

paradigm that more directly addresses differences between men and women in the threat value of attack intent or the passive vulnerability of human injury is one such avenue of investigation.

Chapter 5 - EXPERIMENT 2

Sex differences in response selection towards images of attack with different biological relevance

The threat value of images that show attack intent may differ between men and women due to sex differences in the motivational relevance of these stimuli for male and female individuals. In Experiment 2 the aim was to test whether this sex-specific variation is reflected by ERP activity in response to highly aversive images that show attack intent. In Experiment 1 sex differences in stimulus-locked ERP modulation occurred for attack versions of snake and handgun stimuli. The presence or absence of attack intent in reptile and firearm images also led to differential modulation of the N1, the N2 and late positive components in male and female individuals. These results suggest that sex differences in defensive motivation are influenced by the action disposition of a stimulus and that biological relevance moderates this relationship in picture processing. Moreover, sex-specific variation in ERP activity may depend on the type of response that is required towards the aversive image. The first of two EEG studies, Experiment 2, exploring the relationship between sex-specific variation, response selection and motivational relevance will be detailed in the present chapter.

The background to the depiction of attack intent will be reviewed briefly first, followed by a discussion of evidence which indicates that the motivational relevance of images that show attack intent varies between men and women. Next, an EEG study addressing the effect of biological relevance on sex differences in response selection towards attack images will be described. Many EEG studies which report sex-variation due to unpleasant images involve active engagement with the task at hand, such as direct responses towards target stimuli (Li et al., 2008; Yuan et al., 2009), emotional regulation strategies (Cai, Lou, Long, & Yuan, 2016; Gardener et al., 2013), affective

ratings (Gonzalez-Liencres et al., 2016; Han et al., 2008; Luo et al., 2014), or even the presence of negative stimuli as distractors (Groen et al., 2013; Proverbio et al., 2009). Experimental paradigms which include responses towards images in context may be necessary to elicit the full range of sex-specific variation in ERP activity towards negative stimuli as this strategy is more akin to attention allocation in a real-world environment.

Attack intent is the action disposition most often associated with threat-related attention in picture processing. Whether in the name of self-defence or more devious aims, the depiction of aggression in humans and animals implies an intent to inflict harm. Supporting this, ERP and fMRI evidence indicates that attack intent is processed differently compared to other types of negative stimuli (Carretié et al., 2011; Kveraga et al., 2014; Lu et al., 2015; Schienle, Schäfer, Stark, Walter, & Vaitl, 2005; Wheaton et al., 2013). Attack intent is signalled by a complex array of stimulus-level factors; meaning, signs of physical attack are more often associated with some stimuli compared to others (e.g., big cat vs. kitten, snake vs. turtle, adult human vs. baby). When scenes of threat are employed in the visual search paradigm, for instance, stimulus-level factors other than physical attack are typically prioritised⁶. For instance, an individual's familiarity with the threatening stimulus influences responses to the visual search task (Broeren & Lester, 2013; LoBue, 2010; Purkis, Lester, & Field, 2011), and fear-relevant animals are not necessarily detected faster than fear-irrelevant animals (Lipp, 2006; Lipp, Derakshan, Waters, & Logies, 2004), even when the former are shown in attack position (Tipples, Young, Quinlan, Broks, & Ellis, 2002).

⁶ Two exceptions are Quinlan and Yue (2015) and Masataka et al. (2010). Quinlan and Yue employed physically threatening and non-threatening versions of cats and dogs as targets in a speeded detection task and a classification task. Masataka et al. used two versions of snake stimuli as targets in a visual search task; images in which the snake was in a resting pose, or images with snakes in a striking position.

To date, the results of three studies indicate that men and women respond differently to images of attack intent (Kring & Gordon, 1998; Schienle et al., 2005; Sulikowski & Burke, 2014). First, Kring and Gordon (1998) found a trend for larger SCRs in men than women while watching highly aversive film-clips. These stimuli featured acts of potential violence such as murderous intent, racism, and a massacre. Second, Schienle et al. (2005) reported that fear-relevant images evoked a greater BOLD signal change for men compared to women in the bilateral amygdala and the left fusiform gyrus, a sex difference that was not found when disgust-eliciting images were contrasted to neutral stimuli. Disgust images included scenes of maggots, dead bodies, and unsanitary environments (e.g., garbage pile, vomit), while fear-relevant images consisted of aggressive animals (e.g., sharks, lions) or humans armed with weapons (e.g., knives, firearms). Third, Sulikowski and Burke (2014) found that men responded to images of artificial weapons (i.e., guns, knives) faster than women in a visual search task when these targets were surrounded by neutral household items. This sex difference was not found for non-weapon targets (i.e., staplers, butter knife).

It is unclear whether the biological relevance of prototypical stimuli contributed the results observed by Kring and Gordon (1998), Schienle et al. (2005) or Sulikowski and Burke (2014). In reference to their own findings, Schienle et al. suggest that attack intent is more salient to men than women due to the greater motivational relevance of aggressive cues to men, a sex difference possibly related to the susceptibility of male and female individuals to stress-eliciting stimuli. Responses towards attack intent have not been directly tied to stress reactivity but are implied in the connection between anxiety and threat-related attention (Bar-Haim et al., 2007; Cisler & Koster, 2010). Several behavioural studies that have focused on individual variation in trait anxiety have employed a diverse range of images to denote threat, such as angry faces, human

injury, dangerous animals, and humans armed with weapons (e.g., Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006; Leleu, Douilliez, & Rusinek, 2014; Mogg et al., 2004; Waters, Nitz, Craske, & Johnson, 2007). There remains a need to determine the role of threat value in attention allocation towards aversive images with clear connotations of attack intent for male and female individuals.

The aim of Experiment 2 was to investigate sex differences in response selection towards images of attack. Men and women completed a modified Flanker task as behavioural and EEG data were recorded. Stimuli with distinct biological relevance, reptiles and firearms, were used to construct congruent and incongruent arrays. These stimuli were chosen to represent prototypical stimuli with high or low biological relevance (Blanchette, 2006; Brosch & Sharma, 2005; C. Brown et al., 2010; Fox et al., 2007). Images with an explicit human presence were not employed given the overwhelming presence of these stimuli, including angry faces and human injury, as threat cues in previous research. Scenes showing attacking snakes or aimed handguns were matched by neutral images of passive turtles and unarmed water pistols. As in Experiment 1, individual variation in stress reactivity was gauged by measuring participant levels of trait anxiety, worry, neuroticism and alexithymia. To further elucidate the effect of hormonal contraceptives on ERP modulation, only females taking this form of medication were recruited for Experiment 2.

It was anticipated that sex-specific variation due to biological relevance and attack intent would be evident in behavioural and ERP data. The Flanker task is widely used to examine ERP indices of response selection towards non-affective, simple stimuli such as alphabetic letters and arrows (Folstein & Van Petten, 2008; Kopp, Rist, & Mattler, 1996; Larson, Clayson, & Clawson, 2014). In several cases the paradigm has been modified to include realistic faces to examine behavioural responses or stimuluslocked ERP amplitude towards emotional expressions (Dong, Yang, & Shen, 2009; Liu, Xiao, & Shi, 2013; Moser, Huppert, Duval, & Simons, 2008; Munro et al., 2007). Based on these previous findings it was predicted that performance on the current Flanker task would be signalled by behavioural responses and stimulus-locked modulation in early, middle and late-occurring ERP activity. To date, response-locked error-related negativity (ERN) and correct-related negativity (CRN) have been examined by two previous studies that have utilised the image Flanker task (Moser et al., 2008; Munro et al., 2007). In accordance with these findings, response-locked CRN modulation was expected to occur in ERP activity elicited by the current Flanker task.

Method

Participants

EEG data was collected from 43 volunteers (21 male) who were recruited, reimbursed and excluded in the same manner as described in Experiment 1. All participants completed the general medical history questionnaire, the PSWQ, the TAS-20, the IPIP5F-100 and the STAI before EEG testing. In the final sample, participants were predominantly right-handed (seven left-handed), had either normal or corrected-tonormal vision, and were aged between 18 and 34 years old ($M = 23\pm0.68$). One female made errors on more than 80% of trials for two incongruent conditions during EEG testing, leaving 21 females and 21 males with viable EEG data. All female participants were currently prescribed some form of hormonal contraceptive medication. One woman was implanted with an intrauterine hormonal device (Mirena, 52 mg levonorgestrel) and another three with progestogen-only rods (Implanon, 68 mg etonogestrel). The remaining 16 women were taking the contraceptive pill (Table 5.1). Ethical procedures were in accordance with those described for Experiment 1 (also see Digital Appendix A). Table 5.1. Combined oral contraceptives prescribed to 16 women recruited for Experiment 2. Information is categorised by the brand name most often provided by participants. Alternative brand names, the number of females and the active hormonebased ingredients are also provided.

Pill brand	Alternative names	No. of females	Active ingredients
	Micronelle-20ED,		Levonorgestrel (synthetic progesterone)
Levlen ED	Microgynon-30ED,	11	and ethinyloestradiol (synthetic
	Monofemme		oestrogen)
Diana 25ED	NI/A	4	Cyproterone acetate (synthetic
Diane-55ED	N/A	4	progesterone) and ethinyloestradiol
National 20 days	NI/A	1	Norethisterone (synthetic progesterone)
Normin 28 day	1N/A	1	and ethinyloestradiol

Stimuli and Materials

Images. Congruent and incongruent Flanker arrays were constructed using 40 images⁷, 20 of which featured reptiles and the remaining 20 firearms. Images were chosen from a larger pool of 260 images rated for valence, arousal and threat by seven male and seven female volunteers (Appendix D, see Experiment 1 for full details). Ten images in each stimulus category were unpleasant and high-arousing, while the remaining ten were neutral and low-arousing. Reptile and firearm stimuli were the same as shown in relation to high threat and neutral images in Experiment 1. Reptile images consisted of attacking snakes lunging forward with bared fangs or passive turtles with closed mouths (Figure 5.1). Firearm images showed handguns aimed by human hands at the observer of the scene or unarmed water pistols. Attacking snakes and aimed handguns were rated as significantly more unpleasant, arousing, and threatening than neutral images of turtles and water pistols (Bonferroni-corrected, all *ps* < .002; Appendix E).

⁷ IAPS images: Snakes - 1040, 1101, 1050, 1051, 1052, 1070, 1114, 1120, Handguns - 6230, 6260, 6263



Figure 5.1. Examples of aimed handgun, water pistol, attacking snake and turtle images selected to construct arrays for the modified Flanker task. Shown images are sourced from the Internet.

Flanker task. Images were resized to 314x235 pixels and converted to .jpeg format. In a typical Flanker task participants indicate if a target stimulus is congruent (> >>>) or incongruent (>><>>) to surrounding flankers (Eriksen & Eriksen, 1974). Images were used as Flanker stimuli, and the standard Flanker paradigm was modified to include two, rather than one, levels of incongruence. Each Flanker array consisted of one central target image and four distractor images (Figure 5.2). In each incongruent array, target and distractor images were mismatched on stimulus type, threat level, or both of these characteristics. The task was run using Presentation software to control stimulus timing and record behavioural data. Each trial began with a white fixation cross that appeared for 1000ms (Figure 5.3). The Flanker array was then presented and remained onscreen until the participant responded, or 4000ms had elapsed. Each array was shown in the centre of a dark grey background. Participants indicated whether the target image was of the same or different category to the distractor images (i.e., aimed handguns, water pistols, attacking snakes, or turtles). The next trial began after an



Figure 5.2. Symbol representation of 16 congruency conditions for firearm (top) and reptile (bottom) stimuli. For each distractor type arrays are shown in the order of congruent, incongruent threat level, incongruent stimulus type, and then incongruent both. Target and distractor images were randomly selected from the appropriate image category, and no image appeared more than once in any single array.



Figure 5.3. Sequence of trials within the modified Flanker task. Button labels for congruent or incongruent responses were included underneath each Flanker array when presented (not shown in figure).

interstimulus interval of 500ms.

Flanker array congruency. Congruent and incongruent arrays were presented with equal probability, with 50% of arrays being congruent and the other 50% incongruent. Each image featured as a congruent target 12 times and as an incongruent target 12 times, yielding a total trial count of 960 (480 congruent, 480 incongruent). The target image was randomly selected from the appropriate image category. Four distractor images were drawn from the relevant image category with approximately equal probability. At no time did any one image appear more than once in any single Flanker array, either as a target or in more than one distractor position. For congruent arrays, the stimulus type and threat level of the five presented images were matched (e.g., five different attacking snake images). The three types of incongruent arrays possible for each of the four image categories were classified based on the distractor images in the array (Figure 5.2). This arrangement produced 40 trials for each of the 12 incongruent conditions. For instance, incongruent threat arrays for attacking snakes were comprised of a neutral turtle target mismatched to snake distractors. Incongruent stimulus arrays featured attacking snake distractors mismatched to an aimed handgun target, while incongruent both arrays showed attacking snake distractors mismatched to a neutral water pistol target.

EEG recording and processing

EEG data were collected and processed using the same equipment, acquisition methods and computer programs described in Experiment 1. Stimulus-locked and response-locked epochs were generated for average waveforms in BESA 6. Epochs were time-locked to the onset of the Flanker array or the participant's response. The two epoch types were computed for a duration of 1200ms, from -200ms to 1000ms poststimulus or post-response. For each participant, no less than 80% of trials ($n \ge 30$) were

accepted for each of the 16 congruency conditions.

Procedure

The modified Flanker task was performed in the same conditions detailed for Experiment 1. Instructions for the task were shown on-screen and explained by the supervising researcher. Participants were reminded to remain still and relaxed during EEG recording. Ten practice trials featuring images of humans, neutral everyday objects (e.g., books, umbrella), or a combination of these stimuli⁸ familiarised the participant with the task. Participants then completed the Flanker task across four blocks of 240 trials each as EEG was recorded. The order of Flanker trials was randomised, and selfpaced breaks were scheduled after the end of each block. Participants were instructed to respond to the task as quickly, but as accurately, as possible. The entire task took approximately 45 minutes to complete.

Design and data analysis

A 2[Participant sex: male, female] x 2(Stimulus type: firearm, reptile) x 2(Threat level: attack, neutral) x 4(Congruency: congruent, incongruent threat, incongruent stimulus, incongruent both) mixed design was followed. Procedures for preparation and analysis of behavioural and ERP data were the same as reported for Experiment 1 with one exception, which was that reaction times were analysed with the lmer function from lme4 (Bates et al., 2014). Again, the level of significance was set at $\alpha = .05$, and all values were rounded to two decimal places.

Congruency effects. The number of congruent trials for each distractor image outnumbered those for the 12 incongruent conditions (i.e., 120 vs. 40). Congruent conditions were included in analyses to ease interpretation of results. Congruency

⁸ **IAPS images:** 2191, 2235, 2272, 2384, 2480, 2488, 2514, 2515, 2870, 7038, 7040, 7061, 7081, 7090, 7150, 7165, 7170, 7175, 7211, 7632.

effects for the modified Flanker task were checked by comparing responses to all congruent trials with those for all incongruent trials in behavioural data for the overall, male and female groupings. Overall reaction times for arrays featuring aimed handgun, water pistol, attacking snake, or turtle distractors were also calculated.

Behavioural data. Responses faster than 150ms and slower than 1809ms were excluded from analysis. The non-recursive moving criterion method for outlier removal was used to define the upper 1809ms limit (Selst & Jolicoeur, 1994). This cut-off is two and a half standard deviations above the mean reaction time of all participants (M = 868.27, SD = 376.19). Reaction times faster than 150ms are anticipatory and represent an attentional error for the Flanker task (Jensen, 2006). Based on these criteria, the reaction times of one male participant were excluded from analyses. For the remaining 20 males and 21 females, 0.06% of raw data was comprised of missing values. Statistical analyses were performed on 96.98% of raw behavioural data. Hit rates were calculated to denote accuracy, while reaction times were computed for correct responses to the modified Flanker task. At least 70% of trials for each condition were available to calculate reaction times for each participant. Hit-rates for each congruency condition were not analysed further. Reaction times were analysed in the same manner as described for ERP data, excluding the addition of electrode position factors.

ERP data. Only correct responses to the modified Flanker task were included in the analysis of ERP data. Average waveforms for stimulus-locked and response-locked epochs were computed from 64 channels for the overall, male and female groupings (Appendix F). Error trials from response-locked ERP data were used to generate an average waveform to identify ERN activity corresponding to the timing of the CRN.

Linear mixed effects analysis. See Experiment 1 for full details of linear mixed

effects analysis in the present research. The inclusion of the random Participant intercept was supported by the fit of the base and final models being significantly better than the null model for each dataset (Appendix H, also see Digital Appendix C). Fixed factors for Participant sex, Stimulus type, Threat level, Congruency, Sagittal location and Coronal site were added to the base model first. Questionnaire scores with no meaningful effects on the dataset were discarded, and no more than two personality traits were included in any one final model. The AIC, BIC and loglikelihood values of estimated models can be found in Appendix I. For ERP data descriptions of average waveforms by way of Stimulus type, Threat level and Congruency are provided first, followed by an overview of model estimation, fit statistics and any breakdown procedures applied to the final model. Interactions involving the Coronal site or Sagittal location factors were again only reported if these interacted with the image-related factors of Stimulus type, Threat level, or Congruency.

Results

Behavioural data

Questionnaire scores. The variance of PSWQ, TAS-20, STAI and neuroticism scores were approximately equal (Digital Appendix C). All trait scores were normally distributed apart from those from the STAI-S. Full analyses for the five IPIP5F-100 dimensions can be found in Appendix B. PSWQ, TAS-20 and neuroticism scores were analysed with three separate 2[Participant sex: male, female] independent samples t-tests. Scores from the STAI-S and the STAI-T were analysed with two separate non-parametric 2[Participant sex: male, female] Mann-Whitney U tests with continuity corrections.

The PSWQ. The mean score for the PSWQ was 46.1 (*SE* =1.95), and internal reliability was very strong for this questionnaire score (α = .94). Positive, moderate and

significant correlations occurred between PSWQ scores and those from the two STAI subscales (Table 5.2). As found in Experiment 1, PSWQ scores were very strongly associated with scores for neuroticism. Women ($M = 52.52\pm2.39$) tended to score more highly on the PSWQ than men ($M = 39.67\pm2.39$). The significance of the Sex main effect was confirmed by statistical analysis, t(40) = 3.8, p < .001, d = 1.2.

The TAS-20. Internal reliability was very strong for the TAS-20 (α =.85), and the overall mean for the questionnaire was 48.07 (*SE* =1.71). Positive associations between TAS-20 scores and those from the two subscales of the STAI were significant but weak (Table 5.2). TAS-20 scores between men (*M* = 48.19±2.44) and women (*M* = 47.95±2.44) were comparable, *t*(40) = -0.07, *p* = .95, *d* = -0.02

Neuroticism. The average score for neuroticism was 37.43 (SE = 2.36). Similar to the PSWQ and the TAS-20, the Cronbach alpha value for emotional stability ($\alpha = .94$) indicated the internal reliability of neuroticism scores was very good. Positive and significant correlations occurred between neuroticism scores and scores from the two

	DGUUO		NT	STAI	
	PSWQ	1A5-20	Neuroticism	STAI-S	STAI-T
PSWQ	1				
TAS-20	.12	1			
Neuroticism	.7***	.18	1		
STAI					
STAI-S	.43**	.35*	.39*	1	
STAI-T	.53***	.38*	.68***	.57***	1

Table 5.2. Spearman rank correlation coefficients between scores from the PSWQ, the TAS-20, neuroticism and the two subscales of the STAI. P-value significance is located at the bottom left of the table.

p < .05*, p < .01 **, p < .001***

STAI subscales (Table 5.2). This relationship was moderate for the STAI-S and very strong for the STAI-T. Women ($M = 43.95 \pm 2.67$) reported higher neuroticism scores than men ($M = 30.91 \pm 3.38$), a difference that was found to be statistically significant, t(40) = 3.03, p = .004, d = 0.96.

The STAI. The average STAI-S score was 33.48 (*SE* =1.39; *Mdn* = 32.5, *IQR* = 25-40) and the mean STAI-T score was 39.93 (*SE* =1.49, *Mdn* = 38.5, *IQR* = 32-49). Cronbach alpha coefficients for the overall STAI (α =.94), as well as the STAI-S (α = .9) and the STAI-T (α = .91), indicated very strong internal reliability. Responses to the STAI-T and the STAI-S were also strongly correlated (Table 5.2). STAI-T scores were higher for females (*M* = 42.48±2.12; *Mdn* = 41, *IQR* = 35-50) than males (*M* = 37.38±1.97; *Mdn* = 37, *IQR* = 31-44), however this difference was non-significant, *U* = 158.5, $n_1 = n_2 = 21$, p = .12, r = .14. STAI-S scores were comparable between males (*M* = 32.38±2.07; *Mdn* = 41, *IQR* = 35-50) and females (*M* = 34.57±1.87; *Mdn* = 37, *IQR* = 31-44). Similar to STAI-T scores, the lack of a Sex main effect in STAI-S scores was confirmed by non-parametric testing, *U* = 183.5, $n_1 = n_2 = 21$, p = .24.

Accuracy. Hit-rates for congruent (M = 97.12%) and incongruent (M = 97.37%) Flanker arrays were approximately equal. This lack of difference between congruent and incongruent arrays was consistent for males ($M_{CONG} = 97.24\%$, $M_{INCONG} = 97.7\%$) and females ($M_{CONG} = 97.01\%$, $M_{INCONG} = 97.04\%$). Responses to congruent attacking snake arrays were slightly less accurate than those with turtle, aimed handgun or water pistol images (Table 5.3). Accuracy was slightly higher for incongruent arrays with aimed handgun (M = 97.64%) or water pistol (M = 98.48%) distractors than for incongruent arrays with attacking snake (M = 96.48%) or turtle (M = 96.82%) distractors. Errors were most common for arrays with mismatched turtles and attacking snakes (Table 5.3). Hit-rates for the remaining congruency conditions were above 96%.

Table 5.3. Mean hit-rates for each of the 16 congruency conditions in Experiment 2. Hit-rates are reported as percentages, and are categorised by the image category of the target and the distractors in the Flanker array. Congruent arrays are highlighted in light grey.

	Distractor images/Flankers			
Target image	Aimed handguns	Water pistols	Attacking snakes	Turtles
Overall				
Aimed handgun	97.34%	97.68%	97.81%	99.05%
Water pistol	96.34%	97.08%	98.56%	98.56%
Attacking snake	97.9%	99.06%	96.39%	92.79%
Turtle	98.77%	98.69%	93.19%	97.7%

Responses were most accurate for arrays with neutral distractors paired with targets mismatched on stimulus type and threat level (e.g., an attacking snake target with water pistol distractors, an aimed handgun target with turtle distractors).

Reaction time. Residuals from reaction time data were positively skewed, and a natural logarithm transformation was applied to this dataset. Following this, the distribution of residuals approached normality and possessed approximately equal variance (Digital Appendix C). Analyses were performed on transformed data and the natural logarithm reversed for reported results. Responses to congruent arrays ($M = 853.16\pm23.62$) were faster than to incongruent arrays ($M = 883.44\pm23.54$, Figure 5.4). The reaction times of males and females were similar for congruent ($M_F = 818.19\pm14.37$, $M_M = 815.05\pm15.65$) and incongruent ($M_F = 842.27\pm8.32$, $M_M = 842.98\pm9.51$) Flanker arrays. Congruent aimed handgun, water pistol and turtle images elicited faster reaction times than their respective incongruent arrays (Figure 5.4). However, participants were slower to respond to congruent attacking snakes compared to arrays with incongruent attacking snake distractors. Moderate, positive and

significant correlations between TAS-20 scores and reaction times were found for congruent (r = .39, p < .001) and incongruent (r = .36, p < .001) conditions. These relationships were not driven by any one distractor type or congruency condition.

Linear mixed effects analysis. Scores for Neuroticism (Kenward-Roger: F(32, 543) = 1.5, p = .04) and the TAS-20 (F(32, 543) = 1.74, p = .008) were significantly related to reaction time data, and both Neuroticism and TAS-20 predictors were retained in the final model (Table 5.4). Reaction times were very strongly related across participants (ICC_{Participants} = .86), and the total variance accounted for by the final model was very high ($\Omega_0^2 = .91, \sigma^2 = 0.003, \tau_{00}$ for participants = 0.02). To characterise effects



Figure 5.4. Descriptive means for reaction times categorised by Flanker congruency for firearm (left) and reptile (right) distractors. Attack images are shown to the left of each bar graph (i.e., aimed handguns, attacking snakes), and neutral images are on the right (i.e., water pistols, turtles). Vertical bars denote standard errors.

Table 5.4. *R* notation for the final model estimated for reaction times. Abbreviations for factors are provided at the bottom of the table.

		R-notation	
Final model	lmer(RT~ Stim*Thr*Cong + Cong*Sex*TAS-20 + Cong*Sex*Neur + (~1 Participant), Ex2_RT)		
Stim = Stimulus type Thr = Threat level	Cong = Congruency	TAS-20 = alexithymia scores	Neur = neuroticism scores

solely related to TAS-20 scores, participants were grouped based on whether their TAS-20 score was above or below 48 ($M = 48.15\pm1.75$). The high TAS-20 grouping was comprised of 19 participants (9 male) with an average TAS-20 score of 57.63 (*SE* =1.75). Twenty-one participants (11 males) were included in the low TAS-20 grouping ($M = 39.57\pm1.29$). One female participant was not included in either grouping as her TAS-20 score was 48. Spearman rank correlation coefficients with Bonferroni corrections were calculated using non-transformed reaction times to characterise the influence of Neuroticism or TAS-20 scores in relevant interactions.

Main effects for Stimulus type ($F(1, 585) = 341.89, p < .001, \beta = 0.17$ [0.19, 0.14]), Threat level ($F(1, 585) = 109.87, p < .001, \beta = -0.003$ [0.02, -0.03]) and Congruency ($F(3, 585) = 148.91, p < .001, \beta_{THR} = 0.04$ [0.06, 0.01], $\beta_{STIM} = 0.08$ [0.1, 0.05], $\beta_{BOTH} = 0.1$ [0.13, 0.07]) were significant. The TAS-20 main effect also reached significance, $F(1, 35) = 7.54, p = .01, \beta = 0.01$ [0.01, 0.001], and there was a positive, moderate and significant correlation between TAS-20 scores and reaction times (r = .37, p < .001). Participants from the low TAS-20 grouping (M = 787.09 [803.05, 771.44]) responded faster to Flanker arrays than participants from the high TAS-20 grouping (M = 867.8 [881.11, 854.69]). All main effects, apart from that for TAS-20 scores, were qualified by one or more of three significant two-way interactions in the reaction time final model (Table 5.5). These three two-way interactions were further moderated by at least one of three three-way interactions that reached significance. Two of these three-way interactions indicated that the reaction times of males and females towards congruent and incongruent arrays were related to individual variation in Neuroticism and TAS-20 scores (Figure 5.5).

Males responded more quickly than females to congruent and incongruent both arrays (both ps > .05). There were also moderate correlations between reaction times

Table 5.5. Parameter information for significant two-way interactions involving Threat level and Congruency in the reaction time final model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

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	Parameter	β [95% CI]	
Stim*Cong	F(3, 585) = 68.7 * * *		
ref. Firearm: CON	Reptile: THR	-0.14 [-0.11, -0.17]***	
	Reptile: STIM	-0.17 [-0.14, -0.21]***	
	Reptile: BOTH	-0.01 [0.02, -0.05]	
Thr*Cong	<i>F</i> (3, 585) = 3.96**		
ref. Attack: CON	Neutral: THR	-0.03 [-0.001, -0.07]*	
	Neutral: STIM	-0.08 [-0.05, -0.12]***	
	Neutral: BOTH	-0.03 [0, -0.07].	
Cong*Neur	F(3, 585) = 4.38 * *	<i>F</i> (3, 585) = 4.38**	
ref. CON	THR	0.002 [0.003, 0.0003]*	
	STIM	0.002 [0.004, 0.001]**	
	BOTH	-0.0001 [0.001, -0.002]	
Stim*Thr*Cong	<i>F</i> (3, 585) = 11.29***		
ref. Firearm: Attack: CON	Reptile: Neutral: THR	0.1 [0.15, 0.05]***	
	Reptile: Neutral: STIM	0.13 [0.18, 0.08]***	
	Reptile: Neutral: BOTH	0.11 [0.16, 0.06]***	
Sex*Cong*TAS-20	<i>F</i> (3, 585) = 8.33***		
ref. Female: CON	Male: THR	0.004 [0.007, 0.002]***	
	Male: STIM	0.005 [0.007, 0.003]***	
	Male: BOTH	0.001 [0.003, -0.001]	
Sex*Cong*Neur	<i>F</i> (3, 585) = 5.93***		
	Male: THR	-0.0004 [0.001, -0.002]	
	Male: STIM -0.002 [0, -0.003]		
	Male: BOTH	0.002 [0.004, 0.0005]*	
.1 < p < .05., p < .05*, p < .01 **, p <	.001*** Stim: Stimulus type Thr: Th	reat level TAS-20 = alexithymia scores	

Cong: Congruency, CON = Congruent, THR = Incongruent threat, STIM = Incongruent stimulus,

Neur = neuroticism scores

BOTH = Incongruent both

and TAS-20 scores for males (Bonferroni-corrected α = .006; *r* = .41) and females (*r* = .37, both *p*s < .001) for congruent arrays. In the male grouping, however, similar relationships were observed for responses towards arrays with distractors that were incongruent threat (*r* = .43), incongruent stimulus (*r* = .49) or incongruent both (*r* = .44, all *p*s < .001). Outside of TAS-20 scores, reaction times were significantly slower to incongruent both arrays compared to arrays from the other congruency conditions; a finding that was consistent for male and female participants. Correlations between reaction times and Neuroticism scores were of lesser magnitude compared to those for TAS-20 scores, and none were below the Bonferroni-corrected level of significance. The final three-way interaction between Stimulus type, Threat level and Congruency



Figure 5.5. LS means for reaction times categorised by congruency and participant sex ($M_{\text{NEUR}} = 35.24$, $M_{\text{TAS-20}} = 48.15$). Parameter estimates for LS differences between incongruent both arrays and other congruency conditions for females and males are shown (bottom). Vertical and horizontal bars denote 95% confidence intervals.

indicated that arrays with congruent or incongruent both firearm distractors led to significantly faster reaction times than arrays with reptile distractors in the same congruency conditions (Figure 5.6). Responses towards congruent turtles were significantly faster than to congruent attacking snakes, a difference that did not occur



Figure 5.6. LS means for reaction times to congruent and incongruent arrays, categorised by stimulus type and threat level. Parameter estimates for LS differences between attack and neutral distractors within each stimulus type are shown, as well as those for reptile and firearm distractors of the same threat level. Vertical and horizontal bars denote 95% confidence intervals.

for arrays with incongruent both reptile distractors. Lastly, mismatched attacking snake and aimed handgun images led to significantly slower responses than those with mismatched turtle and water pistol images.

ERP data

Stimulus-locked activity for the anterior N1, the temporal-occipital EPN and the parietal LPP occurred in a similar time frame and location as reported in Experiment 1 (Figure 5.7). Mean amplitudes were derived from 90 to 150ms (anterior N1), 150 to 250ms (EPN), and 450 to 650ms (LPP) following the onset of Flanker arrays. No clear modulation of the N2 or the P3b were evident in averaged waveforms. Two other sources of stimulus-locked negativity were also identified in average waveforms (Appendix F). First, N1 activity in occipital regions localised to the midline was observed in a slightly later time frame compared to the anterior N1 (Figure 5.7). This ERP activity corresponds to reports of a posterior N1 at these same sites (Ernst et al., 2013; Gable & Harmon-Jones, 2012; Lithari et al., 2010; Smit, Posthuma, Boomsma, &



Figure 5.7. Approximate locations of ERP activity elicited by the modified Flanker task on a 64-channel Neuroscan Quik-cap. Activity for the anterior N1 (dark blue area), the occipital N1 (magenta area) and the MPN (light blue areas) are shown to the left, while activity for the LPP (yellow area), the EPN (green areas) and the CRN (orange area) are shown to the right.

De Geus, 2007; Vogel & Luck, 2000). Mean activity for the occipital N1 was computed from 120 to 170ms post-stimulus. Second, the EPN was followed by similar lateroccurring ERP modulation with a more anterior distribution, approximately 300-400ms following Flanker array onset (Figure 5.7). For simplicity, this ERP modulation was called the middle posterior negativity (MPN), and mean amplitudes for this negativity were derived from 290 to 390ms post-stimulus.

In response-locked average waveforms, CRN activity with an anterior distribution was identified (Figure 5.7). The CRN peaked at the time of the response to the Flanker task for most participants (Appendix F). The ERN and the CRN are typically maximal between the response itself and 100ms post-response (Gehring, Liu, Orr, & Carp, 2011). However, several task parameters can affect the latency of the ERN, and assumedly the CRN. These include the sensitivity of response devices to the speed of button presses (Gehring et al.) and stimulus presentation times. In each Flanker trial target and distractor images appeared at the same time, which may have impacted the latency of the CRN and ERN in response-locked ERP data. Mean amplitudes for the CRN were derived from a time-period of 100ms, from -50 to 50ms post-response. Results for the five types of stimulus-locked ERP activity will be described first, followed by details of the analysis performed on response-locked CRN amplitudes.

The anterior N1 (90-150ms). Mean activity for the anterior N1 was derived from the frontal-central electrodes FC1, FCz and FC2 and the central electrodes C1, Cz and C2. Congruent arrays did not appear to modulate anterior N1 activity (first row; Figure 5.8, Figure 5.9). For females, a turtle mismatched to attacking snake distractors led to more negative N1 amplitude than other incongruent threat arrays. In contrast, there was a lack of N1 modulation for male participants in the incongruent threat condition. Incongruent stimulus arrays with attacking snake or water pistol distractors



Figure 5.8. Grand average anterior N1 waveforms averaged across frontal-central and central electrodes for females. Congruency conditions are categorised based on the type of firearm (i.e., aimed handguns, water pistols) or reptile (i.e., attacking snakes, turtles) distractor featured in the Flanker array.





Figure 5.9. Grand average anterior N1 waveforms averaged across frontal-central and central electrodes for males. Congruency conditions are categorised based on the type of firearm (i.e., aimed handguns, water pistols) or reptile (i.e., attacking snakes, turtles) distractor featured in the Flanker array.



led to more negative N1 activity than other incongruent stimulus arrays for females (third row, Figure 5.8). In the same congruency condition, the N1 amplitude of an attacking snake target paired with aimed handgun distractors was reduced compared with other incongruent stimulus arrays for males at midline and right hemisphere sites (third row, Figure 5.9). Modulation of anterior N1 activity by incongruent both arrays was not clear for males. For females, arrays with an aimed handgun target paired with water pistol distractors evoked more negative N1 amplitude than other incongruent both arrays, particularly at midline sites (fourth row, Figure 5.8).

Linear mixed effects analysis. Approximately 60% of one male's anterior N1 data was above the upper 95% confidence limit ($M = -3.24\mu$ V, [0.12, -6.6]). After this male had been excluded, the final anterior N1 model was estimated with the data of 20 males and 21 females. Scores from the STAI-T (Kenward-Roger: F(192, 3410) = 1.19, p = .04) and STAI-S (F(192, 3410) = 1.19, p = .04) were significantly related to N1 modulation. The STAI-T predictor was selected over the STAI-S predictor in the final N1 model due to better model fit (AIC_{STAI-S} = 10184, AIC_{STAI-T} = 10166) despite a comparable number of interaction terms in each model variation (BIC_{STAI-T} = 10593, BIC_{STAI-S} = 10580). A model variation with both trait scores was not tested due to the strong relationship between STAI-T and STAI-S scores (Table 5.6). N1 activity was very strongly clustered between participants (ICC_{Participants} = .72), and the final model explained 70% of the total variance ($\sigma^2 = 0.72$, τ_{00} for participants = 1.89).

Main effects for Threat level (F(1, 3833) = 4.85, p = .03, $\beta = -0.09$ [0.1, -0.29]) and Congruency (F(3, 3833) = 4.26, p = .005, $\beta_{THR} = -0.19$ [0.01, -0.39], $\beta_{STIM} = 0.29$ [0.49, 0.09], $\beta_{BOTH} = 0.09$ [0.29, -0.11]) were significant, and also qualified by a number of significant two-way interactions (Table 5.7). The Threat level and Congruency factors also interacted significantly with Stimulus type or STAI-T scores in one or more

STAI-T = trait anxiety scores

	R-notation		
	K-notation		
	lmer(N1~ Stim*Thr*Cong*STAI-T + Stim*Sex*Cong*STAI-T +		
Final model	Thr*Sex*Cong*STAI-T+Stim*Thr*Sex+Sex*Sag*STAI-T+Stim*Sag+		
STAI-T*Cor + (~1 Participant), Ex2_N1)			
Stim = Stimulus type	Thr = Threat level Cong = Congruency Cor = Coronal site Sag = Sagittal location		

Table 5.6. R notation for the final model estimated for anterior N1 mean amplitudes.Abbreviations for factors are provided at the bottom of the table.

Table 5.7. Parameter information for significant two-way interactions involving Threat level and Congruency in the anterior N1 final model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]	
Stim*Thr	F(1, 3833) = 9.61**		
ref. Firearm: Attack	Reptile: Neutral	0.07 [0.31, -0.17]	
Stim*Cong	$F(3, 3833) = 5.71^{***}$		
ref. Firearm: CON	Reptile: THR	0.21 [0.48, -0.05]	
	Reptile: STIM	-0.36 [-0.1, -0.62]**	
	Reptile: BOTH	0.36 [0.63, 0.1]**	
Thr*Cong	<i>F</i> (3, 3833) = 13.11***		
ref. Attack: CON	Neutral: THR	0.34 [0.61, 0.08]*	
	Neutral: STIM	-0.38 [-0.12, -0.65]**	
	Neutral: BOTH	-0.28 [-0.02, -0.54]*	
Sex*Cong	$F(1, 3833) = 6.76^{**}$		
ref. Females: CON	Male: THR	0.39 [0.66, 0.12]**	
	Male: STIM	0.24 [0.51, -0.03].	
	Male: BOTH	0.1 [0.37, -0.17]	
Thr*STAI-T	F(1, 3833) = 6.62*		
ref. Attack	Neutral	0.01 [0.03, -0.01]	
Cong*STAI-T	$F(3, 3833) = 5.51^{***}$	F(3, 3833) = 5.51 ***	
ref. CON	THR	0.03 [0.05, 0.01]*	
	STIM	-0.01 [0.01, -0.03]	
	BOTH	-0.03 [-0.01, -0.05]**	
$1 < n < 05$ $n < 05^*$ $n < 01^{**}$	n < 0.01 *** Stim: Stimulus type Thr.	Threat level STALT - trait anxiety scores	

.1 , <math>p < .05, p < .01 **, p < .001 *** Stim: Stimulus type Thr: Threat level STAI-T = trait anxiety scores of the structure of the structure

Cong: Congruency, CON = Congruent, THR = Incongruent threat, STIM = Incongruent stimulus, Cor: Coronal site

three-way interactions (Table 5.8). Outside of these effects, Stimulus type was also found to interact significantly with Participant sex ($F(31, 3833) = 6.76, p = .009, \beta \beta =$ 0.21 [0.46, -0.04]), with STAI-T scores ($F(1, 3833) = 4.56, p = .003, \beta = 0.01$ [0.03, -0.01]), and with Sagittal location ($F(1, 3833) = 4.56, p = .03, \beta = -0.12$ [-0.01, -0.22]). The latter two-way interaction indicated that N1 amplitude was more negative for reptiles at central sites compared to frontal-central sites, however, this difference did not reach significance (p = .13, Figure 5.10). No modulation of the anterior N1 occurred for firearm stimuli by way of sagittal location.

Two-way interactions involving Threat level, Stimulus type or Participant sex were further moderated by a significant three-way interaction between these three factors, F(1, 3833) = 67.09, p < .001, $\beta = 0.05$ [0.06, 0.04] (Figure 5.11). The N1

Table 5.8. Parameter information for significant four-way interactions involving in the anterior N1 final model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Stim*Sex*Cong*STAI-T	F(3, 3833) = 2.97, p = .03*	
ref. Firearm: Female: CON	Reptile: Male: THR	0.01 [0.04, -0.02]
	Reptile: Male: STIM	0.03 [0.06, -0.01]
	Reptile: Male: BOTH	-0.04 [-0.01, -0.07]
Thr*Sex*Cong*STAI-T	$F(3, 3833) = 4.42^{**}$	
ref. Attack: Female: CON	Neutral: Male: THR	-0.01 [0.02, -0.04]
	Neutral: Male: STIM	-0.02 [0.02, -0.05]
	Neutral: Male: BOTH	-0.06 [-0.02, -0.09]***
Stim*Thr*Cong*STAI-T	<i>F</i> (3, 3833) = 13.11***	
ref. Firearm: Attack: CON	Reptile: Neutral: THR	0.34 [0.61, 0.08]*
	Reptile: Neutral: STIM	-0.38 [-0.12, -0.65]**
	Reptile: Neutral: BOTH	-0.28 [-0.02, -0.54]*

.1 , <math>p < .05, p < .01 **, p < .01 **, p < .001 *** Stim: Stimulus type Thr: Threat level STAI-T = trait anxiety scores Cong: Congruency, CON = Congruent, THR = Incongruent threat, STIM = Incongruent stimulus, BOTH = Incongruent both



Figure 5.10. LS means for anterior N1 mean amplitudes categorised by the stimulus type of distractor images and sagittal location. Parameter estimates for LS differences between frontal-central and central sites for firearm and reptile distractors are shown (top right). Vertical and horizontal bars denote 95% confidence intervals.

activity of males did not vary as a function of distractor type. For females, the amplitude of the anterior N1 was significantly more negative for arrays with water pistol distractors compared to those arrays with aimed handgun distractors. Arrays with turtle distractors also elicited significantly larger N1 amplitudes than those with water pistol distractors in the female grouping. Main effects and lower-order interactions involving Threat level, Congruency, Stimulus type, Participant sex and STAI-T scores were further moderated by three significant four-way interactions (Table 5.8). Overall there were negative, weak and significant correlations between the amplitude of the anterior N1 and STAI-T scores for males (r = -.26, p < .001), but not females (r = -.004, p = .85), and these associations were consistent in both four-way interactions involving Participant sex. These two interactions will be described first, followed by the interaction between Stimulus type, Threat level, Congruency and STAI-T scores.

Regarding Stimulus type, the congruency of arrays with firearm distractors did



Figure 5.11. LS means for anterior N1 mean amplitudes categorised by stimulus type, threat level and participant sex. Parameter estimates for LS differences between attack and neutral distractors are shown for males and females (bottom left). Vertical and horizontal bars denote 95% confidence intervals.

not appear to modulate N1 amplitude (Figure 5.12). For arrays with reptile distractors, the N1 activity of females was more negative than males (all ps > .05). One exception to this finding was the incongruent both condition, where the magnitude of this sex difference was negligible. For females, arrays with reptile distractors evoked more negative N1 activity than those with firearm distractors in the incongruent threat and incongruent both conditions. The former difference did not reach significance; however, the latter effect was significant. In relation to Threat level, incongruent threat arrays with attack distractors (i.e., a turtle with attacking snakes, a water pistol with aimed handguns) elicited significantly more negative N1 amplitude than arrays with neutral distractors in the same congruency condition for females (Figure 5.13). N1 modulation was also evident for arrays with targets and distractors mismatched on stimulus type and



Figure 5.13. LS means for anterior N1 mean amplitudes categorised by threat level, congruency and participant sex ($M_{\text{STAI-T}} = 40.12$). Parameter estimates for LS differences between attack and neutral distractors in each congruency condition are shown for females and males (bottom). Vertical and horizontal bars denote 95% confidence intervals.

threat level in the female grouping, as those arrays with neutral distractors (i.e., an attacking snake target with water pistol distractors, an aimed handgun target with turtle distractors) evoked more negative anterior N1 activity than incongruent both arrays with attack distractors. For males, arrays with neutral distractors evoked more negative N1 amplitude than arrays with attack distractors in the incongruent stimulus condition (i.e., turtles with water pistols, snakes with handguns).

Finally, the interaction between Stimulus type, Threat level, Congruency, and STAI-T scores confirmed the lack of anterior N1 modulation in the congruent condition (Figure 5.14). Incongruent both arrays did not modulate N1 activity in this four-way interaction either. Attacking snake distractors with a turtle target evoked significantly



Figure 5.14. LS means for anterior N1 mean amplitudes elicited by congruent and incongruent arrays, categorised by stimulus type and threat level ($M_{\text{STAI-T}} = 40.12$). LS differences between attack and neutral distractors within each stimulus type are shown, as well as those for reptile and firearm distractors of the same threat level. Vertical and horizontal bars denote 95% confidence intervals.

larger N1 amplitude than turtle distractors with an attacking snake target, a difference that was not found for incongruent threat arrays with firearm images. Despite this, there was a negative, weak and significant relationship between STAI-T scores and N1 amplitude for arrays with an aimed handgun target and water pistol distractors

(Bonferroni-corrected α = .003; *r* = .25, *p* < .001). The reverse pattern of N1 activity occurred in the incongruent stimulus condition, with arrays featuring water pistol distractors and a turtle target eliciting significantly more negative N1 amplitude compared to arrays with aimed handgun distractors and an attacking snake target.

The occipital N1 (120-170ms). Mean amplitudes for the occipital N1 were derived from the midline electrodes POz and Oz. Congruent and incongruent threat arrays with reptile images evoked noticeably larger occipital N1 activity than congruent firearm images for males (bottom, Figure 5.15). For males, arrays with mismatched firearm targets and reptile distractors also led to more negative N1 activity than arrays with mismatched reptile targets and firearm distractors in the incongruent stimulus and incongruent both conditions. For females, N1 activity for incongruent threat arrays with aimed handgun distractors was reduced compared to those with water pistol or reptile distractors (top, Figure 5.15). For mismatched reptile and firearm images, arrays with water pistol distractors evoked the most negative occipital N1 amplitude. The final notable N1 modulation for females involved arrays with aimed handgun targets and reptile distractors, which led to reduced occipital N1 activity compared to other incongruent stimulus or incongruent both arrays within the respective congruence condition.

Linear mixed effects analysis. Two participants were excluded from the occipital N1 dataset, leaving the data of 19 males and 19 females for analysis. Approximately 70% of the excluded male's occipital N1 data was below the 95% confidence interval limit ($M = -0.22\mu$ V [8.95, -9.39]). For the excluded female, 60% of her occipital N1 data was above the 95% confidence interval limit. Neuroticism (Kenward-Roger: F(64, 1084) = 2.69, p < .001) and PSWQ (F(64, 1084) = 1.54, p = .005) scores were significantly related to occipital N1 activity. The contribution of


Figure 5.15. Grand average occipital N1 waveforms averaged across frontal-central and central electrodes for females (top) and males (bottom). Congruency conditions are categorised based on the type of firearm (i.e., aimed handguns, water pistols) or reptile (i.e., attacking snakes, turtles) distractor featured in the Flanker array.

neuroticism scores (AIC = 5226, BIC = 5896) was stronger than observed for PSWQ scores (AIC = 5299, BIC = 5960). Therefore neuroticism scores were retained as a predictor in the final model (Table 5.9). Occipital N1 activity was very strongly clustered across participants (ICC_{Participants} = .82), and the total variance explained by the final model was very high (Ω_0^2 = .84, σ^2 = 2.59, τ_{00} for participants = 11.39). Main effects for Threat level (*F*(1, 1177) = 1.05, *p* < .001, β = -1.95 [-1.27, -2.63]) and Stimulus type (*F*(1, 1177) = 7.47, *p* = .006, β = -3.13 [-2.37, -3.89]) were significant. These main effects were qualified by four significant two-way interactions, one between the Stimulus type and Threat level factors, and the other involving the Congruency or Participant sex factors (Table 5.10). Most two-way interactions, along with relevant main effects, were further moderated by one or more of three significant three-way interactions. Lastly, lower-order interactions and main effects involving Stimulus type, Threat level, Congruency, Participant sex or neuroticism scores were even further moderated by three four-way interactions reaching significance in the occipital N1 final model (Table 5.11).

For interactions involving the Neuroticism predictor, no correlations between this trait score and N1 amplitudes were significant. However, weak, negative and significant associations were found between Neuroticism scores and N1 activity at the occipital electrode for females (Bonferroni-corrected $\alpha = .01$; r = -.18, p = .001) and at

Table 5.9. R notation for the final model estimated for occipital N1 mean amplitudes.Abbreviations for factors are provided at the bottom of the table.

	R-notation
	lmer(occN1~ Thr*Cong*Sex*Neur + Stim*Cong*Sex*Neur +
Final model	$Stim*Thr*Cong*Neur+Sag*Sex*Neur+Stim*Cong*Sag+({\sim}1 Participant),$
	Ex2_occN1)

Stim = Stimulus type Thr = Threat level Cong = Congruency Sag = Sagittal location Neur = neuroticism scores

Table 5.10. Parameter information for significant two-way and three-way interactions in the occipital N1 final model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Stim*Thr	<i>F</i> (1, 1177) = 14.74***	
ref. Firearm: Attack	Reptile: Neutral	0.02 [0.07, -0.02]
Stim*Cong	F(3, 1177) = 63.09 * * *	
ref. Firearm: CON	Reptile: THR	0.72 [1.8, -0.36]
	Reptile: STIM	3.08 [4.16, 2]***
	Reptile: BOTH	2.56 [3.64, 1.48]***
Thr*Cong	$F(3, 1177) = 6.59^{***}$	
ref. Attack: CON	Neutral: THR	1.13 [2.09, 0.18]*
	Neutral: STIM	0.86 [1.82, -0.1].
	Neutral: BOTH	1.96 [2.92, 1]**
Thr*Sex	$F(1, 1177) = 7.55^{**}$	
ref. Attack: Female	Neutral: Male	0.12 [0.29, -0.04]
Stim*Thr*Cong	F(3, 1177) = 3.12*	
ref. Firearm: Attack: CON	Reptile: Neutral: THR	0.21 [1.21, -0.78]
	Reptile: Neutral: STIM	-1.1 [-0.11, -2.1]*
	Reptile: Neutral: BOTH	0.24 [1.24, -0.76]
Stim*Cong*Neur	$F(3, 1177) = 6.16^{***}$	
ref. Firearm: CON	Reptile: THR	0.01 [0.08, -0.05]
	Reptile: STIM	-0.08 [-0.01, -0.15]*
	Reptile: BOTH	-0.11 [-0.04, -0.18]**
Thr*Cong*Neur	$F(3, 1177) = 4.66^{**}$	
ref. Attack: CON	Neutral: THR	-0.004 [0.06, -0.07]
	Neutral: STIM	0.02 [0.09, -0.04]
	Neutral: BOTH	-0.09 [-0.02, -0.15]*
Stim*Sag*Cong	$F(3, 1177) = 9.11^{***}$	
ref. Firearm: PO: CON	Reptile: PO: THR	0.07 [1.07, -0.93]
	Reptile: PO: STIM	1.92 [2.91, 0.92]***
	Reptile: PO: BOTH	1.92 [2.92, 0.92]***
.1 < p < .05., p < .05*, p < .01 **, p < .	001*** Stim: Stimulus type	Thr: Threat level Neur: neuroticism scores

Cong: Congruency, CON = Congruent, THR = Incongruent threat, STIM = Incongruent Sag: Sagittal location, PO = Parietal-occipital stimulus, BOTH = Incongruent both

Table 5.11. Parameter information for significant four-way interactions in the occipital NI final model, with the reference parameter and estimates (β) provided for each interaction. *F*-statistics are located at the top of the parameter column for each interaction. *P*-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Stim*Thr*Cong*Neur	F(3, 1177) = 3.29*	
ref. Firearm: High Thr: CON	Neutral: Reptile: THR	-0.05 [0.02, -0.12]
	Neutral: Reptile: STIM	-0.06 [0.01, -0.13]
	Neutral: Reptile: BOTH	0.03 [0.1, -0.04]
Stim*Cong*Sex*Neur	F(3, 1177) = 3.08*	
ref. Firearm: Female: CON	Reptile: Male: THR	-0.01 [0.07, -0.07]
	Reptile: Male: STIM	0.08 [0.15, 0.01]*
	Reptile: Male: BOTH	0.08 [0.15, 0.01]*
Thr*Cong*Sex*Neur	F(3, 1177) = 2.92*	
ref. High Thr: Female: CON	Neutral: Male: THR	0.07 [0.14, 0]
	Neutral: Male: STIM	0.02 [0.09, -0.05]
	Neutral: Male: BOTH	0.1 [0.17, 0.03]**
.1 < p < .05., p < .05*, p < .01 **, p < .0	01*** Stim: Stimulus type	Thr: Threat level Neur: neuroticism scores

Cong: Congruency, CON = Congruent, THR = Incongruent threat, STIM = Incongruent stimulus, BOTH = Incongruent both

the parietal-occipital electrode for males (r = -.25, p < .001). Effects relating to the Sagittal location factor will be described first, followed by details of the remaining three four-way interactions. Arrays with congruent or incongruent reptile images elicited significantly more negative N1 activity than those with congruent or incongruent firearm images (Figure 5.16). The magnitude of this N1 modulation was greater at the occipital site compared to the parietal-occipital site. For arrays with mismatched reptile and firearm images, occipital N1 activity was more negative for arrays with firearm distractors compared to those with reptile distractors. These differences were significant at electrode Oz for incongruent stimulus and incongruent both arrays, but not at electrode POz (see Figure 5.16). Stimulus type and Congruency also interacted with Participant sex and neuroticism scores (Table 5.11, Figure 5.17). The N1 activity of



Figure 5.16. LS means for occipital N1 mean amplitudes categorised by stimulus type, congruency and sagittal location. Parameter estimates for LS differences between reptile and firearm distractors at electrodes POz and Oz are shown (top right). Vertical and horizontal bars denote 95% confidence intervals.

males was more negative than that of females for arrays with firearm images or arrays with reptile distractors mismatched on one level of congruence. For males and females, occipital N1 amplitude was significantly more negative for reptile-only arrays compared to firearm-only arrays. The opposite trend occurred for arrays with mismatched reptile and firearm images, as arrays with firearm distractors evoking more negative N1 activity than those with reptile distractors. This effect was significant for females in the relevant congruency conditions, however only reached significance for males in response to incongruent both arrays.

The final two significant four-way interactions from the occipital N1 final model each involved Threat level, Congruency and neuroticism scores (Figure 5.18, Figure



Figure 5.17. LS means for occipital N1 mean amplitudes categorised by stimulus type, congruency and participant sex ($M_{\text{NEUR}} = 37.03$). Parameter estimates for LS differences between attack and neutral distractors for each congruency condition are shown (bottom right). Vertical and horizontal bars denote 95% confidence intervals.

5.19). Regarding Participant sex, N1 activity for males was more negative for arrays with attack distracters in all congruency conditions, apart from the incongruent both condition. Sex-specific N1 modulation was evident for arrays with neutral distractors, but not to the same magnitude as observed for arrays with attack distractors. For females, attack-only arrays elicited significantly larger amounts of occipital N1 activity than neutral-only arrays. These same differences were not found for males in the congruent or incongruent stimulus conditions. The four-way interaction between Stimulus type, Threat level, Congruency and neuroticism scores confirmed effects observed for congruent arrays in grand average waveforms (Figure 5.19). Reptile arrays elicited more negative N1 amplitude than firearm arrays in the congruent and



Figure 5.18. LS means for occipital N1 mean amplitudes categorised by threat level, congruency and participant sex ($M_{\text{NEUR}} = 37.03$). Parameter estimates for LS differences between attack and neutral distractors for each congruency condition are shown (bottom). Vertical and horizontal bars denote 95% confidence intervals.

incongruent threat conditions. N1 activity for aimed handgun arrays was significantly reduced compared to water pistol, attacking snake or turtle arrays ($\beta = 2.77$ [3.33, 2.2], p < .001). Turtle arrays also led to significantly more negative N1 amplitude than for that observed for arrays with water pistols. For arrays where reptile and firearm images were mismatched, reptile distractors led to more negative occipital N1 activity than those with aimed handgun distractors (Figure 5.19). This pattern of N1 modulation reached significance for firearm and attacking snake distractors in the incongruent stimulus condition and for turtles and water pistols in the incongruent both condition.

The EPN (150-250ms). Mean amplitudes for the EPN was computed from the left hemisphere electrodes P7 and PO7, and the right hemisphere electrodes P8 and PO8. The magnitude of the EPN was larger in the right hemisphere than the left



Figure 5.19. LS means for occipital N1 mean amplitudes elicited by congruent and incongruent arrays, categorised by stimulus type and threat level ($M_{\text{NEUR}} = 37.03$). LS differences between attack and neutral distractors within each stimulus type are shown, as well as those for reptile and firearm distractors of the same threat level. Vertical and horizontal bars denote 95% confidence intervals.

hemisphere for male and female groupings (Figure 5.20, Figure 5.21). Congruent aimed handguns evoked more negative EPN activity than other congruent arrays for females in the left hemisphere. For males, the amplitude of the EPN was more negative for congruent attacking snakes and aimed handguns compared to that for neutral congruent



Figure 5.20. Grand average EPN waveforms averaged across the most lateral parietal and parietal-occipital electrodes for females. Congruency conditions are categorised based on the type of firearm (i.e., aimed handguns, water pistols) or reptile (i.e., attacking snakes, turtles) distractor featured in the Flanker array.





Figure 5.21. Grand average EPN waveforms averaged across the most lateral parietal and parietal-occipital electrodes for males. Congruency conditions are categorised based on the type of firearm (i.e., aimed handguns, water pistols) or reptile (i.e., attacking snakes, turtles) distractor featured in the Flanker array.



arrays (i.e., turtles, water pistols) within their stimulus categories in the left hemisphere. In the right hemisphere, congruent water pistols also led to more negative EPN activity than other congruent arrays for males (first row, Figure 5.21). Arrays with mismatched water pistol distractors and aimed handgun targets evoked more negative EPN amplitude than other incongruent threat arrays, although the magnitude of this difference was smaller in the left hemisphere compared to the right hemisphere. Regarding the incongruent stimulus condition, EPN activity for arrays with mismatched aimed handgun distractors and attacking snake targets was larger and more delayed in latency than EPN amplitude for other incongruent stimulus arrays in the left hemisphere (third row; Figure 5.20, Figure 5.21). Finally, EPN modulation in response to incongruent both arrays was not clear for either male or female participants.

Linear mixed effects analysis. Neuroticism was the only questionnaire score significantly related to EPN modulation (Kenward-Roger: F(128, 2325) = 1.72, p < .001) and these scores were included as a predictor in the EPN final model (Table 5.12). EPN activity was moderately clustered between participants (ICC_{Participants} = .4) and the final model accounted for 65% of total variance ($\sigma^2 = 4.01, \tau_{00}$ for participants = 2.7). Main effects for Stimulus type ($F(1, 2601) = 5.88, p = .02, \beta = 0.27$ [0.85, -0.31]) and Participant sex ($F(1, 38) = 8.58, p = .006, \beta = -0.09$ [1.15, -1.32]) were significant. The two-way interaction between Threat level and Congruency also reached significance, $F(33, 2601) = 19, p < .001, \beta_{THR} = -1.74$ [-1.13, -2.34], $\beta_{STIM} = -0.37$ [0.24, -0.97], $\beta_{BOTH} = -1.01$ [-0.41, -1.62]. This two-way interaction, along with the Stimulus type main effect, was moderated by a significant three-way interaction between Stimulus type, Threat level and Congruency (Table 5.13). The main effects of Stimulus type and Participant sex were also qualified by the four-way interaction between these two factors, Congruency and neuroticism scores reaching significance.

		R	-notation	
Final model	lmer(EPN~ Sag*Cor + Stim*Thr*Cong + Sex*Sag*Neur + Sex*Cor*Neur + +Stim*Cong*Sex*Neur + (~1 Participant), Ex2_EPN)			ur + Sex*Cor*Neur +
Stim = Stimulus type Thr = Threat level	Cong = Congruency	Sag = Sagittal location	Cor = Coronal site	Neur = neuroticism scores

Table 5.12. R notation for the final model estimated for EPN mean amplitudes.Abbreviations for factors are provided at the bottom of the table.

Table 5.13. Parameter information for two significant higher-order interactions in the EPN final model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Stim*Thr*Cong	F(3, 2601) = 2.99*	
ref. Firearm: Attack: CON	Reptile: Neutral: THR	1.02 [1.88, 0.16]*
	Reptile: Neutral: STIM	1.07 [1.92, 0.21]*
	Reptile: Neutral: BOTH	0.28 [1.14, -0.57]
Stim*Sex*Cong*Neur	F(3, 2601) = 4.51 **	
ref. Firearm: Female: CON	Reptile: Male: THR	-0.01 [0.05, -0.08]
	Reptile: Male: STIM	0.09 [0.15, 0.02]**
	Reptile: Male: BOTH	0.06 [0.13, -0.003].

.1 , <math>p < .05, p < .01 **, p < .001 *** Stim: Stimulus type Thr: Threat level Neur: neuroticism scores Cong: Congruency, CON = Congruent, THR = Incongruent threat, STIM = Incongruent stimulus, BOTH = Incongruent both

In the congruent condition, aimed handgun arrays evoked significantly more negative EPN amplitude than water pistol arrays, but this same difference was not observed for congruent reptile arrays (Figure 5.22). In the incongruent threat condition, EPN activity was reduced for arrays with attack distractors compared to those with neutral distractors. This difference in EPN modulation reached significance only for arrays with incongruent firearm images. For arrays mismatched on stimulus type rather than threat level, mismatched attacking snakes and aimed handguns led to more



Figure 5.22. LS means for EPN mean amplitudes elicited by congruent and incongruent arrays, categorised by stimulus type and threat level. LS differences between attack and neutral distractors within each stimulus type are shown, as well as those for reptile and firearm distractors of the same threat level. Vertical and horizontal bars denote 95% confidence intervals.

negative EPN than mismatched turtles and water pistols (Figure 5.22). Again, the magnitude of EPN modulation was different for reptile and firearm distractors, as ERP activity for a water pistol mismatched to turtle distractors was significantly reduced

compared to an aimed handgun with attacking snake distractors, but this same difference did not reach significance for arrays with firearm distractors. Lastly, a water pistol mismatched to attacking snake distractors led to reduced EPN compared to other arrays in the incongruent both condition, although this difference was non-significant.

The four-way interaction involving Neuroticism scores indicated arrays with only firearm or reptile images did not lead to sex-specific variation in EPN activity (Figure 5.23). EPN amplitude was reduced for arrays with reptiles mismatched to a firearm target compared to those with firearm distractors and a reptile target. The



Figure 5.23. LS means for EPN mean amplitudes categorised by stimulus type, congruency and participant sex ($M_{\text{NEUR}} = 37.03$). No LS differences between males and females reached significance in the relevant four-way interaction (all ps > .05). Vertical and horizontal bars denote 95% confidence intervals.

magnitude of this difference was larger for females compared to males in the incongruent stimulus and incongruent both conditions, and these differences did not reach significance in either case (both ps > .05). The involvement of the Neuroticism predictor in this interaction was driven by weak and significant correlations between EPN activity and this trait score for arrays with firearm or reptile distractors for females (Bonferroni-corrected $\alpha = .01$; Firearm: r = .12, p = .002; Reptile: r = .14, p < .001) and males (Firearm: r = -.14; Reptile: r = -.13, both ps < .001). In the female grouping more negative EPN amplitude was associated with higher levels of Neuroticism, while the opposite pattern of correlation between EPN activity and Neuroticism scores occurred for male participants for Flanker arrays with firearm or reptile distractors.

The MPN (290-390ms). Mean activity for the MPN was computed from the left hemisphere electrodes TP7 and P7 and the right hemisphere electrodes TP8 and P8. Congruent attack arrays elicited more negative MPN activity than congruent neutral arrays from the same stimulus category (first row; Figure 5.24, Figure 5.25). MPN amplitude for congruent aimed handguns was also much larger than for congruent water pistol and reptile images. In the left hemisphere, MPN amplitude was more negative for incongruent attack targets and neutral distractors compared to incongruent threat arrays with neutral targets and attack distractors. For females, MPN activity for water pistol distractors with an aimed handgun target was also more negative than observed for turtle distractors with an attacking snake target, a difference that did not occur for the male grouping. In the right hemisphere, water pistol distractors with an aimed handgun target led to more negative MPN amplitude than other incongruent threat arrays for females (second row, Figure 5.24). Incongruent threat arrays with firearm distractors elicited more negative MPN activity than those with reptile distractors in the right hemisphere for males (second row, Figure 5.25). Incongruent stimulus arrays with



Figure 5.24. Grand average MPN waveforms averaged across the most lateral temporal-parietal and parietal electrodes for females. Congruency conditions are categorised based on the type of firearm (i.e., aimed handguns, water pistols) or reptile (i.e., attacking snakes, turtles) distractor featured in the Flanker array.





Figure 5.25. Grand average MPN waveforms averaged across the most lateral temporal-parietal and parietal electrodes for males. Congruency conditions are categorised based on the type of firearm (i.e., aimed handguns, water pistols) or reptile (i.e., attacking snakes, turtles) distractor featured in the Flanker array.



Linear mixed effects analysis. TAS-20 scores were significantly related to MPN modulation, F(128, 2325) = 1.32, p = .01 (Kenward-Roger, Table 5.14). Clustering was weak between participants (ICC_{Participants} = .25), and the total variance explained by the MPN final model was moderate ($\Omega_0^2 = .51$, $\sigma^2 = 6.35$, τ_{00} for participants = 2.13). Main effects related to distractor type and Congruency did not reach significance in the MPN final model. The Threat level factor was involved in two significant two-way interactions, one with the Coronal site factor and one with the Congruency factor (Table 5.15). Congruency was also found to interact significantly with Stimulus type (Figure 5.26). Congruent and incongruent firearm images evoked more negative MPN than congruent and incongruent reptile images, although this difference reached significance only for the congruent condition. Arrays with mismatched reptile and firearm images led to more negative MPN amplitude for reptile distractors compared to firearm distractors. However, the magnitude of these differences was much smaller compared to that observed for congruent and incongruent threat arrays.

Two of the three significant two-way interactions in the MPN final model were moderated by a significant interaction between Threat level, Congruency and Coronal site, F(3, 2620) = 2.76, p = .04, $\beta_{THR} = 1.2$ [2.28, 0.13], $\beta_{STIM} = 0.01$ [1.09, -1.06], $\beta_{BOTH} = 1.04$ [2.11, -0.04] (Figure 5.27). Arrays with attack images elicited more negative

Table 5.14. R notation for the final model estimated for MPN mean amplitudes.Abbreviations for factors are provided at the bottom of the table.

	R-notation			
Final model	lmer(MPN~ Thr*Cong*Cor + Sex*Sag*Cor + Sex*Cor*TAS-20 + Stim*Cong (~1 Participant), Ex2_MPN			
Stim = Stimulus type	Cong = Congruency	Sag = Sagittal location	Cor = Coronal site	TAS-20 = alexithymia scores
Thr = Threat level				
Cong: Congrue	ency, CON = Congruent, TH	IR = Incongruent threat, STIN	A = Incongruent stimulus,	BOTH = Incongruent both

MPN mean ai

1

Table 5.15. Parameter information for significant two-way and three-way interactions in the MPN final model, with the reference parameter and estimates (β) provided for each interaction. *F*-statistics are located at the top of the parameter column for each interaction. *P*-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Stim*Cong	<i>F</i> (3, 2620) = 7.9***	
ref. Firearm: CON	Reptile: THR	-0.31 [0.23, -0.85]
	Reptile: STIM	- 1.1 [-0.56, -1.64]***
	Reptile: BOTH	-1.06 [-0.52, -1.59]***
Thr*Cong	<i>F</i> (3, 2620) = 36.17***	
ref. Attack: CON	Neutral: THR	-2.58 [-1.82, -3.34]***
	Neutral: STIM	0.25 [1.01, -0.51]
	Neutral: BOTH	-2.31 [-1.55, -3.07]***
Thr*Cor	F(1, 2620) = 3.92*	
ref. Attack: Left	Neutral: Right	0.18 [0.58, -0.94]
.1 < p < .05•, p < .05*, p < .01 **,	$p < .001^{***}$ Stim: Stimulus type	e Thr: Threat level
3	FIREAI DIS Co Inc	RM VS. REPTILE STRACTORS ngruent THREAT STIMULUS ROTH NS

Figure 5.26. LS means for MPN mean amplitudes categorised by stimulus type and congruency. Parameter estimates for LS differences between firearm and reptile distractors are shown (top right). Vertical and horizontal bars denote 95% confidence intervals.

Both

Congruent Incongruent Incongruent

Stimulus

Threat

-1

Firearm

distractors

Reptile

distractors

0 LS differences

p < .05

p < .01

= p < .001

MPN activity than neutral-only arrays in the congruent and incongruent stimulus conditions. These differences were significant apart from congruent arrays in the right hemisphere. In the left hemisphere arrays with neutral distractors mismatched to attack targets evoked significantly larger MPN amplitude than those with attack distractors and neutral targets. These same differences in the incongruent threat or incongruent both conditions did not reach significance in the right hemisphere (see bottom right, Figure



Figure 5.27. LS means for MPN mean amplitudes categorised by threat level, congruency and coronal site. Parameter estimates for LS differences between left and right hemisphere electrodes for attack and neutral distractors are shown (top right), as well as those between attack and neutral distractors in the left and right hemisphere (bottom right). Vertical and horizontal bars denote 95% confidence intervals.

5.27). MPN activity was significantly more negative in the left compared to the right hemisphere for all arrays apart from those with mismatched attack distractors and neutral targets (see top right, Figure 5.27).

The LPP (450-650ms). Mean amplitudes for the LPP were analysed at the central-parietal electrodes CP1, CPz and CP2, and the parietal electrodes P1, Pz and P2. Aimed handgun arrays evoked more positive LPP activity than other congruent arrays (first row; Figure 5.28, Figure 5.29). In the incongruent threat condition, arrays did not appear to modulate LPP amplitude for males. For females, incongruent threat arrays with neutral distractors (i.e., an attacking snake with turtle distractors, an aimed handgun with water pistol distractors) evoked more positive LPP activity than arrays with attack distractors at the midline in the same congruency condition (second row, Figure 5.28). At midline sites, arrays with mismatched attacking snake and aimed handgun images also elicited more positive LPP amplitude than incongruent stimulus arrays with neutral images (third rows, Figure 5.28, Figure 5.29). For incongruent both arrays, mismatched aimed handgun and turtle images led to larger amounts of LPP activity in comparison to mismatched attacking snake and water pistol images in the right hemisphere. At the midline and in the left hemisphere aimed handguns with turtle distractors also appeared to evoke more positive LPP amplitude than other incongruent both arrays, although this LPP modulation was unclear.

Linear mixed effects analysis. PSWQ (Kenward-Roger: F(192, 3505) = 1.87, p < .001), STAI-T (F(128, 2325) = 1.47, p < .001) and neuroticism (F(128, 2325) = 1.56, p < .001) scores were significantly associated with LPP modulation. Scores from the PSWQ (AIC = 13783, BIC = 16216) led to greater improvement in model fit than STAI-T (AIC = 13864, BIC = 16296) or neuroticism (AIC = 13843, BIC = 16275) scores. A variation of the reduced model with the PSWQ score predictor was trialled



Figure 5.28. Grand average LPP waveforms averaged across central-parietal and parietal electrodes close to the midline for females. Congruency conditions are categorised based on the type of firearm (i.e., aimed handguns, water pistols) or reptile (i.e., attacking snakes, turtles) distractor featured in the Flanker array.





Figure 5.29. Grand average LPP waveforms averaged across central-parietal and parietal electrodes close to the midline for males. Congruency conditions are categorised based on the type of firearm (i.e., aimed handguns, water pistols) or reptile (i.e., attacking snakes, turtles) distractor featured in the Flanker array.



with STAI-T scores added. A similar version with neuroticism scores added was not trialled due to very strong overlap between PSWQ and neuroticism scores. The final LPP model featured both PSWQ and STAI-T scores as predictors (Table 5.16). Clustering across participants was moderate in the LPP final model (ICC_{Participants} = .72), and the final model explained 73% of total variance ($\sigma^2 = 0.72$, τ_{00} for participants = 1.89). All main effects and lower-order interactions were moderated by one or more of six four-way and four three-way interactions reaching significance (Appendix K). To break down these higher-order interactions from the LPP final model, participants were separated into high and low groupings based on the median STAI-T score (*Mdn* = 38.5, *IQR* = 32-49). One male participant with a score of 38 for the STAI-T was not included in these analyses. In the high STAI-T grouping there were 21 participants (8 males, *Mdn* = 49, *IQR* = 44-52) and 20 in the low grouping (11 males, *Mdn* = 32, *IQR* = 28.5-35). Clustering was stronger between participants in the high STAI-T model compared to that observed in the low STAI-T model, and the total variance explained by the

	R-notation		
	lmer(LPP ~ Thr*Cong*PSWQ*STAI-T + Sex*Cong*PSWQ*STAI-T +		
	Sag*Cor*PSWQ*STAI-T + Sag*Sex*PSWQ*STAI-T +		
	Cor*Sex*PSWQ*STAI-T+Sag*Cor*Sex*PSWQ+Sag*Cor*Sex*STAI-T+		
Final model	Stim*Thr*PSWQ + Thr*Sex*PSWQ + Stim*Sex*STAI-T +		
	Stim*Cong*STAI-T + Thr*Sex*STAI-T + Stim*Thr*Cong + Cong*Cor +		
	Stim*Sag + (~1 Participant), Ex2_LPP)		
	lmer(LPP~ Sag*Cor*Sex*PSWQ + Stim*Thr*PSWQ + Sex*Cong*PSWQ +		
Breakdown model	Thr*Sex*PSWQ + Thr*Cong*PSWQ + Stim*Thr*Cong + Stim*Sex +		
	Thr*Sex + Cong*Cor + Stim*Sag + (~1 Participant), Ex2_LPP)		
Stim = Stimulus type	Cong = Congruency Sag = Sagittal location Cor = Coronal site PSWQ = worry scores STAL T trait unit unit unit unit unit unit unit un		
Thr = Threat level	STAI-T = trait anxiety scores		

 Table 5.16. R notation for the final and breakdown models estimated for LPP mean

 amplitudes. Abbreviations for factors are provided at the bottom of the table.

breakdown models was also greater for the high STAI-T grouping than the low STAI-T grouping. (Table 5.17).

High STAI-T grouping (Mdn>38). The main effect of Threat level reached significance, F(1, 1935) = 5.68, p = .02, $\beta = -1.05$ [0.02, -2.12]). This main effect was moderated by a significant interaction between Threat level and Participant sex (Table 5.18). Stimulus type also interacted significantly with Participant sex and with Sagittal location. The two-way interactions between Congruency and Stimulus type, and between Congruency and PSWQ scores, also reached significance for the high STAI-T grouping. Regarding Sagittal location, there was little difference in LPP activity for arrays with reptile ($M_{LS} = 2.91$ [3.62, 2.2]) or firearm ($M_{LS} = 2.96$ [3.67, 2.25]) distractors at parietal electrodes. At central-parietal electrodes LPP amplitude was significantly more positive for arrays with firearm distractors (M = 1.02 [1.73, 0.31]) compared to those with reptile distractors ($M_{LS} = 0.77$ [1.48, 0.06], $\beta = 0.26$ [0.39, (0.13], p < .001). In relation to Participant sex, the LPP amplitude of females was significantly more positive for arrays with firearm distractors ($M_{LS} = 1.48$ [2.39, 0.57]) compared to those with reptile distractors ($M_{LS} = 1.11$ [2.02, 0.2], $\beta = 0.37$ [0.49, -0.24], p < .001). For males LPP activity for arrays with firearm ($M_{LS} = 2.51$ [3.59, 1.42]) or reptile ($M_{LS} = 2.56$ [3.65, 1.48]) distractors was of similar magnitude.

Table 5.17. *Fit statistics for the breakdown models for the high STAI-T and low STAI-T groupings estimated for LPP mean amplitudes.*

	ICC (Participants)	Total variance (Ω^2)	Within-subject variance (σ ²)	Between-subject variance (τ ₀₀)
High STAI-T	.63	.75	1.09	1.84
Low STAI-T	.48	.67	1.61	1.51

Table 5.18. Parameter information for significant two-way and three-way interactions in the breakdown model for the high STAI-T grouping in LPP mean amplitudes, with the reference parameter and estimates (β) provided for each interaction. Information for a trend for the three-way interaction between Participant sex, Congruency and PSWQ scores is also shown. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Stim*Cong	<i>F</i> (3, 1935) = 3.33*	
ref. Firearm: CON	Reptile: THR	0.32 [0.68, -0.05].
	Reptile: STIM	0.66 [1.03, 0.3]***
	Reptile: BOTH	0.2 [0.56, -0.17]
Stim*Sex	<i>F</i> (1, 1935) = 16.12***	
ref. Firearm: Female	Reptile: Male	0.42 [0.63, 0.21]***
Thr*Sex	F(1, 1935) = 7.27 * *	
ref. Attack: Female	Neutral: Male	-1.22 [-0.33, -2.11]**
Stim*Sag	$F(1, 1935) = 16.12^{***}$	
ref. Firearm: CP	Reptile: Parietal	0.2 [0.38, 0.01]*
Cong*PSWQ	$F(3, 1935) = 6.33^{***}$	
ref. CON	THR	-0.02 [0.005, -0.03]
	STIM	-0.004 [0.02, -0.02]
	BOTH	-0.01 [0.01, -0.03]
Stim*Thr*Cong	$F(3, 1935) = 9.57^{***}$	
ref. Firearm: Attack: CON	Reptile: Neutral: THR	-0.73 [-0.21, -1.24]**
	Reptile: Neutral: STIM	-0.96 [-0.44, -1.48]***
	Reptile: Neutral: BOTH	0.25 [0.76, -0.27]
Thr*Sex*PSWQ	F(1, 1935) = 10.84 **	
ref. Attack: Female	Neutral: Male	0.03 [0.05, 0.01]**
Sex*Cong*PSWQ	F(3, 1935) = 2.41.	
ref. Female: CON	Male: THR	-0.01 [0.02, -0.03]
	Male: STIM	0.02 [0.05, -0.002].
	Male: BOTH	0.01 [0.04, -0.01]

.1 , <math>p < .05, p < .01 **, p < .001 *** Stim: Stimulus type Thr: Threat level PSWQ: worry scores

Cong: Congruency, CON = Congruent, THR = Incongruent threat, STIM = Incongruent Sag: Sagittal location, CP = Central-parietal stimulus, BOTH = Incongruent both

The Threat level main effect, as well as relevant two-way interactions, were further qualified by two significant three-way interactions (Table 5.18). A trend was also found for the three-way interaction between Participant sex, Congruency and PSWQ scores (Figure 5.30). No correlations between PSWQ scores and LPP amplitudes reached significance for this trend. The LPP activity of males was more positive than that of females for congruent and incongruent arrays, although this difference was noticeably smaller for incongruent threat arrays compared to arrays from the three other congruency conditions. Supporting this, the LPP amplitude of males for incongruent threat arrays was significantly reduced compared to congruent ($\beta = 1.11$ [1.33, 0.89), incongruent stimulus ($\beta = -0.86$ [-0.64, -1.08]), and incongruent both ($\beta = -0.8$ [-0.58, -1.03]) arrays (all *p*s < .001). The same LPP modulation was not observed for females, however LPP activity for the female grouping was significantly more positive for congruent arrays in comparison to incongruent threat ($\beta = 0.51$ [0.7,0.32]), incongruent



Figure 5.30. LS means for LPP mean amplitudes in the high STAI-T grouping, categorised by congruency and participant sex ($M_{PSWQ} = 51.71$). No meaningful LS differences between males and females, or congruency conditions, reached significance (all ps > .05). Vertical and horizontal bars denote 95% confidence intervals.

stimulus ($\beta = 0.46$ [0.65, 0.28]), and incongruent both ($\beta = 0.51$ [0.69, 0.32]) arrays (Figure 5.30, all *ps* < .001).

In regards to the three-way interaction between Threat level, Stimulus type, and Congruency, congruent aimed handguns evoked significantly larger LPP activity than those showing turtle ($\beta = 0.77$ [1.03, 0.51], p < .001), water pistol, or attacking snake images (Figure 5.31). Reptile or firearm arrays with incongruent threat distractors did



Figure 5.31. LS means for LPP mean amplitudes in the high STAI-T grouping elicited by congruent and incongruent arrays, categorised by stimulus type and threat level. LS differences between attack and neutral distractors within each stimulus type are shown, as well as those for reptile and firearm distractors of the same threat level. Vertical and horizontal bars denote 95% confidence intervals.

not moderate LPP amplitude, although in this congruency condition LPP activity for arrays with water pistol distractors was significantly more positive than for those with turtle distractors. For the incongruent stimulus condition, LPP amplitude was significantly reduced for arrays with turtle distractors compared to those with aimed handgun ($\beta = 0.71$ [0.97, 0.45], p < .001), attacking snake, or water pistol distractors (see Figure 5.31 for other parameter information). These same differences did not occur for arrays in the incongruent both condition. Instead, incongruent both arrays with an attacking snake target and water pistol distractors led to significantly reduced LPP activity in comparison to arrays that showed an aimed handgun target with turtle distractors. Regarding Participant sex and PSWQ scores, LPP activity was significantly more positive for arrays with attack distractors compared to those with neutral distractors. However, the magnitude of this difference was larger for females than males (Figure 5.32). No correlations between PSWQ scores and LPP amplitude reached significance in this interaction. However, there was a very weak trend for a positive association between the PSWQ predictor and LPP activity in the male grouping for arrays with neutral distractors (Bonferroni-corrected $\alpha = .01$; r = .11, p = .05).

Low STAI-T grouping (Mdn <*38).* As observed in the high STAI-T grouping, the main effect of Threat level was significant in the low STAI-T model, $F(1, 1840) = 5.28, p = .01, \beta = -2.19$ [-0.85, -3.53]. This main effect was qualified by two significant two-way interactions, one with Stimulus type and one with Congruency (Table 5.19). Similar to the high STAI-T model, the two-way interactions between Stimulus type and Congruency, and between Stimulus type and Sagittal location, reached significance. In contrast, Participant sex interacted significantly with Congruency in LPP activity for the low STAI-T grouping. In relation to Sagittal location, the lack of difference between LPP activity for arrays with firearm (M = 2.83 [3.58, 2.09]) or reptile (M = 2.93 [3.67,



Figure 5.32. LS means for LPP mean amplitudes in the high STAI-T grouping, categorised by threat level and participant sex ($M_{PSWQ} = 51.71$). LS differences between females and males for attack and neutral distractors are shown, as well as those for attack and neutral distractors for females and males (right). Vertical and horizontal bars denote 95% confidence intervals.

2.19]) distractors observed in the high STAI-T grouping at parietal electrodes occurred for the low STAI-T grouping. Unlike the high STAI-T grouping though, LPP amplitude was similar at central-parietal electrodes for arrays with firearm ($M_{LS} = 1.29$ [2.03, 0.55]) or reptile ($M_{LS} = 1.12$ [1.86, 0.38]) distractors too.

All remaining two-way interactions were further moderated by one or more of five three-way interactions that were significant (Table 5.20). The two three-way interactions involving Participant sex will be described first. In relation to Congruency, the LPP activity of females was more positive than that of males (Figure 5.33). For males, however, LPP amplitude evoked by incongruent threat arrays was reduced compared to those for incongruent stimulus ($\beta = -0.51$ [-0.25, -0.77], p = .003), incongruent both ($\beta = -0.52$ [-0.26, -0.78], p = .003) and congruent arrays ($\beta = 0.39$ [0.65, 0.13], p = .09). These same differences in the incongruent threat condition did not

Table 5.19. Parameter information for significant two-way interactions in the breakdown model for the low STAI-T grouping in LPP mean amplitudes, with the reference parameter and estimates (β) provided for each interaction. *F*-statistics are located at the top of the parameter column for each interaction. *P*-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Stim*Thr	<i>F</i> (1, 1840) = 12.29***	
ref. Firearm: Attack	Reptile: Neutral	2.16 [3.15, 1.17]***
Stim*Cong	F(3, 1840) = 2.8*	
ref. Firearm: CON	Reptile: THR	0.56 [1.01, 0.1]*
	Reptile: STIM	1.26 [1.71, 0.8]***
	Reptile: BOTH	0.27 [0.73, -0.18]
Thr*Cong	$F(3, 1840) = 7.68^{***}$	
ref. Attack: CON	Neutral: THR	2.35 [3.68, 1.02]***
	Neutral: STIM	0.25 [1.58, -1.08]
	Neutral: BOTH	1.48 [2.8, 0.15]*
Sex*Cong	<i>F</i> (3, 1840) = 3.35*	
ref. Female: CON	Male: THR	-2.57 [-0.93, -4.22]**
	Male: STIM	-0.96 [0.68, -2.61]
	Male: BOTH	-1.64 [0.01, -3.28].
Stim*Sag	F(1, 1840) = 4.97*	
ref. Firearm: CP	Reptile: Parietal	0.26 [0.48, 0.03]*
Cong*PSWQ	$F(3, 1840) = 3.88^{**}$	
ref. CON	THR	-0.03 [0.005, -0.06].
	STIM	-0.02 [0.01, -0.05]
	BOTH	-0.0002 [0.03, -0.03]

.1 , <math>p < .05, p < .01 **, p < .001 *** Stim: Stimulus type Thr: Threat level PSWQ: worry scores Cong: Congruency, CON = Congruent, THR = Incongruent threat, STIM = Incongruent Sag: Sagittal location, CP = Central-parietal stimulus, BOTH = Incongruent both

occur for female participants. Negative, weak and significant correlations also occurred between PSWQ scores and LPP amplitude for males in response to arrays with distractors that were congruent (Bonferroni-corrected $\alpha = .006$; r = -.29, p < .001), incongruent threat (r = -.26, p < .001) or incongruent stimulus (r = -.16, p = .006). Sexspecific variation in LPP activity was also evident for the threat level of distractor Table 5.20. Parameter information for significant three-way interactions in the breakdown model for the low STAI-T grouping in LPP mean amplitudes, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Stim*Thr*Cong	F(3, 1840) = 11.97 ***	
ref. Firearm: Attack: CON	Reptile: Neutral: THR	-0.28 [0.36, -0.92]
	Reptile: Neutral: STIM	-1.72 [-1.08, -2.36]***
	Reptile: Neutral: BOTH	-0.12 [0.52, -0.76]
Stim*Thr*PSWQ	$F(1, 1840) = 11.82^{***}$	
ref. Firearm: Attack	Reptile: Neutral	-0.04 [-0.02, -0.06]***
Thr*Cong*PSWQ	$F(3, 1840) = 5.75^{***}$	
ref. Attack: Female: CON	Neutral: Male: THR	-0.04 [-0.01, -0.07]**
	Neutral: Male: STIM	0.02 [0.05, -0.01]
	Neutral: Male: BOTH	-0.01 [0.02, -0.04]
Thr*Sex*PSWQ	F(1, 1840) = 4.65*	
ref. Attack: Female	Neutral: Male	0.03 [0.06, 0.003]*
Sex*Cong*PSWQ	F(3, 1840) = 3.41*	
ref. Female: CON	Male: THR	0.06 [0.1, 0.02]**
	Male: STIM	0.03 [0.07, -0.01]
	Male: BOTH	0.04 [0.08, 0.002]*

.1 , <math>p < .05, p < .01 **, p < .001 *** Stim: Stimulus type Thr: Threat level PSWQ: worry scores Cong: Congruency, CON = Congruent, THR = Incongruent threat, STIM = Incongruent stimulus, BOTH = Incongruent both

images (Figure 5.34). Arrays with attack distractors elicited significantly more positive LPP amplitude than those with neutral distractors for females, but not for males. The LPP activity of females was larger than males for arrays with attack or neutral distractors. This difference, however, was non-significant for neutral distractors and a trend for the sex difference in response to arrays with attack distractors. There were also negative, weak and significant correlations between PSWQ scores and LPP amplitude in the male grouping for arrays with attack (Bonferroni-corrected $\alpha = .01$; r = ..26) or neutral (r = ..14, both ps < .001) distractors.



Figure 5.33. LS means for LPP mean amplitudes in the low STAI-T grouping, categorised by congruency and participant sex ($M_{PSWQ} = 40.7$). No meaningful LS differences between males and females, or congruency conditions, reached significance (all ps > .05). Vertical and horizontal bars denote 95% confidence intervals.



Figure 5.34. LS means for LPP mean amplitudes in the low STAI-T grouping, categorised by threat level and participant sex ($M_{PSWQ} = 40.7$). LS differences between attack and neutral distractors for males and females, as well as between males and females for attack and neutral distractors, are shown (right). Vertical and horizontal bars denote 95% confidence intervals.

The three-way interaction between Stimulus type, Threat level and PSWQ scores in the STAI-T breakdown model showed that LPP activity was overall more positive for arrays with aimed handgun ($M_{LS} = 2.2$ [2.94, 1.46]) or attacking snake ($M_{LS} = 2.13$ [2.87, 1.39]) distractors than those arrays with water pistol ($M_{LS} = 1.92$ [2.87, 1.18]) or turtle ($M_{LS} = 1.92$ [2.66, 1.18]) distractors ($M_{PSWQ} = 40.7$). LPP modulation driven by aimed handguns was significant for arrays with water pistol ($\beta = 0.29$ [0.47, 0.1], p = .01) or turtle ($\beta = 0.28$ [0.46, 0.1], p = .02) distractors, but not in comparison to arrays with attacking snake distractors ($\beta_{WP} = -.21$ [-0.03, -0.39], p = .12; $\beta_T = 0.21$ [0.39, 0.02], p = .17). Positive, weak and significant correlations also occurred between LPP amplitude and PSWQ scores for arrays with water pistol (Bonferroni-corrected $\alpha = .01$; r = .15, p = .002) or attacking snake (r = .15, p < .001) distractors. PSWQ scores also interacted significantly with Threat level and Congruency for the low STAI-T grouping (Figure 5.35). Attack-only arrays elicited significantly larger LPP activity than arrays showing only neutral images, a difference that was not found for arrays with



Figure 5.35. LS means for LPP mean amplitudes in the low STAI-T grouping categorised by threat level and congruency ($M_{PSWQ} = 40.7$). LS differences between attack and neutral distractors for each congruency condition are shown (top right). Vertical and horizontal bars denote 95% confidence intervals.

mismatched attack and neutral images. In the incongruent threat condition these effects were driven by arrays with attack distractors, as the LPP amplitude evoked by these arrays was significantly reduced compared to congruent ($\beta = 0.57 [0.83, 0.31]$, p < .001) and incongruent stimulus ($\beta = -.47 [-0.22, -0.73]$, p = .009) arrays with attack distractors. However, for the incongruent both condition, neutral distractors mismatched to the threat level and stimulus level of target images led to significantly more positive LPP activity than congruent ($\beta = -0.6 [-0.34, -0.86]$, p < .001), incongruent threat ($\beta = -$ 0.71 [-0.45, -0.97], p = .009), and incongruent stimulus ($\beta = -0.47 [-0.21, -0.73]$, p =.01) arrays with neutral distractors. Lastly, there was a significant, weak and positive correlation between LPP activity and PSWQ scores for incongruent both arrays with attack distractors (Bonferroni-corrected $\alpha = .006$; r = .18, p = .003).

The final significant three-way interaction for the low STAI-T grouping occurred between Stimulus type, Threat level and Congruency (Figure 5.36). Patterns of LPP activity were similar to those observed for the high STAI-T grouping for the same three-way interaction. Aimed handguns led to significantly larger LPP amplitude than water pistols, attacking snakes, or turtles ($\beta = -0.71$ [-0.45, -0.97], p = .009) in the congruent condition. Again the magnitude of LPP activity was not influenced by different distractor types in the incongruent threat condition. Arrays with attacking snakes mismatched to an aimed handgun evoked more positive LPP amplitude than other arrays in the incongruent stimulus condition, although these differences reached significance for aimed handgun and turtle distractors (see Figure 5.36 for parameter information), but not for water pistol distractors ($\beta = -0.53$ [-0.2, -0.87], p = .21). LPP modulation differed the most from the high STAI-T grouping for arrays with images mismatched on threat level and stimulus type. Attacking snake distractors with a water pistol target led to reduced LPP activity than elicited for other arrays in the incongruent



Figure 5.36. LS means for LPP mean amplitudes in the low STAI-T grouping, elicited by congruent and incongruent arrays, categorised by stimulus type and threat level. LS differences between attack and neutral distractors within each stimulus type are shown, as well as those for reptile and firearm distractors of the same threat level. Vertical and horizontal bars denote 95% confidence intervals.

both condition (all ps > .05). Moreover, the amplitude of the LPP elicited by incongruent both arrays with firearm distractors mismatched to reptile targets was of similar magnitude.

The CRN (-50 to 50ms). Mean activity for the CRN was computed from the frontal electrodes F1, Fz and F2, and the frontal-central electrodes FC1, FCz and FC2.
The CRN peaked at the time of the response to the Flanker array (Figure 5.37, Figure 5.38). Congruent attacking snakes evoked noticeably more negative CRN than congruent turtles, aimed handguns or water pistols at midline and right hemisphere sites. In the left hemisphere, the CRN for congruent water pistols was reduced compared to other congruent arrays. Incongruent threat arrays with mismatched reptile images elicited more negative CRN than those with mismatched firearm images at midline and left hemisphere sites (second row; Figure 5.37, Figure 5.38). In the right hemisphere, the CRN was reduced for aimed handguns mismatched to a water pistol target compared to other incongruent threat arrays. CRN modulation was also evident for Flanker arrays with mismatched reptile and firearm images. Turtle distractors shown with a water pistol target led to reduced CRN amplitude in comparison to other incongruent stimulus arrays at the midline and in the right hemisphere (third row; Figure 5.37, Figure 5.38). In the left hemisphere, incongruent stimulus attack arrays evoked more negative CRN amplitude than those with neutral images. This latter pattern of CRN activity also occurred for incongruent both arrays with attack distractors at midline and left hemisphere sites. Similar to incongruent stimulus arrays with turtle distractors, CRN amplitude in the right hemisphere was reduced for arrays with turtles and an aimed handgun target compared to other incongruent both arrays.

Linear mixed effects analysis. Scores for the TAS-20 (Kenward-Roger: F(192, 3410) = 1.43, p < .001), neuroticism (F(192, 3410) = 1.33, p = .002), STAI-T (F(192, 3410) = 1.7, p < .001), and STAI-S (F(192, 3410) = 1.38, p < .001) were significantly related to CRN modulation. The final model for CRN mean amplitudes included STAI-T scores as a predictor (Table 5.21). STAI-T scores (AIC = 8703, BIC = 11126) led better improvements in model fit compared to the STAI-S (AIC = 8765, BIC = 11189), the TAS-20 (AIC = 8755, BIC = 11178), or neuroticism (AIC = 8776, BIC = 11199).



Figure 5.37. Grand average response-locked waveforms for the CRN averaged across frontal and frontal-central electrodes for birth control females. Congruency conditions are categorised based on the type of firearm (i.e., aimed handguns, water pistols) or reptile (i.e., attacking snakes, turtles) distractor featured in the Flanker array.





Figure 5.38. Grand average response-locked waveforms for the CRN averaged across frontal and frontal-central electrodes for males. Congruency conditions are categorised based on the type of firearm (i.e., aimed handguns, water pistols) or reptile (i.e., attacking snakes, turtles) distractor featured in the Flanker array.



	R-notation			
	lmer(CRN~ Cong*Sag + Sex*Sag*STAI-T + Stim*Thr*Cong*Sex +			
Final model	Stim*Thr*Cong*STAI-T + Stim*Thr*Sex*STAI-T + Stim*Cong*Sex* STAI-T			
	+ Cong*Sex*Cor*STAI-T + (~1 Participant), Ex2_CRN)			
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Table 5.21. R notation for the final model estimated for CRN mean amplitudes.Abbreviations for factors are provided at the bottom of the table.

 Stim = Stimulus type
 Cong = Congruency
 Sag = Sagittal location
 Cor = Coronal site
 STAI-T = trait anxiety scores

 Thr = Threat level
 Threat level

CRN activity was strongly clustered between participants (ICC_{Participants} = .59), and the CRN final model explained 64% of total variance ($\sigma^2 = 0.44$, τ_{00} for participants = 0.64). The main effects of Threat level (F(1, 3802) = 31.24, p < .001, $\beta = 0.09$ [0.27, -0.07]) and Congruency (F(3, 3802) = 31.21, p < .001, $\beta_{THR} = 0.11$ [0.06, -0.37], $\beta_{STIM} = 0.11$ [-0.02, -0.45], $\beta_{BOTH} = 0.11$ [-0.03, -0.46]) were significant in the CRN final model. These two main effects were qualified by a significant two-way interaction between these two factors, F(3, 3802) = 4.85, p = .002, $\beta_{THR} = 0.12$ [0.35, -0.12], $\beta_{STIM} = 0.12$ [0.22, -0.25], $\beta_{BOTH} = 0.12$ [0.35, -0.12].

The Congruency main effect was moderated by a significant two-way interaction between this factor and Stimulus type, F(3, 3802) = 11.85, p < .001, $\beta_{\text{THR}} = 0.12$ [0.54, 0.07], $\beta_{\text{STIM}} = 0.12$ [0.42, -0.05], $\beta_{\text{BOTH}} = 0.12$ [0.73, 0.26]. The two-way interaction between Participant sex and Stimulus type also reached significance (F(1, 3802) =13.77, p < .001, $\beta = 0.12$ [0.22, -0.27]), as did the three-way interaction between these two factors and STAI-T scores (F(1, 3802) = 10.51, p = .002, $\beta = 0.01$ [0.06, 0.02]). The three-way interaction between Stimulus type, Threat level, and STAI-T scores (F(1, 3802) = 17.51, p < .001, $\beta = 0.01$ [0.04, -0.003]) was also significant, as well as that between Participant sex, Congruency, and STAI-T scores (F(3, 3802) = 21.23, p < .001, $\beta_{\text{THR}} = 0.01$ [0.01, -0.05], $\beta_{\text{STIM}} = 0.01$ [0.03, -0.02], $\beta_{\text{BOTH}} = 0.01$ [0.02, -0.03]). Each three-way interaction was further qualified by one or more of five four-way interactions that reached significance in the CRN final model (Table 5.22).

The four-way interaction between Stimulus type, Threat level, Participant sex and STAI-T scores showed that arrays with aimed handgun distractors led to more negative CRN amplitude compared to arrays with water pistol, attacking snake or turtle distractors (Figure 5.39). These differences were either significant or a trend for female,

Table 5.22. Parameter information for significant four-way interactions in the CRN final model, with the reference parameter and estimates (β) provided for each interaction. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Stim*Thr*Sex*Cong	$F(3, 3802) = 9.28^{***}$	
ref. Firearm: Attack: Female: CON	Reptile: Neutral: Male: THR	0.25 [1.32, 0.35]***
	Reptile: Neutral: Male: STIM	0.25 [0.18, -0.8]
	Reptile: Neutral: Male: BOTH	0.25 [1.12, 0.14]*
Stim*Thr*Cong*STAI-T	<i>F</i> (3, 3802) = 11.97***	
ref. Firearm: Attack: CON	Reptile: Neutral: THR	0.01 [0.1, 0.05]***
	Reptile: Neutral: STIM	0.01 [0.04, -0.01]
	Reptile: Neutral: BOTH	0.01 [0.05, 0.004]*
Stim*Thr*Sex*STAI-T	F(1, 3802) = 35.94 * * *	
ref. Firearm: Attack: Female	Reptile: Neutral: Male	0.01 [-0.04, -0.07]***
Stim*Sex*Cong*STAI-T	$F(3, 3802) = 9.34^{***}$	
ref. Firearm: Female: CON	Reptile: Male: THR	0.01 [0.07, 0.02]**
	Reptile: Male: STIM	0.01 [-0.001, -0.05]*
	Reptile: Male: BOTH	0.01 [0.03, -0.02]
Sex*Cor*Cong*STAI-T	F(6, 3802) = 6.37 ***	
ref. Firearm: Female: CON	Male: Midline: THR	0.02 [-0.01, -0.07]**
	Male: Midline: STIM	0.02 [-0.01, -0.07]*
	Male: Midline: BOTH	0.02 [-0.01, -0.07]**
	Male: Right: THR	0.02 [-0.04, -0.1]***
	Male: Right: STIM	0.02 [-0.05, -0.11]***
	Male: Right: BOTH	0.02 [-0.05, -0.12]***

.1

Cong: Congruency, CON = Congruent, THR = Incongruent threat, STIM = Incongruent stimulus, BOTH = Incongruent both



Figure 5.39. LS means for CRN mean amplitudes categorised by stimulus type, threat level and participant sex ($M_{\text{STAI-T}} = 40.12$). LS differences between different distractor types are shown for males and females (bottom left). Vertical and horizontal bars denote 95% confidence intervals.

but not male, participants. In the female grouping, there were negative, weak and significant correlations between STAI-T scores and CRN amplitudes for arrays with aimed handgun (Bonferroni-corrected $\alpha = .006$; r = -.23, p < .001) or turtle (r = -.14, p = .002) distractors. Similar positive relationships were also observed in the male grouping for arrays with aimed handgun (r = .21, p < .001), water pistol (r = .21, p < .001) or turtle (r = -.14, p = .003) distractors. The Coronal site factor also interacted significantly with Congruency, Participant sex and STAI-T scores (Figure 5.40). CRN amplitude was more variable for female than male participants across coronal sites for each congruency condition, and the CRN activity of females was more negative than that of males



Figure 5.40. LS means for CRN mean amplitudes categorised by congruency, participant sex and coronal site ($M_{\text{STAI-T}} = 40.12$). No meaningful differences between males and females reached sigificancefor this four-way interaction (all *ps* < .05). Vertical and horizontal bars denote 95% confidence intervals

overall. Moderate, positive and significant correlations were also found between STAI-T scores and CRN amplitude in the right hemisphere for arrays with incongruent stimulus (Bonferroni-corrected $\alpha = .002$; r = .32) or incongruent both (r = .33, both ps < .001) distractors.

The four-way interaction involving Stimulus type, Congruency Participant sex and STAI-T scores indicated that reptile-only arrays evoked more negative CRN than those with mismatched reptile distractors and firearm targets (Figure 5.41). These differences reached significance for the incongruent both condition for males and females. For incongruent stimulus arrays, however, the difference between reptile-only arrays and those with mismatched reptile distractors and firearm targets was significant only for incongruent threat arrays in the male grouping. These sex differences may have been linked to trait anxiety, as there were positive, weak and significant associations between STAI-T scores and CRN amplitude for males in response to arrays with reptile distractors that were incongruent stimulus (Bonferroni-corrected $\alpha = .003$; r = .28,



Figure 5.41. LS means for CRN mean amplitudes categorised by stimulus type, congruency and participant sex ($M_{\text{STAI-T}} = 40.12$). LS differences between firearm and reptile distractors are shown for males and females (top right), as well as those between reptile-only arrays and those with reptile distractors and firearm targets (bottom). All differences between males and females for firearm and reptile distractors were non-significant (all *ps* > .05). Vertical and horizontal bars denote 95% confidence intervals.

p < .001) or incongruent both (r = .22, p = .001). Similar weak to moderate relationships were also found for arrays with firearm distractors in the male grouping for the incongruent threat (r = .37) and incongruent both (r = .24, both ps < .001) conditions. Outside of STAI-T scores, incongruent both arrays with firearm distractors elicited

significantly more negative CRN than those with reptile distractors for females, but not males. A trend also occurred for more negative CRN activity for congruent reptiles than congruent firearms for males, but not females.

The Stimulus type, Threat level and Congruency factors featured in the last two significant four-way interactions in the CRN final model. Regarding STAI-T scores, CRN activity was not modulated by congruent or incongruent threat arrays (Figure 5.42). In the incongruent stimulus condition, attack arrays with aimed handgun distractors evoked more negative CRN than other incongruent stimulus arrays. These differences reached significance for turtle ($\beta = -0.32$ [-0.2, -0.44], p < .001) and water pistol distractors, but not for attacking snake distractors (see Figure 5.42 for other parameter information). In the incongruent both condition, reduced CRN was found for those arrays with turtle distractors compared to arrays with attacking snake, aimed handgun, or water pistol distractors. This CRN modulation was significant for aimed handgun ($\beta = -0.36$ [-0.4, -0.48], p < .001) and attacking snake distractors, but not for water pistol distractors (see Figure 5.42 for other parameter information). For arrays with images mismatched on threat level, there were positive and weak relationships between STAI-T scores and CRN amplitude for arrays with water pistol distractors. This association was significant in the incongruent threat condition (Bonferronicorrected $\alpha = .003$; r = .27, p < .001), and a trend in the incongruent both condition (r =.18, p = .005).

Regarding Participant sex, patterns of CRN activity were similar for males and females in the congruent and incongruent threat conditions (Figure 5.43). However, the CRN activity of males was significantly more negative for aimed handguns with an attacking snake target than water pistols with a turtle target, while CRN amplitude for incongruent stimulus arrays with reptile distractors was of equivalent magnitude. CRN



Figure 5.42. LS means for CRN mean amplitudes elicited by congruent and incongruent arrays, categorised by stimulus type and threat level ($M_{\text{STAI-T}} = 40.12$). LS differences between attack and neutral distractors within each stimulus type are shown, as well as those for reptile and firearm distractors of the same threat level. Vertical and horizontal bars denote 95% confidence intervals.

activity for turtles with a water pistol target was reduced compared to other incongruent stimulus arrays for females, but none of these differences reached significance (all *ps* > .05). For females incongruent both arrays with firearm distractors also evoked more negative CRN amplitude than arrays with reptile distractors. These differences were significant for arrays with aimed handgun distractors (Figure 5.43, $\beta_T = -0.44$ [-0.27, -0.61], *p* < .001), but not those with water pistol distractors. Lastly, incongruent both



Figure 5.43. LS means for CRN mean amplitudes categorised by stimulus type, threat level, congruency and participant sex. No meaningful differences between males and females reached sigificance for this four-way interaction (all ps > .05). Vertical and horizontal bars denote 95% confidence intervals.

arrays elicited more negative CRN activity than arrays with neutral distractors for males, but only the difference between arrays with attacking snakes paired with a water pistol and turtles with an aimed handgun reached significance.

Discussion

The objective of Experiment 2 was to examine sex-specific variation in response selection towards the threat value of snake and handgun images showing attack intent. Consistent with predictions, biological relevance influenced sex differences in ERP modulation throughout the picture processing stream. Fluctuation in stimulus-locked activity for the anterior N1, the EPN and the LPP occurred in response to Flanker arrays. Amplitude modulation corresponding to a posterior N1 and a later-occurring EPN (i.e., the MPN) were also observed in averaged ERP data. The depiction of attack intent, rather than biological relevance, was linked to sex differences in early and lateoccurring ERP modulation. Similar to Experiment 1, activity for the LPP was related to individual variation in trait anxiety and worry. N1 and CRN modulation were both influenced by trait anxiety scores, while occipital N1 and EPN amplitude were moderated by individual variation in neuroticism. These findings imply negative emotionality is connected to ERP activity evoked by the image Flanker task; a link supported by EEG studies that have employed standard versions of the Flanker paradigm (Moran, Taylor, & Moser, 2012; Schroder, Moran, Infantolino, & Moser, 2013; Weinberg, Liu, & Shankman, 2016).

Sex-specific variation in response selection towards attack intent

An advantage of the image Flanker task employed in the present research was the incorporation of direct responses to aversive and neutral stimuli in context rather than in isolation. The presence of pleasant or neutral images alongside negative stimuli in EEG studies that have employed the oddball paradigm may have facilitated, or dampened, sex-specific variation in ERP modulation (Groen et al., 2013; Li et al., 2008; Proverbio et al., 2009; Rozenkrants & Polich, 2008; Yuan et al., 2009). The relative influence of biological relevance on response selection in male and female individuals was examined by matching the attack intent of reptile and firearm stimuli. The use of naturalistic scenes, rather than faces, as Flanker stimuli were validated by behavioural data and response-locked CRN activity. Responses were overall faster to congruent than incongruent arrays but made with equivalent accuracy, a result that corresponds with previous research (Moser, Moran, & Jendrusina, 2012). CRN modulation was also evident at anterior electrodes in a time frame consistent with prior EEG studies (Gehring et al., 2011; Moser et al., 2008, 2012; Weinberg et al., 2016).

Sex differences in Experiment 2 were most evident in early and late-occurring ERP modulation. The CRN activity of women was reduced for incongruent both arrays with reptile distractors compared to those with firearm distractors, an effect not observed for men. Regarding stimulus-locked ERPs, the amplitude of the anterior and occipital N1 activity was modulated by images of attack intent for female participants. The anterior N1 was sensitive to arrays in which threat level was mismatched for women, while occipital N1 amplitude was moderated by attack-only or neutral-only arrays. These effects in N1 modulation were not observed in men, although incongruent stimulus arrays with mismatched attack images led to more negative anterior N1 activity than mismatched neutral arrays for male participants. To date, this type of modulation for the anterior N1 is without precedent in relation to sex-specific variation in ERP activity. In contrast, modulation of the occipital N1 corresponds to sex differences in posterior N1 activity observed in one EEG study (Lithari et al., 2010). Akin to N1 activity in anterior regions, the posterior N1 is implicated in early perceptual processing (Luck, Heinze, Mangun, & Hillyard, 1990; Vogel & Luck, 2000). In picture

processing, the distribution of the posterior N1 is more typically localised to parietal, rather occipital, regions (Foti et al., 2009; Hajcak et al., 2012).

The threat level of distractors was also found to moderate LPP amplitude for female participants. Arrays with attack distractors led to more positive LPP activity than those with neutral distractors in women with below average levels of trait anxiety. The same difference in LPP modulation was not observed in women with above average levels of trait anxiety or in men. Individual variation in worry was also related to these sex differences in LPP activity for participants with below average levels of trait anxiety. Again this sex-specific variation in the LPP has not been previously found in relation to images of attack intent. Previous EEG studies examining sex differences towards unpleasant naturalistic scenes have not specifically examined the influence of anxious traits on picture processing (see Chapter 2). Two recent EEG studies, however, have linked LPP activity elicited by unpleasant images to individual variation in worry (Burkhouse, Woody, Owens, & Gibb, 2015; Grant, Judah, White, & Mills, 2014). Higher levels of worry were associated with larger LPP activity towards threatening images in both cases. Scenes of threat included content such as physical assault, humans armed with weapons, aggressive animals, human injury, and poverty.

As observed in Experiment 1, similarities between male and female individuals were evident in ERP modulation. Regarding the anterior N1, arrays with mismatch attacking snake and aimed handgun images led to more negative N1 activity than those with mismatched neutral images in the same congruency condition. Reptile-only arrays were also found to evoke more negative occipital N1 activity than arrays with firearm images, but the reverse pattern of N1 modulation occurred for arrays with images mismatched on stimulus type. These results contrast those from an EEG study that found no difference in target-locked P1 modulation between cues that were

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biologically-relevant threats (e.g., snakes, spiders) and artificial threats (e.g., knives and syringes) in a dot-probe task (C. Brown et al., 2010). The anterior N1 activity of women also tended to be more negative than that observed for men in response to arrays with reptile, but not firearm, distractors. Sex-specific variation has previously been reported for EPN modulation in relation to images of snakes, spiders, and slugs (Van Strien, Franken, & Huijding, 2014). Similar to the results observed in Experiment 2 however, these sex differences in EPN activity did not reach statistical significance.

The emotional salience of attack intent in unpleasant images

The dynamic between biological relevance and attack intent was apparent in EPN and LPP modulation. These two types of ERP activity were larger for congruent aimed handguns compared to arrays with water pistol, attacking snake, or turtle images. This modulation was pre-empted in occipital N1 modulation, as the N1 activity for aimed handgun arrays was reduced compared to that observed for other congruent arrays. Artificial weapons such as aimed handguns are regularly included as negative stimuli in picture processing research (e.g., Burkhouse et al., 2015; Matsuda & Nittono, 2015; Wheaton et al., 2013). The present findings raise the possibility that humans armed with weapons are prioritised over other forms of attack intent. LPP modulation for congruent arrays even contrasts to results from Experiment 1, as high threat forms of snakes and handguns both led to the largest amounts of LPP activity in their respective stimulus categories in this study. LPP activity for congruent arrays was also tempered by effects observed for incongruent conditions. First, attack arrays with snake distractors led to larger LPP activity than neutral arrays with turtle distractors, a difference that did not occur for arrays with firearm distractors. Second, LPP amplitude in participants with above-average levels of trait anxiety was more positive to an aimed handgun with turtles than to other incongruent both arrays, an effect not observed for

participants with below average trait anxiety.

The results from the current EEG study must be approached with caution. Regarding the differentiation of firearm from reptile images in occipital N1, EPN and LPP activity, these effects may be specific to the Flanker task paradigm. Performance on visual search tasks that incorporate images as stimuli is allegedly susceptible to stimulus-level features unrelated to emotional salience (Cave & Batty, 2006; Quinlan, 2013). Given that many modified versions of the visual search task employ naturalistic scenes as targets and distractors, these short-comings also apply to the current Flanker task. Snake-only arrays also led to much slower responses and more negative CRN activity than other congruent arrays. In recent years, the unique physical characteristics of snakes have been scrutinised (Hayakawa, Kawai, & Masataka, 2011; LoBue, 2014; Lobue & Deloache, 2011). Perceptual features associated with an attacking snake, such as a curvilinear body or bared fangs, may have driven sex-specific variation and other effects observed in Experiment 2. Despite this, the present findings support the notion that individual- and stimulus-level factors both contribute to the threat value of a negative stimulus.

Another limitation is that the depiction of attack intent in images can be interpreted in several ways. The types of attack stimuli shown in visual search tasks can include a snake poised to strike (Masataka, Hayakawa, & Kawai, 2010), snarling cats and dogs (Yue & Quinlan, 2015), or an artificial weapon being shown armed or unarmed (Sulikowski & Burke, 2014). In the current EEG study attack intent was defined in terms of threat value, such that snakes and aimed handguns implied imminent violence. The presence of multiple threat cues could drive increasing levels of aversiveness in unpleasant images. The association of snakes and aimed handguns with danger, for instance, may be enhanced based on the signs of threat present in the

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negative scene (e.g., attack stance, reptilian features, attack aimed towards the observer of the image). Supporting this, several visual search studies that have not employed aggressive versions of animal images have reported a detection advantage for unpleasant targets (e.g., Lipp, 2006; LoBue & DeLoache, 2008; Lobue & Deloache, 2011; Öhman, Flykt, & Esteves, 2001). Therefore, attack intent could be one of the several factors that drive the attribution of threat value to a stimulus, and not the sole determinant of sex differences in picture processing.

Chapter 6 - EXPERIMENT 3

Sex differences in response selection towards highly aversive images of humans

The threat value of injured humans may be qualitatively different to other types of aversive images, a dynamic influenced by the action disposition of the human shown in the negative scene. This discrepancy could also contribute to sex-specific variation in picture processing when scenes of injured humans are presented alongside other unpleasant images. In the previous chapter, the relationship between attack intent and biological relevance for male and female individuals was examined with images that did not feature humans. A limitation of this approach is that the emotional salience of artificial objects, such as weapons, may depend upon the inferred presence of a human. In the present chapter, the role of threat value in the emotional salience of aversive human images will be detailed first, followed by a discussion of the effect of participant sex on this type of picture processing. An EEG study in which the relationship between sex-specific variation, response selection, and action disposition in the motivational relevance of human images was investigated will then be described.

Threat value, or the interaction between external cues and internal states in the attribution of threat to a stimulus, has been indirectly examined in EEG and fMRI studies that employ images with strong connotations of threat, disgust, or pain. Images of fear-eliciting or threatening stimuli include scenes of attack intent by humans or animals, while disgust images depict threats that are more contaminative in nature (e.g., unhygienic conditions, rotten food and disease). Supporting this distinction, images of threat and disgust elicit distinct patterns of ERP activity and BOLD activation (Carretié et al., 2011; Krusemark & Li, 2011; Lu et al., 2015; Schienle et al., 2005; Wheaton et al., 2013). Select fMRI studies, however, have also shown that images of humans in pain moderate BOLD activation (Costantini, Galati, Romani, & Aglioti, 2008;

Morrison, Peelen, & Downing, 2007). A particularly aversive form of human stimulus, injured humans, are also differentiated from other types of aversive images in brainbased measures (Schäfer et al., 2010; Schienle et al., 2006; Wright et al., 2004). It is presently unclear whether threat, disgust or pain is the primary driver of threat value for aversive images of humans.

Unpleasant images of humans vary widely in action dispositions, ranging from the display of obvious signs of aggression to situations in which the human is clearly vulnerable. These stimuli can be broadly classified as those that insinuate more direct or active forms of threat, or those in which more passive hazards are depicted. The emotional salience of images that show severe injury (e.g., blood, contamination, physical threat) may be driven by the vulnerability of the human in the image, or by the presence of multiple danger cues in these negative scenes. Human injury has repeatedly escaped categorisation in picture processing due to having clear connotations of disgust, threat, and pain. When examined as a unique semantic category, images of severe injury include scenes of unconscious or recently deceased humans subjected to invasive medical procedures, murder or accident victims, life threatening bodily damage (e.g., burns, open wounds), or severe physical mutilation (Mocaiber et al., 2009; Schäfer et al., 2010; Schienle et al., 2006; Weinberg & Hajcak, 2010).

The influence of action disposition on the processing of aversive images was investigated by Kveraga et al. (2014), who measured BOLD activation in response to scenes of humans or animals. Merely negative images were highly aversive with little connotation of direct threat and included depictions of animals or humans who were dead, injured, or unconscious. Direct threats were denoted by scenes of attack intent, such as animals showing bared fangs, humans armed with weapons, and aggressive humans or animals. Indirect threat stimuli were similar, but showed attack intent from a

third-person perspective (e.g., animal attacks, crimes committed by humans, surgery). BOLD activation in the amygdala and the periaqueductal grey cortex, two brain regions associated with threat-related processing, was largest for direct threat, followed by indirect threat, and then merely negative images. The reverse pattern of BOLD activation was reported in the retrosplenial and parahippocampal cortices, two brain areas implicated in the default mode network (Buckner, Andrews-Hanna, & Schacter, 2008). The results observed by Kveraga et al. imply the action disposition of specific image content moderates the processing of highly aversive images.

Although the images employed by Kveraga et al. (2014) included animals, their findings suggest action disposition contributes to the threat value of negative scenes that show humans. It must be noted, however, that a predominantly female sample was recruited by Kveraga et al. for their fMRI study. The effects observed by the researchers may have been driven by brain activation specific to women rather than men. In line with this, the female response to stress is theorised to align with a "tend and befriend" approach rather than the traditional fight-or-flight response in some circumstances (S. E. Taylor, 2006, 2011; S. E. Taylor et al., 2000). Several lines of evidence support the link between threat value, an individual's biological sex and the predisposition to affiliative and care-taking behaviour. Female infants are more likely to display empathic behaviour compared to male infants, a difference that remains stable throughout childhood and beyond (Christov-Moore et al., 2014). Hormone fluctuation during adolescence is also associated with changes in social behaviour for men and women (Forbes & Dahl, 2010). There is a greater tendency, moreover, for males to show negative emotionality compared to females during infancy, a trend that reverses in childhood, adolescence, and adulthood (Craske, 2003).

The aim of Experiment 3 was to compare response selection between men and

women towards aversive images of humans with active or passive dispositions. A severely wounded person represents a more passive hazard compared to the more active threat of an assailant armed with a weapon. Sex-specific variation in N2 and late positive activity elicited by unpleasant images of humans have been reported by several EEG studies (Gonzalez-Liencres et al., 2016; Groen et al., 2013; Han et al., 2008; Luo et al., 2014; Proverbio et al., 2009). To date, the influence of stimulus congruency on differences between male and female individuals in ERP activity towards highly aversive images of humans has not been systematically investigated. EEG was recorded as men and women completed a modified Flanker task which featured aversive and neutral images of humans as stimuli in the present study. Sex differences in stress reactivity were again indexed by measuring participant's levels of trait anxiety, worry, alexithymia and neuroticism. Women taking some form of birth control medication and men were recruited for the present study.

Scenes of humans who are severely injured (Costantini et al., 2008; Morrison et al., 2007; Schäfer et al., 2010; Schienle et al., 2006; Wright et al., 2004) or explicitly show attack intent (Carretié et al., 2011; Krusemark & Li, 2011; Kveraga et al., 2014; Lu et al., 2015; Schienle et al., 2005; Wheaton et al., 2013) may evoke unique patterns of brain activity in male and female individuals. The results from Experiment 3 were expected to clarify whether images of human injury or attack intent by humans contribute to sex differences in motivational relevance. Findings from Experiment 2 demonstrate that the modified Flanker task elicits sex-specific variation in behavioural performance and ERP modulation. In the current experiment, it was anticipated that activity for the stimulus-locked anterior N1, occipital N1 and the LPP would reflect sex differences in response selection towards congruent and incongruent images of severe injury and attack intent. Flanker congruency was also expected to moderate activity for

the EPN, the MPN and the response-locked CRN, but not in relation to sex-specific variation.

Method

Participants

EEG data was collected from 41 volunteers (20 male) aged between 18 and 36 years ($M = 23.9\pm0.72$). Participants were recruited, reimbursed and excluded following the same guidelines outlined in Experiment 1. Thirty-nine participants were right-handed (two left-handed), and all had normal or corrected-to-normal vision. Similar to Experiments 1 and 2, before EEG testing participants completed the general medical history questionnaire, the PSWQ, the TAS-20, the IPIP5F-100, and the STAI. Data from one female participant were excluded due to this woman making errors on more than 50% of trials for two incongruent conditions during EEG testing, leaving 20 females and 20 males with usable data. All female participants, including the excluded female, were prescribed some form of hormonal contraceptive. Two women were implanted with progestogen-only rods (Implanon, 68mg etonogestrel), while the remaining 18 women were taking the contraceptive pill (Table 6.1). Ethical procedures were the same as reported for Experiments 1 and 2 (also see Digital Appendix A).

Stimuli and materials

Images. Stimulus selection for Experiment 3 was based on valence, arousal, threat, and disgust ratings of 125 images by five male ($M_{Age} = 27$, SD = 2.83) and five female ($M_{Age} = 36$, SD = 7.83) volunteers. Before rating the 125 images were resized to 800 x 500 pixels and converted to .jpeg format. Injury images with male or gender-neutral actors were selected from the IAPS or downloaded from the Internet (Lang et al., 2008). Humans who were clearly male featured in the remaining images as women are shown to differentiate between male and female faces to a greater extent than men in

Table 6.1. Combined oral contraceptives prescribed to 18 women recruited for Experiment 3. Information is categorised by the brand name most often provided by participants. Alternative brand names, the number of females prescribed and the active hormone-based ingredients are also provided.

Pill brand	Alternative names	No. of females	Active ingredients
Levlen ED	Microgynon-50ED, Monofemme,	9	Levonorgestrel (synthetic progesterone) and ethinyloestradiol (synthetic oestrogen)
Estelle-35ED	Chelsea-35ED, Diane-35ED, Brenda-35ED	7	Cyproterone acetate (synthetic progesterone) and ethinyloestradiol
Yasmin	Yaz Flex	2	Drospirenone (synthetic progesterone) and ethinyloestradiol

ERP activity (Oliver-Rodríguez, Guan, & Johnston, 1999; Sun, Gao, & Han, 2010). Three types of high-arousing, active disposition stimuli were rated: angry men, scenes featuring fighting men, and men aiming handguns at the observer. Unlike Experiments 1 and 2, the person aiming the handgun was clearly visible. These images were modified to blur the face of the assailant to minimise the impact of facial features on behavioural and ERP data. Scenes of men sleeping or relaxing with their eyes closed were shown as low-arousing counterparts to injury stimuli. These stimuli and the higharousing active disposition images were downloaded from the Internet (Australian Copyright Council, 2014). Low-arousing stimuli for the active disposition category were neutral images of unarmed men selected from the IAPS (Lang et al., 2008) or EmoMadrid (CEACO, 2012) image databases.

Valence, arousal, threat and disgust ratings were collected from volunteers across two blocks with the same four modified six-point scales from Experiment 1. Volunteers were seated in a quiet room with a computer screen positioned at eye level. Trials began with a small white fixation cross shown for 1000ms, after which an image appeared for 1000ms. The scale for the first affective rating was then presented, followed by the second affective rating. Each rating scale remained onscreen until the volunteers responded using buttons one to six on a normal keyboard. The next trial began after an inter-stimulus interval of 500ms, with each image being presented once in each of the two blocks in a random order. Valence and arousal ratings were collected in the first block, while ratings for threat and disgust were recorded in the second block. Half of the volunteers completed ratings for valence before arousal, while the other half rated arousal before valence. The same procedure was applied in the second block for threat and disgust ratings. Forty images⁹ were selected from the pool of 125 images to construct Flanker arrays in Experiment 3 (see Figure 6.1, Appendix L). Twenty images were unpleasant and high-arousing, while the remaining 20 were low-arousing and rated with neutral to pleasant valence (Figure 6.2).

Ten images of men with aimed handguns were chosen as high-arousing, active disposition counterparts to 10 images of human injury. The 20 low-arousing stimuli consisted of 10 images that depicted unarmed men and 10 featuring men who were asleep or relaxed with eyes shut. Four separate 2(Threat type: active disposition, passive disposition) x 2(Arousal level: high, low) Friedman ANOVAs were performed on data for each rating type. These tests were significant for valence (χ^2 (3) = 26.21, *p* < .001, *W* = .87), arousal (χ^2 (3) = 24.24, *p* < .001, *W* = .8), threat (χ^2 (3) = 25.31, *p* < .001, *W* = .84), and disgust (χ^2 (3) = 25.17, *p* < .001, *W* = .84). Wilcoxon signed rank tests with Bonferroni corrections (α = .008) were used to compare the four image categories in each rating type. High-arousing images were rated as significantly more unpleasant, arousing, threatening and disgusting than low-arousing images (Figure 6.2). Ratings for

⁹**Unarmed men:** IAPS images - 2038, 2102, 2191, 2370, 2382, 2391; EmoMadrid -EM0504, EM0658, EM0672, EM0678; **Severe injur**y: IAPS - 3080, 3102, 3120, 3131, 3140, 3213, 3250



Figure 6.1. Examples of high and low arousing stimuli selected for active and passive disposition categories for the modified Flanker task. Shown images are sourced from the Internet.



Figure 6.2. Average ratings of valence, arousal, threat and disgust for 40 human images, categorised by threat type and arousal level. P-values for all differences between the medians of high and low arousal images below the Bonferroni-corrected significance level ($\alpha = .008$). Vertical bars denote 95% confidence intervals.

active and passive disposition images in each arousal category were approximately equal, excluding disgust ratings of high-arousing images. Images of human injury (*Mdn* = 5.85, IQR = 5.5-6) was rated as more disgusting compared to those images showing men with aimed handguns (*Mdn* = 4.3, IQR = 3.7-5), Z = 2.67, p = .008, r = .6).

Flanker task. The structure, design and execution of the modified Flanker task were the same as described for Experiment 2. The two levels of incongruence were threat type and arousal level (Figure 6.3). Congruent trials showed five different stimuli from the same image category. Images included as targets or distractors in incongruent arrays were mismatched on arousal level, threat type, or both arousal level and threat



Figure 6.3. Symbol representation of 16 congruency conditions for active (top; men with aimed handguns, unarmed men) and passive (bottom; severe injury, sleeping men) image distractors. For each distractor type arrays are shown in the order of congruent, incongruent arousal level, incongruent threat type, and then incongruent both. Distractor and target images were randomly selected from the appropriate image category, and no image appeared more than once in any single array.

type. For instance, images featuring men with aimed handguns were shown with an unarmed male target in the incongruent arousal condition and a severe injury target in the incongruent threat condition. For the incongruent both condition, aimed handgun distractors accompanied a target image featuring a sleeping man. Participants responded to arrays by indicating whether the target and distractor stimuli were from the same or different image category (i.e., aimed handguns, unarmed men, severe injury, sleeping men). Each participant completed 480 trials for congruent arrays and 480 trials for incongruent arrays. This design produced a maximum trial count of 40 for each of the 12 incongruent conditions.

EEG recording and processing

Data collection. EEG data was continuously sampled at 1000Hz from 64 electrodes using the same equipment and the same acquisition method as outlined in Experiment 1. Off-line processing was performed in BESA 6 after EEG data was exported from Curry 7.

Event-locked ERP reduction and scoring. Procedures for ERP data processing were the same as performed in Experiments 1 and 2. Stimulus-locked and response-locked epochs were computed with a pre-stimulus/response baseline of 200ms using the original average reference. No less than 80% of trials ($n \ge 30$) were accepted for each of the 16 conditions for each participant.

Procedure

Participants completed the modified Flanker task in the same setting as Experiment 2 following the same instructions. Ten practice trials featured images of turtles, neutral everyday objects, or a combination of these¹⁰. Experimental trials were

¹⁰ **IAPS images included:** 7038, 7040, 7061, 7081, 7090, 7150, 7165, 7170, 7175, 7211, 7211.

randomised across four blocks of 240 trials each as EEG was recorded. Self-paced breaks were scheduled after the end of each block. A white fixation cross was presented for 1000ms, followed by the Flanker array which remained onscreen until the participant's response or 4000ms had elapsed. After 500ms the next trial began. Similar to Experiment 2, button position was not counterbalanced across the four blocks. The entire task took approximately 45 minutes to complete

Design and data analysis

A 2[Participant sex: male, female] x 2(Arousal level: high, low) x 2(Threat type: active disposition, passive disposition) x 4(Congruency: congruent, incongruent arousal, incongruent threat, incongruent both) mixed design was followed. Preparation and analysis of behavioural and ERP data were the same as reported for Experiments 1 and 2. Congruency effects were also examined in the same manner detailed in Experiment 2 for aimed handgun, unarmed men, severe injury and sleeping men distractors.

Behavioural data. Missing values comprised 0.14% of raw data for the 20 female and 20 male participants. Responses faster than 150ms were again removed (Jensen, 2006), as were reaction times more than two and a half standard deviations above the mean reaction time (M = 1022, SD = 470.85). The upper limit of 2199ms indicated responses to the modified Flanker task were overall slower compared to behavioural performance in Experiment 2. Statistical analyses were performed on 96.46% of raw behavioural data. At least 23 correct responses for each condition were available to calculate reaction times for each participant. Hit-rates for each congruency condition were calculated to indicate the accuracy of responses towards Flanker arrays and were not analysed further. Linear mixed effects analysis of reaction times followed the same format as performed on ERP data excluding the inclusion of electrode position factors.

ERP activity. Data was reduced and scored in a similar manner to Experiment 2. Stimulus-locked and response-locked ERP average waveforms were computed across 64 channels for the overall, male and female groupings. The average waveform for response-locked data during error trials was computed to confirm the timing of the ERN in relation to the CRN. Again, ERP data was down-sampled from 1000Hz to 500Hz for graphing of waveforms. Optimal time frames for mean amplitudes were based on visual inspection of the individual, overall, and group average waveforms, as well as previous reports of relevant ERP activity.

Linear mixed effects analysis. See Experiment 1 for full details of linear mixed effects analysis in the present research. The analysis procedure followed that described for the modified Flanker task in Experiment 2. The fit of the base model was significantly better than that of the corresponding null model for reaction times and each ERP dataset, confirming the necessity of the random intercept for Participant in each base model (Appendix H, Digital Appendix D). The AIC, BIC and loglikelihood values of models estimated for each ERP dataset are provided in Appendix I. For each ERP dataset descriptions of average waveforms by way of Arousal level, Threat type and Congruency are detailed first. Following this model estimation, fit statistics, and any breakdown procedures applied to the final model in each dataset are described. Again, interactions involving the Coronal site or Sagittal location factors will only be reported if these factors interact with the Threat type, Arousal level, or Congruency factors.

Results

Behavioural data

Questionnaire scores. PSWQ and Neuroticism scores followed a normal distribution and possessed approximately equal variance (Digital Appendix D). Full analyses for the five IPIP5F-100 dimensions can be found in Appendix B. The variance

of the two STAI subscales was approximately equal. STAI-S and STAI-T scores, however, did not follow a normal distribution. Scores from the TAS-20 did not follow a normal distribution, and the variance of this data was also not equal. PSWQ and neuroticism scores were analysed with two separate 2[Participant sex: male, female] independent samples *t*-test. Scores from the STAI and TAS-20 were analysed with three separate non-parametric 2[Participant sex: male, female] Mann-Whitney U tests with continuity corrections.

The PSWQ. The average score for the PSWQ was 46.88 (*SE* =1.83). PSWQ scores possess very strong internal reliability (α = .92). There was a strong, negative relationship between PSWQ and emotional stability scores, indicating a positive association between worry and neuroticism scores (Table 6.2). Similar to the two previous experiments, the PSWQ scores of females (*M* = 54.3±1.86) were greater than those for males (*M* = 39.45±2.1). This difference between the sexes was significant, t(38) = 5.29, p < .001, d = 1.49.

The TAS-20. The mean TAS-20 score was 44.05 (*SE* =1.61, *Mdn* = 43, *IQR* = 37.5-48), and internal reliability was strong among TAS-20 scores (α = .83). Unequal variance in this dataset was driven by one male with a very high TAS-20 score (82). Removing this data point did not normalise the distribution of TAS-20 scores, therefore the participant's data was retained. Scores for males (*M* = 45.55 ±2.61; *Mdn* = 44.5, *IQR* = 38-49.5) were slightly greater than those of females (*M* = 42.55 ±1.89; *Mdn* = 42.5, *IQR* = 36.5-46), but this difference was not significant, *U* = 168.5, *n*₁ = *n*₂ = 20, *p* = .4, *r* = -.13.

Neuroticism. The Cronbach alpha for emotional stability scores from the IPIP5F-100 was very strong ($\alpha = .9$), indicating the internal reliability of neuroticism scores was very good. Neuroticism scores were strongly and positively correlated with

Table 6.2. Spearman rank correlation coefficients between scores from the PSWQ, the TAS-20, neuroticism and the two subscales of the STAI. P-value significance is located at the bottom left of the table.

	PSWQ	TAS-20	Normatiaiana	STAI	
			Neuroticism	STAI-S	STAI-T
PSWQ	1				
TAS-20	2	1			
Neuroticism	.65***	.12	1		
STAI					
STAI-S	.09	.07	.22	1	
STAI-T	.23	.21	.56***	.59***	1

p < .05*, p < .01 **, p < .001***

neuroticism scores (Table 6.2). The average Neuroticism score was 32.8 (*SE* =1.98), and females ($M = 38.4 \pm 2.39$) reported higher levels of neuroticism compared to males ($M = 27.2 \pm 2.66$). This difference between males and females in Neuroticism scores was significant, t(38) = 3.13, p = .003, d = 1.02.

The STAI. For the STAI-S, the average score was 30.05 (*SE* =1.56; *Mdn* = 29.5, IQR = 24.5-33), and for the STAI-T the average score was 38.25 (SE =1.36; *Mdn* = 36, IQR = 32-44). Cronbach alpha values for the total STAI ($\alpha = .83$), the STAI-S ($\alpha = .88$) and the STAI-T ($\alpha = .89$) suggested very strong internal reliability. There was a positive and strong association between STAI-S and STAI-T scores (Table 6.2). The STAI-S scores of females ($M = 31.2 \pm 2.05$; *Mdn* = 30.5, IQR = 22.5-36) and males ($M = 28.9 \pm 1.07$; *Mdn* = 29, IQR = 25-32.5) were similar. STAI-T scores for females ($M = 39.3 \pm 2.17$; *Mdn* = 35, IQR = 32-46.5) and males ($M = 37.2 \pm 1.66$; *Mdn* = 38, IQR = 32-42.5) were also equivalent. Separate 2[Participant sex: male, female] Mann-Whitney U tests confirmed any differences between males and females were not significant in

STAI-S (*U* = 182.5, *n*₁ = *n*₂ = 20, *p* = .65, *r* = .07) or STAI-T (*U* = 185, *n*₁ = *n*₂ = 20, *p* = .7, *r* = .06) scores.

Accuracy. Hit-rates for congruent arrays (M = 95.82%) were slightly lower than those for incongruent arrays (M = 97.29%). This difference between congruent and incongruent arrays was consistent for males ($M_{CONG} = 94.95\%$, $M_{INCONG} = 97.82\%$), however accuracy was approximately equal for congruent (M = 96.65%) and incongruent arrays (M = 96.76%) for the female grouping. Overall responses to congruent images of severe injury or unarmed men were less accurate than those towards arrays with congruent aimed handguns or sleeping men (Table 6.3). Accuracy for arrays with incongruent aimed handgun distractors was approximately equal to those observed for congruent handgun images. Hit-rates for arrays with incongruent injury distractors were noticeably higher compared to congruent injury images, with injury distractors paired with a handgun target eliciting the highest levels of accuracy for the 16 congruency conditions. The lowest levels of accuracy were observed for arrays with

Table 6.3. Mean hit-rates for each of the 16 congruency conditions in Experiment 3. Hit-rates are reported as percentages, and are categorised by the image category of the target and the distractors in the Flanker array. Congruent arrays are highlighted in light grey.

	Distractor images/Flankers			
-	Aimed handguns	Unarmed men	Severe injury	Sleeping men
Target image				
Aimed handgun	98.63%	98.2%	99.23%	98.6%
Unarmed man	98.87%	92.17%	97.85%	89.47%
Severe injury	98.98%	97.92%	94.87%	98.12%
Sleeping man	98.98%	94.14%	97.52%	97.45%

sleeping men distractors and an unarmed male target¹¹. Hit-rates for arrays with unarmed male distractors and a sleeping man target were also relatively low compared to other incongruent arrays (Table 6.3).

Reaction times. Similar to Experiment 2, residuals from reaction time data were positively skewed. Analyses were performed after a natural logarithm transformation was applied to reaction time data. Following this, reaction times were normally distributed with approximately equal variance (Digital Appendix D). The natural logarithm was reversed for reported values. Responses to congruent arrays ($M = 951.89 \pm 16.29$) were faster than to incongruent arrays ($M = 1000.28 \pm 9.13$), indicating performance on the Flanker task aligned with that on standard versions of the paradigm. This difference occurred for arrays with aimed handgun, injury, or sleeping men distractors (Figure 6.4). However, responses to congruent images of unarmed men were slower compared to those for incongruent arrays with these stimuli as distractors.

Linear mixed effects analysis. No trait scores were found to moderate reaction times in the modified Flanker task (Table 6.4). Reaction times were very strongly clustered for each participant (ICC_{Participants} = .85). The final model explained 89% of the total variance in reaction time data ($\sigma^2 = 0.004$, τ_{00} for participants = 0.03). Main effects for Arousal level (F(1, 577) = 432.55, p < .001, $\beta = 0.33$ [0.37, 0.3]), Threat type (F(1,577) = 8.73, p = .003, $\beta = -0.34$ [-0.29, -0.39]) and Congruency (F(3, 577) = 65.36, p <.001, $\beta_{ARO} = 0.17$ [0.21, 0.14], $\beta_{THR} = 0.11$ [0.15, 0.08], $\beta_{BOTH} = 0.16$ [0.2, 0.13]) were significant. A trend also occurred for the main effect of Participant sex, F(1, 38) = 3.1, p= .09, $\beta = 0.09$ [0.2, -0.01]. The Arousal level and Threat type main effects were qualified by significant two-way interactions between Arousal level and Threat type

¹¹ Some participants noted these arrays were easily confused with congruent unarmed men and incongruent arrays with a sleeping man target and unarmed men distractors. This may have led to the lower hit-rates observed for these three congruency conditions compared to other arrays in Experiment 3.



Figure 6.4. Descriptive means for reaction times categorised by Flanker congruency for active (left) and passive (right) distractor images. High-arousing images are shown to the left of each bar graph (i.e., aimed handguns, human injury), and low-arousing images to the right (i.e., unarmed men, sleeping men). Vertical bars denote standard errors.

Table 6.4. *R* notation for the final model estimated for reaction times. Abbreviations for factors included in analyses are provided at the bottom of the table.

R-notation				
Final model lmer(RT_nlog~ Aro*Thr*Cong + Aro*Cong*Sex + (~1 Participant), Ex3_RTs)				
Aro = Arousal lev	vel Thr = Threat type	Cong = Congruency	nlog = Natural logarithm	

 $(F(1, 577) = 72.67, p < .001, \beta = -0.08 [-0.04, -0.13])$, and Arousal level and Congruency $(F(3, 577) = 167.75, p < .001, \beta_{ARO} = -0.34 [-0.29, -0.39], \beta_{THR} = -0.05 [0.01, -0.1], \beta_{BOTH} = -0.29 [-0.23, -0.34])$.

All main effects and two-way interactions were further moderated by two threeway interactions reaching significance. First, there was a significant interaction between Arousal level, Threat type and Congruency, F(3, 577) = 31.81, p < .001, $\beta_{ARO} = 0.22$ [0.28, 0.16], $\beta_{THR} = 0.27$ [0.33, 0.21], $\beta_{BOTH} = 0.14$ [0.19, 0.08] (Figure 6.5). Congruent arrays with high-arousing images elicited significantly faster reaction times than their



Figure 6.5. LS means for reaction times categorised by arousal level, threat type and congruency. Parameter estimates for LS differences are shown between active and passive distractors for high and low arousal images (middle), and between high and low arousal distractors for active and passive images (bottom). Vertical and horizontal bars denote 95% confidence intervals.

low-arousing equivalents in the same threat type category. Responses to congruent unarmed men were also significantly slower compared to congruent injury ($\beta = 0.19$ [0.22, 0.16], p < .001) or sleeping men images (see Figure 6.5 for parameter information). Congruent aimed handguns evoked significantly faster reaction times than congruent images of injury. No differences in reaction times were evident in the incongruent arousal condition. For incongruent threat arrays, responses to incongruent
high-arousing images were significantly faster than to incongruent low-arousing images. In the incongruent both condition, arrays with sleeping men distractors elicited significantly faster responses than those with unarmed men or injury distractors (Figure 6.5). Reaction times for aimed handguns mismatched to a sleeping man target were also significantly faster than to those with an injury target and unarmed men distractors.

The second significant three-way interaction occurred between Arousal level, Congruency and Participant sex, F(3, 577) = 5.41, p < .001, $\beta_{ARO} = 0.04$ [0.1, -0.01], β_{THR} = -0.06 [0, -0.12], β_{BOTH} = 0.04 [0.1, -0.02] (Figure 6.6). Participants responded significantly faster to congruent than incongruent arrays when distractors were higharousing images (Table 6.5). The reaction times of females were also faster than males for all congruency conditions (all ps > .05). For males, reaction times were of similar magnitude for arrays with incongruent injury or aimed handgun distractors. For females, mismatched injury and aimed handgun images elicited significantly faster responses than incongruent arousal and incongruent both arrays with high-arousing distractors. The pattern of responses was similar between male and female participants for arrays with low-arousing distractors. Arrays with high-arousing targets and low-arousing distractors evoked significantly faster reaction times than arrays with low-arousing images only (Table 6.5). For incongruent threat arrays, the magnitude of this difference was much larger than observed for congruent arrays, such that responses to congruent low-arousing arrays were significantly faster compared to incongruent threat arrays with low-arousing images.

ERP data

The stimulus-locked amplitudes for the anterior N1, the occipital N1, the EPN, the MPN, and the LPP were maximal at similar locations and latencies observed in Experiment 2. Response-locked CRN activity was also evident at anterior sites close to



Figure 6.6. LS means for reaction times categorised by arousal level, congruency and participant sex. Vertical bars denote 95% confidence intervals.

Table 6.5. Pairwise contrasts between the levels of Congruency for high and low arousal distractors in reaction times, categorised by participant sex. The parameter estimate (β) and associated 95% confidence intervals are provided. P-value significance is located at the bottom left of the table.

Contract	Females	Males
Contrast	β [95% CI]	β [95% CI]
High arousal		
Congruent - IncAROUSAL	-0.13 [-0.16, -0.1]***	-0.13 [-0.16, -0.1]***
Congruent - IncTHREAT	-0.06 [-0.08, -0.03]*	-0.08 [-0.11, -0.05]***
Congruent - IncBOTH	-0.13 [-0.16, -0.1]***	-0.12 [-0.15, -0.09]***
IncAROUSAL - IncTHREAT	0.08 [0.05, 0.1]***	0.05 [0.02, 0.08]
IncAROUSAL - IncBOTH	0.001 [-0.03, 0.03]	0.01 [-0.02, 0.04]
IncTHREAT - IncBOTH	-0.07 [-0.1, -0.04]***	-0.04 [-0.07, -0.01]
Low arousal		
Congruent - IncAROUSAL	0.1 [0.07, 0.13]***	0.05 [0.02, 0.08]*
Congruent - IncTHREAT	-0.15 [-0.17, -0.12]***	-0.11 [-0.14, -0.08]***
Congruent - IncBOTH	0.09 [0.06, 0.12]***	0.06 [0.03, 0.09]**
IncAROUSAL - IncTHREAT	-0.24 [-0.27, -0.21]***	-0.16 [-0.19, -0.14]***
IncAROUSAL - IncBOTH	-0.01 [-0.04, 0.02]	0.01 [-0.02, 0.04]
IncTHREAT - IncBOTH	0.23 [0.2, 0.26]***	0.17 [0.14, 0.2]***

 $p < .05^*, p < .01 \ ^{**}, p < .001^{***}$

the midline. Mean amplitudes were derived for the anterior N1 (90-150ms), the occipital N1 (120-170ms), the EPN (150-250ms), and the LPP (450-650ms) from the same time frames and electrodes as described for Experiment 2. The MPN was computed from a slightly later time window, from 310 to 410ms post-stimulus. Activity for the CRN again peaked at the time of responses to Flanker arrays, and was calculated from -50 to 50ms post-response.

The anterior N1 (90-150ms). Mean amplitudes for the anterior N1 were analysed at the frontal-central electrodes FC1, FCz and FC2 and the central electrodes C1, Cz and C2. Congruent and incongruent both arrays did not appear to modulate anterior N1 activity (first and fourth rows; Figure 6.7, Figure 6.8). In the incongruent arousal condition, N1 activity was slightly reduced for unarmed men paired with a handgun target compared to other incongruent arousal arrays for female participants. This N1 modulation did not occur for males in the incongruent arousal condition. In the left hemisphere, arrays with aimed handgun distractors and an injury target led to more negative anterior N1 amplitude than other incongruent threat arrays for females (third row, Figure 6.7). At midline and right hemisphere sites, N1 activity for incongruent threat arrays with aimed handgun distractors was reduced compared to other arrays in this congruency condition. In contrast, incongruent threat arrays with unarmed men or injured distractors evoked more negative anterior N1 amplitude than other incongruent threat arrays for males at right hemisphere and midline sites (third row, Figure 6.8).

Linear mixed effects analysis. Only STAI-S scores were significantly related to anterior N1 modulation, and these were included as a predictor in the final model (Table 6.6). Between participants N1 activity was very strongly clustered (ICC_{Participants} = .82), and the final model accounted for 83% of total variance ($\sigma^2 = 0.64$, τ_{00} for participants = 2.93). Numerous significant main effects, two-way and three-way interactions were



Figure 6.7. Grand average waveforms showing the anterior N1 averaged across frontal-central and central electrodes for females. Congruency conditions are categorised based on the active (i.e., men with aimed handguns, unarmed men) or passive (i.e., severe injury, sleeping men) disposition of the human shown in distractor images.





Figure 6.8. Grand average waveforms showing the anterior N1 averaged across frontal-central and central electrodes for males. Congruency conditions are categorised based on the disposition of the human in distractor images for each Flanker array, active (i.e., men with aimed handguns, unarmed men) or passive (i.e., severe injury, sleeping men).



Table 6.6. *R* notation for the final model estimated for anterior N1 mean amplitudes. *Abbreviations for factors included in analyses are provided at the bottom of the table.*

		R-notation	
Final model	lmer(antN1~ Sag*Cor + Cor*STAI-S + Sex*Sag*STAI-S + Aro*Thr*Cong*Sag + Aro*Thr*Cong*Sex + Aro*Thr*Cong*STAI-S + (~1 Participant), Ex3_antN1)		
Breakdown model	lmer(antN1~ Sag*Cor + C Aro*Thr*Cong*Sag + Aro (~1 Participant), Ex3_antN	or*STAI-S + Sex*Sag* *Thr*Cong*Sex + Arc [1]	*STAI-S + •*Thr*Cong*STAI-S +
Aro = Arousal level Thr = Threat type	Sag = Sagittal location Cong = Congruency	Cor = Coronal site	STAI-S = state anxiety scores

qualified by all three four-way interactions reaching significance (Appendix K). These interactions were broken-down by separating participants into male (n = 20) and female (n = 20) groupings. In the breakdown model for the anterior N1, mean amplitudes were more strongly clustered for males (ICC_{Participants} = .87) than females (ICC_{Participants} = .76). The breakdown model also explained more total variance for male ($\Omega^2 = .87$, $\sigma^2 = .52$, τ_{00} for participants = 3.49) compared to female ($\Omega^2 = .78$, $\sigma^2 = .76$, τ_{00} for participants = 2.37) participants.

Females. The main effect of Threat type reached significance, F(1, 1847) = 6.13, $p = .01, \beta = 0.5$ [0.82, 0.19], and a trend occurred for the main effect of Congruency, $F(3, 1847) = 2.15, p = .09, \beta_{ARO} = 0.53$ [0.84, 0.21], $\beta_{THR} = 0.34$ [0.66, 0.03], $\beta_{BOTH} = 0.11$ [0.42, -0.2]. The Threat type main effect and the trend for Congruency were moderated by one or more of six significant two-way interactions (Table 6.7). Several significant two-way interactions involving Arousal level, Threat type, or Congruency were further modified by one or more of five significant three-way interactions involving these factors (Table 6.8). All significant three-way interactions, as well as

Table 6.7. Parameter information for significant two-way interactions qualified by higher order interactions in the anterior N1 breakdown model for females. The reference parameter, estimate (β) and associated 95% confidence intervals are provided. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Aro*Thr	$F(1, 1847) = 4.41^*$	
ref. High: Active	Low: Passive	-0.75 [-0.31, -1.2]***
Thr*Cong	$F(3, 1847) = 7.55^{***}$	
ref. Active: CON	Passive: ARO	-0.87 [-0.43, -1.32]***
	Passive: THR	-0.37 [0.07, -0.82]
	Passive: BOTH	-0.04 [0.41, -0.48]
Aro*Sag	F(1, 1847) = 6.49*	
ref. High: FC	Low: Central	-1.24 [-0.8, -1.68]***
Sag*Cong	F(3, 1847) = 5.67 * * *	
ref. FC: CON	Central: ARO	-1.36 [-0.92, -1.8]***
	Central: THR	-1.25 [-0.8, -1.69]***
	Central: BOTH	-1.29 [-0.84, -1.73]***
Aro*STAI-S	F(1, 1847) = 5.9*	
ref. High	Low	-0.05 [-0.02, -0.07]***
Cong*STAI-S	F(3, 1847) = 4.29 **	
Ref. CON	ARO	0.001 [0.03, -0.02]
	THR	-0.03 [-0.01, -0.06]*
	BOTH	-0.02 [0.001, -0.05].
.1 < p < .05., p < .05*, p < .01 **,	p < .001*** Aro: Arousal level	Sag: Sagittal location

Congruency: Cong, CON = Congruent, ARO = Incongruent arousal, THR = Incongruent threat, BOTH = Incongruent both

relevant main effects and two-way interactions, were further qualified by two significant four-way interactions in the female breakdown model. The four-way interaction between Arousal level, Threat type, Congruency and STAI-S scores will be described first, F(3, 1847) = 6.37, p < .001, $\beta_{ARO} = -0.11$ [-0.06, -0.16], $\beta_{THR} = -0.04$ [0.01, -0.09], $\beta_{BOTH} = -0.07$ [-0.03, -0.12]. Table 6.8. Parameter information for significant three-way interactions in the anterior N1 breakdown model for females. The reference parameter, estimate (β) and associated 95% confidence intervals are provided. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Aro*Thr*Cong	<i>F</i> (3, 1847) = 21.32***	
ref. High: Active: CON	Low: Passive: ARO	1.85 [2.48, 1.23]***
	Low: Passive: THR	1.07 [1.69, 0.44]***
	Low: Passive: BOTH	-0.06 [0.57, -0.69]
Aro*Thr*Sag	F(1, 1847) = 6.69 **	
ref. High: Active: FC	Low: Passive: Central	1.27 [1.89, 0.64]***
Aro*Sag*Cong	F(3, 1847) = 2.97*	
ref. High: FC: CON	Low: Central: ARO	1.34 [1.96, 0.71]***
	Low: Central: THR	0.95 [1.58, 0.32]**
	Low: Central: BOTH	1.03 [1.66, 0.4]**
Thr*Sag*Cong	$F(3, 1847) = 5.56^{***}$	
ref. Active: FC: CON	Passive: Central: ARO	1.44 [2.06, 0.81]***
	Passive: Central: THR	1.16 [1.79, 0.53]***
	Passive: Central: BOTH	1.34 [1.97, 0.72]***
Aro*Cong*STAI-S	F(3, 1847) = 3.02*	
ref. High: CON	Low: ARO	0.03 [0.07, 0].
	Low: THR	0.03 [0.07, 0].
	Low: BOTH	0.05 [0.08, 0.01]**
.1 < p < .05., p < .05*, p < .01 **, p < .0	01*** Aro: Arousal level	Sag: Sagittal location STALS = state anxiety scores

Congruency: Cong, CON = Congruent, ARO = Incongruent arousal, THR = Incongruent threat, BOTH = Incongruent both

Anterior N1 activity was of similar magnitude for each type of congruent array in the female grouping (Figure 6.9). However, there was a moderate, positive and significant correlation between STAI-S scores and N1 amplitudes for congruent unarmed men images (Bonferroni-corrected $\alpha = .003$; r = .35, p < .001). The magnitude of N1 activity for incongruent arousal or incongruent threat arrays with high-arousing distractors was also similar (top right, Figure 6.9). In these two congruency conditions,





unarmed men distractors mismatched to aimed handgun or sleeping men targets evoked significantly more negative anterior N1 amplitude than arrays with sleeping men distractors mismatched to injury or unarmed men targets. In the incongruent arousal condition, arrays with aimed handgun distractors also elicited significantly more negative N1 activity than those with unarmed men distractors, while incongruent

arousal arrays with sleeping men distractors led to larger amounts of anterior N1 amplitude than those with injury distractors (bottom right, Figure 6.9). Similar relationships to that observed for congruent unarmed men occurred for incongruent threat arrays with unarmed men (r = .31) or injury (r = .31, both ps = .001) distractors, and incongruent arousal arrays with sleeping men distractors (r = .36, p < .001). Arrays with sleeping men targets and aimed handgun distractors evoked larger N1 activity than other incongruent both arrays. These differences reached significance for injury distractors (see right Figure 6.9, Sleeping men: $\beta_{BOTH} = -0.09$ [0.12, 0.31], p > .05). Weak, positive and significant associations were also found between STAI-S scores and the amplitude of the anterior N1 for incongruent both arrays with aimed handgun (r = .27, p = .003) or sleeping (r = .28, p = .002) distractors.

The second significant four-way interaction occurred between Arousal level, Threat type, Congruency and Sagittal location, F(3, 1847) = 3.63, p = .01, $\beta_{ARO} = -1.44$ [-0.55, -2.32], β_{THR} = -0.93 [-0.05, -1.82, β_{BOTH} = -1.04 [-0.16, -1.93] (Figure 6.10). N1 activity was significantly reduced for congruent aimed handguns compared to congruent injury (β = 0.85 [1.16, 0.54]), sleeping men (β = 1.07 [1.38, 0.75]) or unarmed men images (β = 0.81 [1.12, 0.5]) at central electrodes (all *ps* < .001). Congruent aimed handguns also evoked significantly more negative N1 amplitude at frontal-central electrodes than at central electrodes (β = -1.22 [-0.91, -1.53], *p* < .001). Incongruent threat and incongruent arousal arrays with unarmed men distractors led to more negative N1 activity than those with sleeping men. These differences between arrays with unarmed or sleeping men distractors reached significance only in the incongruent arousal condition (see bottom Figure 6.10). Incongruent both arrays with aimed handgun distractors also elicited larger amounts of N1 amplitude than those with



Frontal-central electrodes





Figure 6.10. LS means for anterior N1 mean amplitudes categorised by arousal level, threat type, congruency and sagittal location for females. Parameter estimates for LS differences are shown between active and passive distractors for low arousal images at frontal-central and central electrodes (bottom). Vertical and horizontal bars denote 95% confidence intervals.

mismatched injury distractors and unarmed men targets (both ps > .05).

Males. The main effect of Congruency ($F(3, 1835) = 3.03, p = .03, \beta_{ARO} = -0.08$ [0.18, -0.34], $\beta_{THR} = 0.24$ [0.51, -0.02], $\beta_{BOTH} = -0.11$ [0.15, -0.37]) was significant in the male breakdown model. STAI-S scores were involved in two significant two-way

interactions, one of which moderated the Congruency main effect, F(3, 1835) = 4.99, p $= .002, \beta_{ARO} = -0.01 [0.03, -0.05], \beta_{THR} = -0.02 [0.02, -0.06], \beta_{BOTH} = 0.02 [0.06, -0.02]$ $(M_{\text{STAI-S}} = 30.07)$. N1 amplitude was most negative for incongruent both arrays $(M_{\text{LS}} = -$ 2.97 [-2.09, -3.85]), followed by incongruent arousal arrays ($M_{LS} = -2.92$ [-2.04, -3.8]), then incongruent threat arrays ($M_{LS} = -2.89$ [-2.01, -3.77]), and then lastly congruent arrays ($M_{LS} = -2.83$ [-1.95, -3.71]). Only the contrast between congruent and incongruent both arrays reached significance, $\beta = 0.14$ [0.24, 0.05], p = .01. Moreover, a very weak trend was found for a positive correlation between STAI-S scores and N1 activity for congruent arrays (Bonferroni-corrected $\alpha = .01$; r = .1, p = .03). Arousal level also interacted significantly with STAI-S scores, F(1, 1835) = 8.03, p = .005, $\beta = -$ 0.01 [0.03, -0.05] ($M_{\text{STAL-S}} = 30.07$). The magnitude of N1 activity for arrays with high $(M_{\rm LS} = -2.91 \ [-2.03, -3.79])$ or low $(M_{\rm LS} = -2.89 \ [-2.01, -3.77])$ arousal distractors was similar however, $\beta = -0.02$ [0.05, -0.08] p = .56. The involvement of STAI-S scores in this interaction was driven by a very weak trend for a positive correlation between STAI-S scores and N1 amplitude for arrays with high-arousing distractors (Bonferronicorrected $\alpha = .01$; r = .06, p = .05).

In addition to the aforementioned effects, significant two-way interactions occurred between Arousal level and Threat type F(1, 1835) = 8.65, p = .003, $\beta_{\text{MID}} = -$ 0.21 [0.17, -0.58], and between Threat type and Congruency (F(3, 1835) = 10.61, p < .001, $\beta_{\text{ARO}} = 0.15$ [0.51, -0.22], $\beta_{\text{THR}} = -0.49$ [-0.12, -0.86], $\beta_{\text{BOTH}} = 0.02$ [0.39, -0.35]). These two-way interactions, along with the Congruency main effect, were further qualified by a significant three-way interaction between Arousal level, Threat type and Congruency, F(3, 1835) = 12.0, p < .001, $\beta_{\text{ARO}} = 0.54$ [1.07, 0.02], $\beta_{\text{THR}} = 0.94$ [1.46, 0.41], $\beta_{\text{BOTH}} = -0.21$ [0.31, -0.74] (Figure 6.11). Similar to the female grouping, no modulation of N1 activity was evident for congruent arrays in this interaction.





Incongruent arrays with unarmed men distractors also elicited significantly more negative N1 activity than arrays with sleeping men distractors in the same two congruency conditions (top right, Figure 6.11). Unlike N1 modulation observed for the female grouping, other effects were found in anterior N1 activity for male participants. The N1 amplitude of incongruent threat arrays with aimed handgun distractors was

significantly reduced compared to those arrays with unarmed men or injured human distractors in the same congruency condition (right, Figure 6.11). Mismatched injury distractors and unarmed man targets also elicited more negative N1 activity than mismatched sleeping men distractors and aimed handgun targets.

Unlike the female grouping, the four-way interaction between Threat type, Congruency, Sagittal location and Arousal level did not reach significance for the male breakdown model, F(3,1835) = 0.72, p = .54. Main effects and lower-order interactions involving Threat type, Congruency and Sagittal location were further moderated by a significant three-way interaction between these three factors, F(3, 1835) = 3.39, p = .02, $\beta_{ARO} = 0.48 [1, -0.03], \beta_{THR} = 0.71 [1.23, 0.2], \beta_{BOTH} = 0.69 [1.2, 0.17]$ (Figure 6.12). At frontal-central electrodes, anterior N1 activity was significantly more negative for incongruent arousal arrays with mismatched handgun and unarmed men images compared to those arrays with mismatched injury and sleeping men images (bottom right, Figure 6.12). At central electrodes, congruent injury or sleeping men images led to significantly larger amounts of N1 activity than congruent aimed handgun or unarmed men images, a difference that did not occur at frontal-central electrodes. The amplitude of the anterior N1 for arrays with active or passive distractors was also moderated by congruency condition. Arrays with mismatched passive targets and active distractors (i.e., injury/sleeping man with aimed handguns/unarmed men) evoked significantly more negative N1 amplitude at central electrodes compared to frontalcentral electrodes (top right, Figure 6.12). The opposite pattern of N1 modulation occurred for arrays consisting of congruent or incongruent passive images, as anterior N1 activity for these Flanker arrays was significantly larger at frontal-central electrodes than at central electrodes in the congruent and incongruent arousal conditions.

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The occipital N1 (120-170ms). Mean activity for the occipital N1 was derived from the midline electrodes POz and Oz. Congruent injury or unarmed man images evoked noticeably larger occipital N1 amplitude than those featuring congruent sleeping men or men with aimed handguns (Figure 6.13). Incongruent both arrays with injury or

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Figure 6.13. Grand average waveforms showing the occipital N1 averaged across the parietal occipital and occipital midline electrodes for females (top) and males (bottom). Congruency conditions are categorised based on the disposition of the human in distractor images for each Flanker array, active (i.e., men with aimed handguns, unarmed men) or passive (i.e., severe injury, sleeping men).

unarmed men distractors also evoked more negative N1 activity than arrays with mismatched aimed-handgun and sleeping men images. For males, arrays with incongruent sleeping men or armed men distractors led to more negative occipital N1 amplitude than arrays with unarmed men or injury distractors in the incongruent arousal and incongruent threat conditions (bottom, Figure 6.13). These same differences also occurred for females in response to incongruent arousal and incongruent threat arrays. However, arrays with sleeping men distractors and an injury target also elicited more negative occipital N1 amplitude than arrays with aimed handgun distractors and an unarmed man target in the female grouping (top, Figure 6.13). The magnitude of N1 modulation in the incongruent threat condition was also of smaller magnitude for female compared to male participants.

Linear mixed effects analysis. During model estimation modulation for the occipital N1 was significantly moderated by PSWQ (Kenward-Roger: F(64, 1080) = 1.42, p = .02) or Neuroticism (F(64, 1080) = 1.4, p = .02) scores. Due the strong correlation between PSWQ and emotional stability scores (r = -.65, p < .001) models in which both trait scores featured were used only for evaluative purposes. The reduced model with PSWQ scores did not include any interaction between this predictor and any image-related factor. Therefore, Neuroticism scores were included in the final model for the occipital N1 (Table 6.9). Activity for the occipital N1 was very strongly clustered

Table 6.9. *R* notation for the final model estimated for occipital N1 mean amplitudes. Abbreviations for factors included in analyses are provided at the bottom of the table.

			R-notation	
Final model	lmer(occN1~ A	Aro*Thr*Cong*Sag t), Ex3_occN1)	+ Aro*Thr*Cong*Ne	eur + Sag*Sex*Neur +
Aro = Arousal level	Thr = Threat type	Cong = Congruency	Sag = Sagittal location	Neur = neuroticism scores

across participants (ICC_{Participants} = .8), and the final model explained 82% of total variance ($\sigma^2 = 2.58$, τ_{00} for participants = 10.26). The main effect for Threat type (*F*(1, 1187) = 8.52, *p* = .004, β = -1.56 [-0.85, -2.26]) was significant. This main effect was moderated by two significant higher-order interactions, one with Arousal level (*F*(1, 1187) = 21.6, *p* < .001, β = 2.32 [3.32, 1.32]) and another with Arousal level and Congruency (*F*(3, 1187) = 73.06, *p* < .001, β_{ARO} = -3.03 [-1.62, -4.45], β_{THR} = -2.91 [-1.5, -4.32], β_{BOTH} = 0.03 [1.44, -1.38].

These two interactions and the Threat type main effect were further qualified by two significant four-way interactions. Most effects observed in average waveforms for the occipital N1 were confirmed by the four-way interaction between Arousal level, Threat type, Congruency and Neuroticism scores, F(3, 1187) = 3.14, p = .02, $\beta_{ABO} - 0.05$ $[0.03, -0.13], \beta_{THR} = -0.03 [0.05, -0.11], \beta_{BOTH} = 0.07 [0.15, -0.01]$ (Figure 6.14, Table 6.10). Similar to Experiment 2, no correlations between Neuroticism scores and N1 amplitude were significant. However, moderate, positive and significant associations were found between Neuroticism scores and N1 activity at the occipital electrode for males (Bonferroni-corrected $\alpha = .01$; r = .31) and at the parietal-occipital electrode for females (r = .34, both ps < .001). Outside of Neuroticism scores, arrays with injury or unarmed men distractors led to significantly more negative N1 activity than those with aimed handgun or sleeping men distractors in the congruent and incongruent both conditions (all ps > .05). Arrays with sleeping men distractors mismatched to the threat type or the arousal level of the target also led to more negative N1 amplitude than other incongruent arousal and incongruent threat arrays. This difference reached significance for arrays with unarmed men distractors (see Figure 6.14) and incongruent arousal arrays with injury distractors (see Table 6.10), but not for the incongruent arousal or incongruent threat arrays with aimed handgun distractors ($\beta_{ARO} = 0.4$ [0.9, -0.1],



Figure 6.14. LS means for occipital N1 mean amplitudes categorised by arousal level, threat type and congruency ($M_{\text{NEUR}} = 32.8$). Parameter estimates for LS differences between active and passive distractors for high and low arousal images are shown (bottom left). Vertical and horizontal bars denote 95% confidence intervals.

Table 6.10. Parameter information for LS differences between high and low arousal distractors in occipital N1 mean amplitudes ($M_{NEUR} = 32.8$). Contrasts are categorised by congruency condition and the threat type of distractors, and the 95% confidence interval, t-statistic and p-value is also provided. P-value significance is located at the bottom left of the table.

Congruency condition	Active distractors (Aimed HG vs. Unarmed)	Passive distractors (Injury vs. Sleeping)	
	β [95% CI]	β [95% CI]	
Congruent	1.66 [2.16, 1.15]***	-1.71 [-1.21, -2.21]***	
IncAROUSAL	-0.94 [-0.44, -1.44]*	0.99 [1.49, 0.49]*	
IncTHREAT	-0.81 [-0.31, -1.3]	0.9 [1.39, 0.4].	
IncBOTH	1.99 [2.49, 1.49]***	-1.62 [-1.12, -2.11]***	

 $p < .05^*, p < .01^{**}, p < .001^{***}$

 $\beta_{\text{THR}} = 0.31$ [0.81, -0.18], both *ps* > .05). Lastly, in the incongruent arousal condition mismatched aimed handgun distractors and an unarmed man target evoked more negative N1 amplitude than those with mismatched unarmed men distractors and an aimed handgun target (Table 6.10).

The second significant four-way interaction between Threat type, Arousal level, Congruency and Sagittal location indicated that effects observed in average waveforms for the occipital N1 were affected by electrode position, F(3, 1187) = 14.09, p < .001, $\beta_{ARO} = -4.55$ [-2.55, -6.55], $\beta_{THR} = -4.33$ [-2.33, -6.33], $\beta_{BOTH} = 0.45$ [2.44, -1.55] (Figure 6.15). No differences of interest in N1 amplitude between distractor types reached significance at the POz electrode (all ps > .05), with one exception. Congruent images of injury evoked significantly more negative N1 activity than aimed handguns at the POz electrode, $\beta = 1.55$ [2.26, 0.85], p = .008. The same pattern of N1 modulation observed in the four-way interaction involving Neuroticism scores emerged at the Oz electrode, with one variation. The difference in N1 activity between incongruent arousal arrays with mismatched aimed handgun unarmed men images did not reach did not reach significance in the four-way interaction involving Threat type, Arousal level, Congruency and Sagittal location (bottom left, Figure 6.15).

The EPN (150-250ms). Mean EPN activity was computed from the left hemisphere electrodes P7 and PO7 and the right hemisphere electrodes P8 and PO8. Congruent aimed handguns evoked more negative EPN activity than congruent unarmed men, whereas the magnitude of the EPN was similar for arrays with congruent injury or sleeping men images (first row; Figure 6.16, Figure 6.17). In the incongruent arousal condition, EPN amplitude was reduced for aimed handgun distractors paired with an unarmed man target compared to other incongruent arousal arrays. However, the magnitude of this difference was negligible for males in the right hemisphere



Figure 6.15. LS means for occipital N1 mean amplitudes categorised by arousal level, threat type, congruency and sagittal location. Parameter estimates for LS differences at electrode Oz are provided, between active and passive distractors for high and low arousal images (middle), and between high and low arousal distractors for active and passive images (bottom). Vertical and horizontal bars denote 95% confidence intervals.



Figure 6.16. Grand average EPN waveforms averaged across the most lateral parietal and parietal-occipital electrodes for females. Congruency conditions are categorised based on the disposition of the human in distractor images for each Flanker array, active (i.e., men with aimed handguns, unarmed men) or passive (i.e., severe injury, sleeping men).





Figure 6.17. Grand average EPN waveforms averaged across the most lateral parietal and parietal-occipital electrodes for males. Congruency conditions are categorised based on the disposition of the human in distractor images for each Flanker array, active (i.e., men with aimed handguns, unarmed men) or passive (i.e., severe injury, sleeping men).



(second row; Figure 6.17). Incongruent threat arrays with injury distractors evoked more negative EPN activity than arrays with sleeping men or active distractors (third row; Figure 6.16, Figure 6.17). In the right hemisphere, incongruent both arrays with aimed handgun or sleeping men distractors also elicited larger amounts of EPN activity than arrays with mismatched injury and unarmed men images. These same differences occurred in the left hemisphere, although the magnitude of this difference was larger for sleeping men with an aimed handgun target compared to aimed handgun distractors with a sleeping man target.

Linear mixed effects analysis. The data of one female was excluded from EPN analyses. Approximately 70% of this female's EPN mean amplitudes was above the 95% confidence interval upper limit at parietal-occipital electrodes ($M_P = 1.22\mu V$ [6.08, -3.64], $M_{PO} = 4.36\mu V$ [11.95, -.23]). The final model for the EPN was computed using the data from 20 males and 19 females. Scores from the PSWQ (Kenward-Roger: F(128, 2128) = 1.41, p = .002) and the STAI-S (F(128, 2128) = 2.26, p < .001) were significantly related to EPN modulation. PSWQ and STAI-S scores were both retained in the EPN final model (Table 6.11). EPN mean amplitudes were moderately clustered between participants (ICC_{Participants} = .51). Seventy percent of the total variance was explained by the final model ($\sigma^2 = 3.24, \tau_{00}$ for participants = 3.39). Numerous significant main effects and two-way interactions were moderated by all six three-way interactions reaching significance (Appendix K). To break down these effects, participants were separated into high (n = 18) and low (n = 19) groupings based on their STAI-S scores.

STAI-S scores were not normally distributed; however, the median (Mdn = 30, IQR = 24.5-33) and mean ($M = 30.1\pm1.16$) of the sample were equivalent. Therefore, a mean split of 30 was used to separate participants into high and low STAI-S groupings.

Table 6.11. *R* notation for the final model estimated for EPN mean amplitudes. Abbreviations for factors included in analyses are provided at the bottom of the table.

		R-notation	
Final model	lmer(EPN~ Sag*Cor + Sex + Cor*PSWQ*STAI-S + A Ex3_EPN)	*Sag*PSWQ + Sex*S .ro*Thr*Cong + Cor*T	ag*STAI-S + Sex*Cor*PSWQ Chr*Cong + (~1 Participant),
Breakdown model	lmer(EPN~ Sag*Cor + Sex Cor*Thr*Cong + (~1 Partie	*Sag*PSWQ + Sex*C cipant), Ex3_EPN)	or*PSWQ + Aro*Thr*Cong +
Aro = Arousal level Thr = Threat type	Sag = Sagittal location Cong = Congruency	Cor = Coronal site	STAI-S = state anxiety scores PSWQ = worry scores

The high grouping was comprised of 8 males and 10 females (*Mdn* = 34, *IQR* = 32-37), while the low grouping contained 11 males and 8 females (*Mdn* = 24, *IQR* = 22-27). The scores of one female and one male were the same as the mean and were not included in either STAI-S grouping. STAI-S scores were removed from the final model, as well as any redundant interactions (Table 6.11). The breakdown model contained one two-way interaction and four three-way interactions, two of which included PSWQ scores. EPN mean amplitudes were moderately clustered for the high (ICC_{Participants} = .49) and low (ICC_{Participants} = .53) STAI-S groupings. Seventy-three percent of the total variance was explained by the breakdown model for the high STAI-S grouping (σ^2 = 3.13, τ_{00} for participants = 3.03) and 67% for the low STAI-S grouping (σ^2 = 3.56, τ_{00} for participants = 4.06).

High STAI-S grouping (> 30). The main effects of Arousal level ($F(1, 1103) = 35.43, p < .001, \beta = 3.6$ [4.18, 3.02] and Congruency ($F(3, 1103) = 3.98, p = .008, \beta_{ARO} = 2.35$ [3.06, 1.64], $\beta_{THR} = 2.1$ [2.81, 1.4], $\beta_{BOTH} = 1.98$ [2.69, 1.27]) reached significance. These two main effects were moderated by one or more of two significant two-way interactions (Table 6.12). The Congruency main effect was further moderated

Table 6.12. Parameter information for significant two-way interactions qualified by significant three-way interactions in the EPN breakdown model for the high STAI-S grouping. The reference parameter, estimate (β) and associated 95% confidence intervals are provided. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	eter	β [95% CI]
<i>F</i> (1, 1103) = 29.74***		
Low: Passive		-3.49 [-2.67, -4.3]***
$F(3, 1103) = 37.19^{***}$		
Low: ARO		-4.65 [-3.84, -5.47]***
Low: THR		-2.57 [-1.75, -3.38]***
Low: BOTH		-2.42 [-1.6, -3.23]***
Aro: Arousal level	Sag: Sagittal location	STAI-S = state anxiety scores
	F(1, 1103) = 29.74 Low: Passive $F(3, 1103) = 37.19$ Low: ARO Low: THR Low: BOTH Aro: Arousal level Thr: Threat type	$F(1, 1103) = 29.74^{***}$ Low: Passive $F(3, 1103) = 37.19^{***}$ Low: ARO Low: THR Low: BOTH Aro: Arousal level Sag: Sagittal location Thr: Threat type Cor: Coronal site

Congruency: Cong, CON = Congruent, ARO = Incongruent arousal, THR = Incongruent threat, BOTH = Incongruent both

by a significant three-way interaction between this factor, Threat type and Coronal site, $F(3, 1103) = 4.86, p = .002, \beta_{ARO} = 0.12 [1.28, -1.03], \beta_{THR} = 1.48 [2.64, 0.32], \beta_{BOTH} =$ 1.79 [2.95, 0.63] (Figure 6.18). EPN amplitude was significantly more negative at left hemisphere sites compared to right hemisphere sites. For arrays with mismatched passive targets and active distracters (i.e., incongruent threat and incongruent both), EPN activity was reduced compared to arrays with active images only (i.e., aimed handguns, unarmed men, aimed handguns/unarmed men) in the left hemisphere. The opposite pattern of EPN activity occurred for passive images, with mismatched active targets and passive distractors leading to reduced EPN amplitude in comparisons to arrays featuring injury or sleeping men images (i.e., congruent and incongruent arousal). Two-way interactions and main effects involving Arousal level, Threat type or Congruency were further moderated by a significant three-way interaction between these three factors, $F(3, 1103) = 41.92, p < .001, \beta_{ARO} = 4.8 [5.95, 3.64], \beta_{THR} = 4.57$ [5.73, 3.42], $\beta_{BOTH} = 0.02 [1.18, -1.13]$ (Figure 6.19). Arrays with aimed handgun



Figure 6.18. LS means for EPN mean amplitudes categorised by threat type, congruency and coronal site for the high STAI-S grouping. Parameter estimates for LS differences are shown between left and right hemisphere electrodes for active and passive distractors in each congruency condition (top right). Vertical and horizontal bars denote 95% confidence intervals.

distractors evoked significantly more negative EPN activity than those with injury or unarmed men distractors in the congruent and incongruent both conditions. A trend occurred for the same difference occurred between arrays with aimed handgun or unarmed men distractors in the incongruent threat condition. The opposite pattern of EPN modulation was observed for incongruent arousal arrays with active images, as unarmed men distractors with an aimed handgun target evoked significantly more negative EPN activity than the reverse combination. Regarding passive images, arrays





with sleeping men distractors elicited significantly larger EPN amplitude than those with unarmed men distractors in the congruent and incongruent both conditions. This same difference reached significance occurred between incongruent both arrays with sleeping men or injury distractors, however in the incongruent threat condition EPN

activity for incongruent both arrays with injury distractors was significantly larger than for those with sleeping men distractors.

Low STAI-S grouping (< 30). Main effects for Arousal level (*F*(1, 1158) = 24.04, *p* < .001, β = 3.77 [4.39, 3.15]) and Congruency (*F*(3, 1158) = 4.01, *p* = .008, β_{ARO} = 2.55 [3.29, 1.82], β_{THR} = 2.47 [3.21, 1.74], β_{BOTH} = 2.2 [2.94, 1.46]) were significant. These two main effects were qualified by at least two of three significant two-way interactions (Table 6.13). Main effects and two-way interactions involving Arousal level, Threat type and Congruency were further modified by a significant three-way interaction between Arousal level, Threat type and Congruency, *F*(3, 1158) = 40.35, *p* < .001, β_{ARO} = 4.94 [6.15, 3.73], β_{THR} = 5.05 [6.26, 3.84], β_{BOTH} = 0.46 [1.66, - 0.75] (Figure 6.20). EPN modulation by the distractor type in Flanker arrays was in

Table 6.13. Parameter information for significant two-way interactions qualified by a significant three-way interaction in the EPN breakdown model for the low STAI-S grouping. The reference parameter, estimate (β) and associated 95% confidence intervals are provided. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table

	Paramet	er	β [95% CI]
Aro*Thr	<i>F</i> (1, 1158) = 18.85***		
ref. High: Active	Low: Passive		-3.56 [-2.69, -4.42]***
Aro*Cong	<i>F</i> (3, 1158) = 36.94**	<*	
ref. High: CON	Low: ARO		-5.1 [-4.23, -5.96]***
	Low: THR		-3.2 [-2.34, -4.06]***
	Low: BOTH		-2.76 [-1.9, -3.62]***
Thr*Cong	<i>F</i> (3, 1158) = 3.47*		
ref. Active: CON	Passive: ARO		-2.45 [-1.41, -3.49]***
	Passive: THR		-3.34 [-2.3, -4.38]***
	Passive: BOTH		-0.98 [0.06, -2.02].
.1 , $p < .05$ *, $p < .01$ **, $p < .001$ ***	Aro: Arousal level	Sag: Sagittal location	STAI-S = state anxiety scores
	Thr: Threat type	Cor: Coronal site	

Congruency: Cong, CON = Congruent, ARO = Incongruent arousal, THR = Incongruent threat, BOTH = Incongruent both

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Figure 6.20. LS means for EPN mean amplitudes categorised by arousal level, threat type and congruency for the low STAI-S grouping. Parameter estimates for LS differences are shown between active and passive distractors for high and low arousal images (top right), and between high and low arousal distractors for active and passive images (bottom right). Vertical and horizontal bars denote 95% confidence intervals.

many respects similar to that reported for the high STAI-S grouping. Arrays with congruent or incongruent both aimed handgun distractors again elicited significantly more negative EPN activity than those with injury distractors. However, EPN amplitude for incongruent threat arrays with injury distractors was significantly more negative than for those with aimed handgun distractors. Moreover, the amplitude of the EPN was significant more negative for congruent aimed handguns than congruent unarmed men. Regarding arrays with sleeping men distractors, EPN modulation was the same as observed in the high STAI-S grouping.

The MPN (310-410ms). Mean activity for the MPN was analysed at the left hemisphere electrodes TP7 and P7, and the right hemisphere electrodes TP8 and P8. Congruent aimed handguns elicited the most negative MPN amplitude, followed by congruent injury and sleeping men images, and then arrays with congruent unarmed men (first row; Figure 6.21, Figure 6.22). Incongruent arousal arrays did not appear to modulate MPN activity. Incongruent threat arrays with injury distractors evoked the most negative MPN amplitude for females, followed by arrays with aimed handgun distractors, and then those arrays with low-arousing distractors (third row, Figure 6.21). For males, MPN activity was reduced for arrays with sleeping men distractors and an unarmed man target in comparison to other for incongruent threat arrays (third row, Figure 6.22). MPN modulation was similar for males and females in the incongruent both condition (fourth row; Figure 6.21, Figure 6.22). Arrays with sleeping men distractors and an aimed handgun target elicited more negative MPN activity than other incongruent both arrays in the left hemisphere. In the right hemisphere, arrays with mismatched aimed handgun and sleeping men images led to more negative MPN amplitude than observed for arrays with mismatched injury and unarmed men images.

Linear mixed effects analysis. A trend was found for the contribution of STAI-S scores to MPN modulation (Kenward-Roger: F(124, 2198) = 1.23, p = .05), and this predictor was included in the final model (Table 6.14). MPN mean amplitudes were moderately clustered across participants (ICC_{Participants} = .45), and the final model explained 66% of total variance ($\sigma^2 = 4.29$, τ_{00} for participants = 3.57). The main effects



Figure 6.21. Grand average MPN waveforms averaged across the most lateral central-parietal and parietal electrodes for females. Congruency conditions are categorised based on the active (i.e., men with aimed handguns, unarmed men) or passive (i.e., severe injury, sleeping men) disposition of the human shown in distractor images.





Figure 6.22. Grand average MPN waveforms averaged across the most lateral central-parietal and parietal electrodes for males. Congruency conditions are categorised based on the active (i.e., men with aimed handguns, unarmed men) or passive (i.e., severe injury, sleeping men) disposition of the human shown in distractor images.



of Arousal level ($F(1, 2475) = 27.38, p < .001, \beta = 2.05$ [2.7, 1.4]) and Congruency ($F(3, 2475) = 2.73, p = .04, \beta_{ARO} = 1.39$ [2.03, 0.74], $\beta_{THR} = 1.09$ [1.73, 0.45], $\beta_{BOTH} =$ 0.75 [1.39, 0.11]) were significant. These main effects were qualified by two two-way and one three-way interaction that reached significance (Table 6.15). These interactions,

Table 6.14. *R* notation for the final model estimated for MPN mean amplitudes. Abbreviations for factors included in analyses are provided at the bottom of the table.

		R-notation	
Final model	lmer(MPN~ Cor*Sag + Sag*Sex+ Cor*Sex*STAI-S + Aro*Thr*Cong*Sag + (~1 Participant), Ex3_MPN)		
Aro = Arousal level Thr = Threat type	Sag = Sagittal location Cong = Congruency	Cor = Coronal site	STAI-S = state anxiety scores

Table 6.15. Parameter information for significant two-way and three-way interactions qualified by the significant four-way interaction in the final model for MPN mean amplitudes. The reference parameter, estimate (β) and associated 95% confidence intervals are provided. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Aro*Thr	<i>F</i> (1, 2475) = 38.28***	
ref. High: Active	Low: Passive	-2.17 [-1.25, -3.08]***
Aro*Cong	<i>F</i> (3, 2475) = 21.22***	
ref. High: CON	Low: ARO	-2.37 [-1.45, -3.28]***
	Low: THR	-1.85 [-0.83, -2.88]***
	Low: BOTH	-1.3 [-0.39, -2.21]**
Aro*Thr*Cong	<i>F</i> (3, 2475) = 38.17***	
ref. High: Active: CON	Low: Passive: ARO	2.34 [3.63, 1.06]***
	Low: Passive: THR	2.81 [4.15, 1.47]***
	Low: Passive: BOTH	0.53 [1.82, -0.76]0
.1 < <i>p</i> < .05., <i>p</i> < .05*, <i>p</i> < .01 **, <i>p</i> < .001***	Aro: Arousal level	Sag: Sagittal location
	Thr: Threat type	STAI-S = state anxiety scores

Congruency: Cong, CON = Congruent, ARO = Incongruent arousal, THR = Incongruent threat, BOTH = Incongruent both

along with the two main effects, were further moderated by a significant four-way interaction between Arousal level, Threat type, Congruency and Sagittal location, F(3, 2475) = 4.83, p = .002, $\beta_{ARO} = 2.48$ [4.3, 0.65], $\beta_{THR} = 2.28$ [4.18, 0.38], $\beta_{BOTH} = -0.3$ [1.53, -2.12] (Figure 6.23, Figure 6.24).

Patterns of MPN activity for congruent arrays were similar across centralparietal and parietal electrodes. MPN amplitude was most negative for congruent images of men with aimed handguns, followed by congruent arrays with passive images, and then unarmed men. These differences all reached significance at parietal sites, however at central-parietal sites only the difference in MPN modulation between



Figure 6.23. LS means for MPN mean amplitudes categorised by arousal level, threat type, congruency and sagittal location. Vertical bars denote 95% confidence intervals.



Figure 6.24. Parameter estimates for LS differences in MPN mean amplitudes in the four-way interaction between arousal level, threat type, congruency and sagittal location. Those between high and low arousal distractors for active and passive images at parietal electrodes (top) are shown, as well as those between active and passive distractors for high and low arousal images (middle, bottom). Horizontal bars denote 95% confidence intervals.

aimed handguns and unarmed men was significant (Figure 6.23, Figure 6.24) At parietal sites the amplitude of the MPN was of similar magnitude in the incongruent arousal and incongruent threat conditions at central-parietal electrodes. At parietal sites this lack of MPN modulation occurred for incongruent arousal arrays, but not for incongruent threat arrays. MPN amplitude for sleeping men paired with an unarmed man was reduced compared to other incongruent threat arrays. These differences reached significance for incongruent threat arrays with injury or aimed handgun distractors ($\beta = -1.5$ [-0.86, -2.14], p = .002), but not for those with unarmed men distractors (for parameter
information see Figure 6.24). In the incongruent both condition, arrays with aimed handgun or sleeping men distractors evoked more negative MPN activity than arrays with mismatched injury and unarmed men images. These differences reached significance at parietal electrodes, but not at central-parietal electrodes.

The LPP (450-650ms). Mean amplitudes for the LPP were analysed at the central-parietal electrodes CP1, CPz and CP2, and the parietal electrodes P1, Pz and P2. Congruent images of men with aimed handguns evoked the most positive LPP activity, followed by images of injury, then sleeping men, and then unarmed men (first row; Figure 6.25, Figure 6.26). The magnitude of the difference between congruent injury and aimed handgun images was larger in the male grouping compared to the female grouping. No clear LPP modulation by way of incongruent arousal arrays was evident for females or males. However, in the incongruent threat condition arrays with mismatched injury and aimed handguns evoked more positive LPP activity than those arrays with mismatched sleeping and unarmed men (third row; Figure 6.25, Figure 6.26). The magnitude of these differences was larger at midline and right hemisphere sites compared to the left hemisphere. In the incongruent both condition, mismatched aimed handgun and sleeping men images led to more positive LPP amplitude than mismatched injury and unarmed men images for females, an effect that was less clear in the left hemisphere compared to right hemisphere and midline sites (fourth row, Figure 6.25). Finally, for males, LPP activity was most positive for mismatched aimed handgun and sleeping men images, followed by arrays with injury distractors and an unarmed man target, and then arrays with unarmed men distractors and an injury target at the midline and in the right hemisphere (fourth row, Figure 6.26).

Linear mixed effects analysis. Scores from the STAI-S (Kenward-Roger: F(192, 3303) = 1.23, p = .02) and the STAI-T (F(192, 3303) = 1.5, p < .001) were

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Figure 6.25. Grand average LPP waveforms averaged across central-parietal and parietal electrodes close to the midline for females. Congruency conditions are categorised based on the active (i.e., men with aimed handguns, unarmed men) or passive (i.e., severe injury, sleeping men) disposition of the human shown in distractor images.





Figure 6.26. Grand average LPP waveforms averaged across central-parietal and parietal electrodes close to the midline for males. Congruency conditions are categorised based on the active (i.e., men with aimed handguns, unarmed men) or passive (i.e., severe injury, sleeping men) disposition of the human shown in distractor images.



significantly related to LPP modulation. Further model variations were tested with the STAI-T predictor included, and this trait score was retained in the final model (Table 6.16). The clustering of LPP activity was moderate across participants (ICC_{Participants} = .44). Sixty-seven percent of the total variance was accounted for by the final model (σ^2 =1.2, τ_{00} for participants =0.94). Main effects for Arousal level (F(1, 3724) = 502.81, p < .001, β = -2.57 [-2.27, -2.86]), Congruency (F(3, 3724) = 68.66, p < .001, $\beta_{ARO} = -2.01$ [-1.68, -2.33], β_{THR} = -1.09 [-0.76, -1.41], β_{BOTH} = -1.64 [-1.32, -1.97]) and STAI-T scores (F(1, 36) = 6.11, p = .02, $\beta = 0.01$ [0.06, -0.03]) were significant.

The three main effects were qualified by one or more of four significant twoway interactions (Table 6.17). Arousal Level interacted significantly with Coronal site, F(2, 3724) = 7.56, p < .001, $\beta_{MID} = -0.27$ [-0.1, -0.44], $\beta_{RIGHT} = -0.31$ [-0.14, -0.48] (top, Figure 6.27). Arrays with high-arousing distractors elicited significantly more positive LPP activity than those with low-arousing distractors. LPP amplitude for high-arousing distractors at midline and right hemisphere sites was also larger compared to the left hemisphere, an effect not found for arrays with low-arousing distractors. The Coronal site factor interacted significantly with Congruency in LPP activity, F(6, 3724) = 3.79, p< .001, Midline: $\beta_{ARO} = 0.19$ [0.43, -0.05], $\beta_{THR} = 0.05$ [0.29, -0.19], $\beta_{BOTH} = 0.13$ [0.37, -0.11], Right hemisphere: $\beta_{ARO} = 0.53$ [0.77, 0.29], $\beta_{THR} = 0.3$ [0.54, 0.06], $\beta_{BOTH} = 0.45$

Table 6.16. *R* notation for the final model estimated for LPP mean amplitudes. Abbreviations for factors included in analyses are provided at the bottom of the table.

	R-notation
	lmer(LPP~ Aro*Cor + Cong*Cor + Aro*Thr*Cong + Aro*Thr*STAI-T +
Final model	Aro*Cong*Sex + Thr*Cong*Sex + Aro*Cong*Sag + Cor*Sag*Sex*STAI-T + Cong*Sex + Cor*Sag*Sex + Cor*Sag + Cor*S
	(~1 Participant), Ex3_LPP

Aro = Arousal level Cong = Congruency Sag = Sagittal location Cor = Coronal site STAI-T= trait anxiety scores Thr = Threat type Table 6.17. Parameter information for significant two-way interactions qualified by higher-order interactions in the final model for LPP mean amplitudes. The reference parameter, estimate (β) and associated 95% confidence intervals are provided. *F*-statistics are located at the top of the parameter column for each interaction. *P*-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Aro*Thr	<i>F</i> (1, 3724) = 158.34**	
ref. High: Active	Low: Passive	1.47 [1.75, 1.19]***
Aro*Cong	<i>F</i> (3, 3724) = 136.38***	
ref. High: CON	Low: ARO	2.45 [2.84, 2.06]***
	Low: THR	0.64 [1.04, 0.25]**
	Low: BOTH	2.2 [2.59, 1.81]***
Aro*Sag	$F(1, 3724) = 27.46^{***}$	
ref. High: Central-parietal	Low: Parietal	0.56 [0.84, 0.28]***
Thr*STAI-T	F(1, 3724) = 6.54*	
ef. Active distractors Passive distractors		-0.001 [0.01, -0.01]
.1 ., $p < .05$ *, $p < .01$ **, $p < .001$ ***	Aro: Arousal level	Sag: Sagittal location
	Thr: Threat type	STAI-T = trait anxiety scores

[0.69, 0.21] (bottom, Figure 6.27). LPP activity for incongruent arousal arrays in the left hemisphere was reduced compared to the midline and right hemisphere, although this LPP modulation was non-significant (both ps > .05). For congruent arrays, LPP amplitude was significantly reduced in the right hemisphere in comparison to sites in the left hemisphere and at the midline.

Main effects and relevant two-way interactions involving Arousal level, Threat type, Congruency and STAI-T scores were further modified by one or more of five significant three-way interactions (Table 6.18). The three-way interaction between Threat type, Congruency and Participant sex showed that the LPP activity of females was more positive than that of males, and the magnitude of these differences was noticeably larger for arrays with active distractors mismatched to passive targets (i.e., incongruent threat, incongruent both) compared to other arrays (Figure 6.28,



Figure 6.27. LS means for LPP mean amplitudes categorised by arousal level and coronal site (top) and by congruency and coronal site (bottom). Parameter estimates for LS differences between left hemisphere, midline and right hemisphere sites are shown for high and low arousal distractors (top middle), as well as between high and low arousal distractors for left hemisphere, midline and right hemisphere sites (top right). LS differences between left hemisphere, midline and right hemisphere sites are also shown for congruent arrays (bottom right). Vertical and horizontal bars denote 95% confidence intervals.

Table 6.18. Parameter information for five significant three-way interactions in the final model for LPP mean amplitudes. The reference parameter, estimate (β) and associated 95% confidence intervals are provided. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Aro*Thr*Cong	<i>F</i> (3, 3724) = 12.13***	
ref. High: Active: CON	Low: Passive: ARO	-0.88 [-0.49, -1.28]***
	Low: Passive: THR	-1.08 [-0.69, -1.48]***
	Low: Passive: BOTH	-0.35 [0.04, -0.74].
Aro*Sex*Cong	F(3, 3724) = 8.08 * * *	
ref. High: Females: CON	Low: Males: ARO	-0.4 [0, -0.79]*
	Low: Males: THR	0.18 [0.57, -0.22]
	Low: Males: BOTH	-0.72 [-0.33, -1.11]***
Thr*Sex*Cong	<i>F</i> (3, 3724) = 5.59***	
ref. Active: Females: CON	Passive: Males: ARO	-0.29 [0.1, -0.69]
	Passive: Males: THR	0.47 [0.86, 0.07]*
	Passive: Males: BOTH	0.29 [0.69, -0.1]
Aro*Sag*Cong	F(3, 3724) = 3.97 **	
ref. High: CP: CON	Low: Parietal: ARO	-0.31 [0.09, -0.7]
	Low: Parietal: THR	0.09 [0.48, -0.31]
	Low: Parietal: BOTH	-0.53 [-0.13, -0.92]**
Aro*Thr*STAI-T	<i>F</i> (1, 3724) = 8.58**	
ref. High: Active	Low: Passive	0.02 [0.04, 0.01]**
.1 < p < .05., p < .05*, p < .01 **, p < .001***	Aro: Arousal level	Sag: Sagittal location
	Thr: Threat type	STAI-T = trait anxiety scores

Congruency: Cong, CON = Congruent, ARO = Incongruent arousal, THR = Incongruent threat, BOTH = Incongruent both

Table 6.19). This same difference between the male and female groupings also occurred for incongruent arousal arrays with mismatched injury and sleeping men images. Overall congruent arrays evoked significantly larger LPP amplitude than incongruent arrays (Table 6.19). The three-way interaction between Arousal level, Congruency and participant sex indicated that the LPP activity of males and females was significantly more positive to high-arousing than low-arousing arrays in the congruent and



Figure 6.28. LS means for LPP mean amplitudes categorised by threat type, congruency and participant sex. No differences between males and females for arrays with active or passive distractors reached significance (all ps > .05). Vertical bars denote 95% confidence intervals.

Table 6.19. Parameter information for LS differences between levels of Congruency for active and passive distractors in LPP mean amplitudes, categorised by participant sex. The parameter estimate (β) and associated 95% confidence intervals are provided. P-value significance is located at the bottom left of the table.

	Females	Males
Contrast	β [95% CI]	β [95% CI]
Active distractors		
Congruent - IncAROUSAL	0.59 [0.78, 0.39]***	0.57 [0.77, 0.38]***
Congruent - IncTHREAT	0.6 [0.79, 0.4]***	0.75 [0.95, 0.55]***
Congruent - IncBOTH	37 [0.57, 0.18]*	0.57 [0.77, 0.37]***
IncAROUSAL - IncTHREAT	0.01 [0.21, -0.19]	0.17 [0.37, -0.02]
IncAROUSAL - IncBOTH	-0.22 [-0.02, -0.41]	-0.004 [0.19, -0.2]
IncTHREAT - IncBOTH	-0.23 [-0.03, -0.42]	-0.18 [0.02, -0.37]
Passive distractors		
Congruent - IncAROUSAL	0.47 [0.67, 0.27]***	0.75 [0.94, 0.55]***
Congruent - IncTHREAT	0.77 [0.97, 0.57]***	0.45 [0.65, 0.26]***
Congruent - IncBOTH	0.56 [0.76, 0.36]***	0.47 [0.66, 0.27]***
IncAROUSAL - IncTHREAT	0.3 [0.5, 0.11]	-0.3 [-0.1, -0.49]
IncAROUSAL - IncBOTH	0.09 [0.29, -0.1]	-0.28 [-0.09, -0.48]
IncTHREAT - IncBOTH	-0.21 [-0.01, -0.41]	0.01 [0.21, -0.18]

 $p < .05^*, p < .01^{**}, p < .001^{***}$





incongruent threat conditions (Figure 6.29, Table 6.20). Males, but not females, also exhibited significantly reduced LPP amplitude to incongruent both arrays with lowarousing distractors compared to those with high-arousing distractors (see Figure 6.29, Table 6.20). However, the LPP activity of females was overall larger than that of males except for arrays with incongruent both high-arousing distractors or for incongruent threat low-arousing distractors. For females, incongruent both arrays with high-arousing distractors led to significantly reduced LPP amplitude compared to incongruent threat arrays with high-arousing distractors, an effect not observed in the male grouping (Table 6.20). LPP activity for incongruent threat arrays with low-arousing distractors Table 6.20. Parameter information for LS differences between the levels of Congruency for high and low arousal distractors in LPP mean amplitudes, categorised by participant sex. The parameter estimate (β) and associated 95% confidence intervals are provided. P-value significance is located at the bottom left of the table.

Contract	Females	Males
Contrast	β [95% CI]	β [95% CI]
High arousal		
Congruent - IncAROUSAL	1.46 [1.65, 1.26]***	1.39 [1.59, 1.19]***
Congruent - IncTHREAT	0.76 [0.95, 0.56]***	0.76 [0.96, 0.56]***
Congruent - IncBOTH	1.35 [1.54, 1.15]***	1.04 [1.23, 0.84]***
IncAROUSAL - IncTHREAT	-0.7 [-0.5, -0.9]***	-0.63 [-0.44, -0.83]***
IncAROUSAL - IncBOTH	-0.11 [0.09, -0.31]	-0.35 [-0.16, -0.55]
IncTHREAT - IncBOTH	0.59 [0.79, 0.39]***	0.28 [0.47, 0.08]
Low arousal		
Congruent - IncAROUSAL	-0.4 [-0.2, -0.6]**	-0.07 [0.13, -0.27]
Congruent - IncTHREAT	0.61 [0.81, 0.41]***	0.44 [0.64, 0.24]**
Congruent - IncBOTH	-0.42 [-0.22, -0.61]**	-0.003 [0.2, -0.2]
IncAROUSAL - IncTHREAT	1.01 [1.21, 0.82]***	0.51 [0.7, 0.31]***
IncAROUSAL - IncBOTH	-0.01 [0.18, -0.21]	0.07 [0.26, -0.13]
IncTHREAT - IncBOTH	-1.03 [-0.83, -1.22]***	-0.44 [-0.25, -0.64]**

 $p < .05^*, p < .01 \ ^{**}, p < .001^{***}$

was reduced for males and females compared to other Flanker arrays. The magnitude of these differences, however, was larger for females than males (Figure 6.29).

The remaining three three-way interactions that reached significance all involved the Arousal level factor. In relation to Sagittal location, high-arousing arrays led to significantly more positive LPP activity than those with low-arousing images at central-parietal and parietal electrodes (all ps < .001, Figure 6.30). The magnitude of these differences was larger at central-parietal than at parietal electrodes. LPP activity for arrays with high- or low-arousing distractors was also equivalent when high- and



Figure 6.30. LS means for LPP mean amplitudes categorised by arousal level, congruency and sagittal location. Vertical bars denote 95% confidence intervals.

low-arousing images were mismatched in the incongruent arousal or incongruent both conditions at both sagittal locations (all ps > .05). Regarding STAI-T scores, this predictor interacted significantly with Arousal level and Threat type (Figure 6.31). There were weak, positive and significant correlations between STAI-T scores and LPP amplitude for arrays distractors that were images of men with aimed handguns (Bonferroni-corrected $\alpha = .01$; r = .25), injury (r = .24), unarmed men (r = .18), or sleeping men (r = .27, all ps < .001). Outside of STAI-T scores, LPP activity was significantly more positive for arrays with aimed handgun distractors compared to those with injury distractors. However, when low-arousing distractors were compared, arrays with sleeping men distractors evoked significantly larger LPP amplitude than those shown with unarmed men distractors. Finally, effects related to the Arousal level and Threat type of distractor images were moderated by Congruency in LPP mean amplitudes (Figure 6.32). For congruent arrays LPP activity was most positive for aimed handguns, followed by injury, then unarmed men, and lastly sleeping men (all



Figure 6.31. LS means for LPP mean amplitudes categorised by arousal level and threat type ($M_{\text{STAI-T}} = 38.26$). Parameter estimates for LS differences between active and passive distractors for high and low arousal images, and between high and low arousal distractors for active and passive images (top right). Vertical and horizontal bars denote 95% confidence intervals.

ps < .001). In the incongruent threat condition, high-arousing arrays led to significantly larger LPP amplitude than observed for low-arousing incongruent threat arrays. When images were mismatched on arousal level trends were found for more positive LPP activity for arrays with sleeping men distractors in comparison to arrays with injury distractors, a difference that did not occur for active distractors. Lastly, incongruent both arrays with aimed handgun or sleeping men distractors elicited significantly larger LPP amplitude than arrays with injury or unarmed men distractors in the same congruency condition.

The CRN (-50 to 50ms). Response-locked mean amplitudes for the CRN were analysed at the frontal electrodes F1, Fz and F2, and the frontal-central electrodes FC1, FCz and FC2. No clear CRN modulation was observed for males or females in the incongruent both condition (Figure 6.33, Figure 6.34). In the right hemisphere,





congruent arrays did not modulate CRN activity. For females, CRN amplitude for congruent men with aimed handguns was reduced compared to other congruent arrays (first row, Figure 6.33). For males, congruent unarmed men evoked more negative CRN activity than other congruent arrays at right hemisphere and midline sites (first row, Figure 6.34).





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Figure 6.34. Grand response-locked CRN waveforms averaged across frontal and frontal-central electrodes close to the midline for males. A Congruency conditions are categorised based on the active (i.e., men with aimed handguns, unarmed men) or passive (i.e., severe injury, sleeping men) disposition of the human shown in distractor images.



Incongruent arousal Flanker arrays. At left hemisphere and midline sites incongruent arousal arrays with active distractors led to the most negative CRN amplitude, followed by arrays with injury distractors, and then those with sleeping men distractors for females (second row, Figure 6.33). A similar pattern of CRN modulation occurred in the right hemisphere for females. In this instance, however, the magnitude of CRN amplitude for incongruent arousal arrays with sleeping men distractors was equivalent. For males, arrays with sleeping men distractors and an injured human target elicited more negative CRN activity than other incongruent arousal arrays in the left hemisphere (second row, Figure 6.34).

Incongruent threat Flanker arrays. Incongruent threat arrays with sleeping men distracters evoked the most negative CRN activity, followed by arrays with unarmed men distractors, and then arrays with injury or aimed handgun distractors for females (third row, Figure 6.33). For males, incongruent threat arrays with passive distractors led to more negative CRN amplitude than those with active distractors in the right hemisphere (third row, Figure 6.34). At the midline arrays with sleeping men distractors and an unarmed man target elicited larger amounts of CRN activity than other incongruent threat arrays for males. In the left hemisphere, CRN amplitude for males was most negative for incongruent threat arrays with sleeping men distractors, followed by those with injury or unarmed men distractors, and then arrays with aimed handgun distractors.

Linear mixed effects analysis. STAI-S scores were the only trait score significantly related to CRN modulation (Kenward-Roger: F(192, 3303) = 1.32, p = .003) and these were included in the final CRN model (Table 6.21). There was strong clustering of CRN mean amplitudes among participants (ICC_{Participants} = .6), and the final model explained 64% of total variance ($\sigma^2 = .38$, τ_{00} for participants = .56). All

Table 6.21. *R* notation for the final and breakdown models estimated for CRN mean amplitudes. Abbreviations for factors included in analyses are provided at the bottom of the table.

		R-notation	
	lmer(CRN~Aro*Sag + Sag	*STAI-S + Cor*STAI	-S + Aro*Cor + Cong*Cor +
Final model	Sex*Sag*Cor + Aro*Thr*Cong*STAI-S + Thr*Cong*Sex*STAI-S +		
	Aro*Thr*Cong*Sex + (~1 Participant), Ex3_CRN)		
B 11 11	lmer(CRN~Aro*Sag + Sag	*STAI-S + Cor*STAI	-S + Aro*Cor + Cong*Cor +
Breakdown model	Sag*Cor + Aro*Thr*Cong*STAI-S + (~1 Participant), Ex3_CRN)		
Aro = Arousal level	Sag = Sagittal location	Cor = Coronal site	STAI-S = state anxiety scores
Thr = Threat type	Cong = Congruency		

interactions included in the final model reached significance (Appendix K). To breakdown these interactions participants were separated into male (n = 20) and female (n = 20) groupings. CRN mean amplitudes were strongly clustered for males (ICC_{Participants} = .58) and females (ICC_{Participants} = .61). The breakdown model also accounted for similar amounts of variance for males ($\Omega^2 = .64$, $\sigma^2 = .31$, τ_{00} for participants = .42) and females ($\Omega^2 = .63$, $\sigma^2 = .45$, τ_{00} for participants = .7).

Females. The main effect of Arousal level ($F(1, 1853) = 16.41, p < .001, \beta = -0.02$ [0.18, -0.22]), 0.12]) was significant. This main effect, along with several significant two and three-way interactions (Table 6.22), were qualified by a significant four-way interaction between Arousal level, Threat type, Congruency and STAI-S scores, $F(3, 1853) = 3.18, p = .02, \beta_{ARO} = -0.01$ [0.03, -0.05], $\beta_{THR} = -0.02$ [0.02, -0.06], $\beta_{BOTH} = 0.04$ [0.07, 0] (Figure 6.35). No correlations between STAI-S scores and CRN amplitudes were significant in this interaction. However, a weak, negative and significant correlation was found between STAI-S scores and CRN activity at frontal electrodes for arrays with injury distractors (Bonferroni-corrected $\alpha = .006$; r = -.2, p = .002). Outside of STAI-S scores, CRN activity was not moderated by congruent arrays

Table 6.22. Parameter information for significant two-way and three-way interactions qualified by the significant four-way interaction in the CRN breakdown model for females. The reference parameter, estimate (β) and associated 95% confidence intervals are provided. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Aro*Cong	<i>F</i> (3, 1853) = 29.55***	
ref. High: CON	Low: ARO	-0.32 [-0.08, -0.56]*
	Low: THR	-0.45 [-0.2, -0.69]***
	Low: BOTH	0.43 [0.67, 0.19]***
Thr*Cong	<i>F</i> (3, 1853) = 14.23***	
ref. Active: CON	Passive: ARO	0.26 [0.5, 0.02]*
	Passive: THR	0.11 [0.35, -0.13]
	Passive: BOTH	0.4 [0.64, 0.16]**
Aro*Thr*Cong	<i>F</i> (3, 1853) = 15.35***	
ref. High: Active: CON	Low: Passive: ARO	0.29 [0.63, -0.06]
	Low: Passive: THR	-0.49 [-0.15, -0.84]**
	Low: Passive: BOTH	-0.79 [-0.45, -1.13]***
Aro*Thr*STAI-S	F(1, 1853) = 6.13*	
ref. High: Active	Low: Passive	-0.02 [0.01, -0.05]
Aro*Cong*STAI-S	F(3, 1853) = 4.17 **	
ref. High: CON	Low: ARO	-0.008 [0.02, -0.04]
	Low: THR	-0.01 [0.01, -0.04]
	Low: BOTH	-0.01 [0.02, -0.04]
Thr*Cong*STAI-S	F(3, 1853) = 4.82 **	
ref. Active: CON	Passive: ARO	0.03 [0.06, 0]*
	Passive: THR	0.01 [0.04, -0.01]
	Passive: BOTH	0.01 [0.04, -0.01]
.1 < p < .05., p < .05*, p < .01 **, p <	<.001*** Aro: Arousal level	STAI-S = state anxiety scores

Thr: Threat type

Congruency: Cong, CON = Congruent, ARO = Incongruent arousal, THR = Incongruent threat, BOTH = Incongruent both

nor arrays with incongruent threat high-arousing distractors. Incongruent threat arrays with sleeping men distractors led to the most negative CRN amplitude in this congruency condition, followed by those with unarmed men distractors, and then arrays





with high-arousing images (all ps < .01). In the incongruent arousal condition, CRN activity for unarmed men paired with an aimed handgun target led to more negative amplitude than arrays with ($\beta = -0.47$ [-0.3, -0.64]), p < .001), aimed handgun or sleeping men distractors (see Figure 6.35 for parameter information). Lastly, for incongruent both arrays CRN amplitude was more negative for arrays with aimed

handgun or sleeping men distractors than those with injury or unarmed men distractors. However, these differences reached significance for incongruent both arrays with unarmed men distractors, not those with injury distractors.

Males. The main effects of Threat type $(F(1, 1841) = 13.75, p < .001, \beta = -0.09$ [0.06, -0.23]) and Congruency (F(3, 1841) = 5.54, p < .001, $\beta_{ARO} = -0.22$ [-0.04, -0.39], β_{THR} = -0.16 [0.02, -0.33], β_{BOTH} = -0.21 [-0.03, -0.39]) reached significance. A trend also occurred for STAI-S scores, F(1, 18) = 4.21, p < .001, $\beta = -0.04$ [0.03, -0.11]), and a positive, moderate and significant relationship was found between STAI-S scores and CRN activity (r = .34, p < .001). The trend and the Threat type main effect were each moderated by one of two significant two-way interactions (Table 6.23). The Coronal site factor was also found to interact significantly with Congruency, and with Arousal level (Figure 6.36). Regarding Congruency, arrays with incongruent distractors evoked significantly more negative CRN at midline and left hemisphere sites compared to those in the right hemisphere. These differences were largest between the left and right hemisphere. In relation to Arousal level, no differences between arrays with high and low arousal distractors reached significance (all ps > .05, bottom Figure 6.36). CRN amplitude for arrays with high-arousing distractors was significantly reduced in the right hemisphere compared to midline and left hemisphere sites. These same differences also occurred between arrays with active or passive low-arousing distractors, however only a trend was found for more negative CRN activity in the left hemisphere in comparison to the midline.

The remaining significant two-way interactions, along with relevant main effects, were further qualified by three significant three-way interactions. STAI-S scores were found to interact significantly with Threat type and Congruency (F(3, 1841) = 2.7, p = .04, $\beta_{ARO} = -0.03$ [0.01, -0.08], $\beta_{THR} = 0.03$ [0.01, -0.07], $\beta_{BOTH} = -0.02$ [0.02, -0.06]

Table 6.23. Parameter information for significant two-way interactions in the CRN breakdown model for males. The reference parameter, estimate (β) and associated 95% confidence intervals are provided. F-statistics are located at the top of the parameter column for each interaction. P-value significance is located at the bottom left of the table.

	Parameter	β [95% CI]
Thr*Cong	$F(3, 1841) = 6.68^{***}$	
ref. Active: CON	Passive: ARO	0.16 [0.36, -0.05]
	Passive: THR	-0.11 [0.1, -0.31]
	Passive: BOTH	-0.11 [0.1, -0.32]
Aro*Cor	F(2, 1841) = 3.86*	
ref. High: Left	Low: Midline	0.07 [0.19, -0.05]
	Low: Right	0.17 [0.3, 0.05]**
Cor*Cong	$F(6, 1841) = 4.69^{***}$	
ref. Left: CON	Midline: ARO	0.2 [0.37, 0.02]*
	Midline: THR	0.36 [0.54, 0.19]***
	Midline: BOTH	0.19 [0.37, 0.02]*
	Right: ARO	0.36 [0.54, 0.19]***
	Right: THR	0.19 [0.37, 0.02]*
	Right: BOTH	0.43 [0.6, 0.25]***
Cong*STAI-S	$F(3, 1841) = 18.45^{***}$	
ref. CON	ARO	-0.03 [0, -0.06]*
	THR	0 [0.03, -0.03]
	BOTH	-0.04 [-0.01, -0.07]*
.1 < p < .05., p < .05*, p < .01 **	p < .001 *** Aro: Arousal level	STAI-S = state anxiety scores

Congruency: Cong, CON = Congruent, ARO = Incongruent arousal, THR = Incongruent threat, BOTH = Incongruent both

(Figure 6.37). Consistent with the trend found for STAI-S scores, there were positive and significant correlations between STAI-S scores and CRN amplitude for each level of this three-way interaction. The strongest of these associations occurred in the incongruent arousal and incongruent both conditions for arrays with distractor images that were active (Bonferroni-corrected $\alpha = .006$; Incongruent arousal: r = .39, Incongruent both: r = .41) or passive (Incongruent arousal: r = .44, Incongruent both:





Figure 6.36. LS means for CRN mean amplitudes categorised by congruency and coronal site (top), and by arousal level and coronal site (bottom), for males. Parameter estimates for LS differences are shown between left hemisphere, midline and right hemisphere sites for each type of incongruent array (top right), as well as for those between left hemisphere, midline and right hemisphere sites for high and low arousal distractors (bottom right). Vertical and horizontal bars denote 95% confidence intervals.



Figure 6.37. LS means for CRN mean amplitudes categorised by threat type and congruency for males ($M_{\text{STAI-S}} = 28.93$). Parameter estimates for LS differences are shown between active and passive distractors for each congruency condition (top right). Vertical and horizontal bars denote 95% confidence intervals.

r = .39; all p < .001). Outside of STAI-S scores, incongruent threat arrays with mismatched passive distractors and active targets elicited significantly more negative CRN activity than those with mismatched active distractors and passive targets.

A significant three-way interaction was found between Arousal level, Threat type and STAI-S scores (F(1, 1841) = 9.72, p = .002, $\beta = -0.04$ [0.01, -0.08], Figure 6.38). Positive, significant and weak to moderate correlations were found between STAI-S scores and CRN amplitude in response to arrays with aimed handgun (Bonferroni-corrected $\alpha = .01$; r = .36), injury (r = .28), unarmed men (r = .31), or sleeping men (r = .39, all ps < .001) distractors. Outside of STAI-S scores, CRN amplitude for arrays with injury distractors was significantly larger than those elicited by arrays with aimed handgun distractors. The same difference between arrays with unarmed or sleeping men distractors did not reach significance. The third and final significant three-way interaction involved Arousal level, Threat type and Congruency, F(3, 1841) = 3.52, p = .02, $\beta_{ARO} = -0.02$ [0.04, -0.08], $\beta_{THR} = 0.01$ [0.08, -0.05], $\beta_{BOTH} =$



Figure 6.38. LS means for CRN mean amplitudes categorised by arousal level and threat type for males ($M_{\text{STAI-S}} = 28.93$). Parameter estimates for LS differences are shown between active and passive distractors for high and low-arousing images (top right). Vertical and horizontal bars denote 95% confidence intervals.

0.01 [0.07, -0.05] (Figure 6.39). No differences of interest between arrays with mismatched high and low-arousing images reached significance (all ps > .05). This same lack of CRN modulation also occurred for congruent arrays. In the incongruent threat condition, however, arrays with sleeping men distractors evoked significantly more negative CRN activity than those arrays with unarmed men distractors. Although this same difference occurred between incongruent threat arrays with injury or aimed handgun distractors this CRN modulation did not reach significance (see Figure 6.39).

Discussion

In Experiment 3 the objective was to examine sex differences in response selection towards active or passive dispositions in highly aversive images featuring humans. The presence of injured humans or men with aimed handguns in Flanker arrays led to sex-specific modulation in the anterior N1, the LPP and the response-locked CRN. As expected, sex-specific effects observed in EPN and MPN amplitudes were not



Figure 6.39. LS means for CRN mean amplitudes categorised by arousal level, threat type and congruency for males. Parameter estimates for LS differences are shown between active and passive distractors for high and low arousal images (bottom left). Vertical and horizontal bars denote 95% confidence intervals.

related to the congruency of distractor images. Inconsistent with predictions, the amplitude of the occipital N1 in response to Flanker arrays was not moderated by participant sex. More striking was the association of state anxiety scores with modulation of anterior N1, EPN, MPN and response-locked CRN activity. In line with results from Experiment 2, individual variation in trait anxiety scores was related to LPP modulation, while occipital N1 amplitude was moderated by participants' level of neuroticism. Findings from the present EEG study provide support for the influence of action disposition on the motivational relevance of highly aversive images with humans for male and female individuals.

The association of state anxiety with anterior N1 and CRN modulation indicates that responsiveness towards aversive images of humans differs between men and

women. To the researcher's knowledge, this is the first evidence of a connection between sex differences in ERP activity, state anxiety and the action disposition of humans in negative scenes. Previously sex-specific variation in covert attention has been linked to trait anxiety when aversive images, including those of humans, are employed as threat cues (Koster et al., 2006; Waters et al., 2007). Levels of state and trait anxiety are thought to disassociate anxiety as a momentary emotional state and as a source of individual variation (Spielberger, 2010). In the present study, a man armed with a handgun paired with unarmed men distractors elicited more negative anterior N1 and CRN activity than most other incongruent arousal arrays for women, but not for men. For women, CRN and anterior N1 amplitudes were also more negative for a sleeping man paired with aimed handgun distractors compared to arrays with an unarmed man and injury distractors. Female participants could be more sensitive than males to images showing men with aimed handguns when these are presented alongside low-arousing images.

The association of state anxiety with anterior N1 amplitude for females, and with CRN activity for males, suggests these two types of ERP modulation are indexing sex differences in motivational relevance during the modified Flanker task. In support of this supposition, in the male grouping injury distractors mismatched to an aimed handgun target led to more negative anterior N1 and CRN activity than aimed handguns with an injury target. Men could be more responsive to the context of aversive human images, while for women this differentiation requires stimuli with incongruent levels of arousal. However, sex-specific variation in CRN activity was not reflected in reaction times. High-arousing arrays led to faster responses compared to those with mismatched low-arousing targets and high-arousing distractors. This effect was consistent across males and females for congruent arrays. For incongruent threat arrays, this same

difference was only found for females and not males. These results indicate the arousal level of images employed as stimuli contributed to sex differences in reaction times observed in previous behavioural studies (Koster et al., 2006; Sulikowski & Burke, 2014; Waters et al., 2007).

Regarding sex differences in LPP modulation, the magnitude of LPP activity was moderated by the action disposition of aversive and neutral images. When aimed handgun or unarmed male distractors were paired with passive disposition targets, this increased the difference between males and females in LPP amplitude, indicating these arrays required additional attentional processing by women. This discrepancy also occurred for passive arrays with mismatched injury and sleeping men images. In this case, a reduction in LPP amplitude for men led to the larger difference between male and female individuals in LPP activity. Regarding arousal level, LPP amplitude for females was larger than males for all congruency conditions bar two: arrays mismatched on threat type with low-arousing distractors, and incongruent both arrays with higharousing distractors. Sex-specific variation in activity for the anterior N1, the CRN, and the LPP suggest the threat value of highly aversive images with humans is influenced by action disposition. This indicates the intermixing of human stimuli in unpleasant image categories may be a potential confound in several EEG studies that have investigated sex differences in ERP activity towards unpleasant images (see Chapter 2).

The motivational relevance of severe injury versus attack intent

Several similarities were observed between men and women in ERP modulation. Congruent aimed handguns were differentiated from congruent unarmed men in EPN and LPP activity. This same difference did not occur between for congruent injury and sleeping men images in EPN amplitude, only in LPP modulation. The precedence assigned to aimed handguns over severe injury was further supported by incongruent

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both arrays with mismatched handgun images eliciting greater EPN and LPP activity than arrays in this congruency condition. These effects were clearest in the right hemisphere and may have been enhanced by the presence of sleeping men targets or distractors in the relevant incongruent both arrays. Individual variation in state or trait anxiety was most closely associated with the amplitudes of the EPN and the LPP in Experiment 3, which suggests that the motivational relevance of aversive human images is moderated by anxiety-related traits in non-clinical populations. Moreover, EEG studies that have reported larger LPP amplitude towards severe human injury than other types of unpleasant images may not have matched the presence of humans between negative semantic categories (Schäfer et al., 2010; Weinberg & Hajcak, 2010). A person with an aimed weapon is presumably a more imminent threat than stimuli with a more passive disposition, as the former stimulus is a direct threat to one's physical safety.

Effects in occipital N1, EPN and LPP activity were also consistent across male and female participants. EPN amplitude was more negative to injury distractors mismatched to an aimed handgun compared to other incongruent threat arrays, whereas mismatched high-arousing images evoked larger amounts of LPP activity than mismatched low-arousing images in this same congruency condition. Different patterns of EPN and LPP modulation for human injury, threat, and disgust images have been reported previously (Weinberg & Hajcak, 2010; Wheaton et al., 2013). Regarding the occipital N1, arrays with high-arousing congruent or incongruent both distractors elicited more negative occipital N1 activity than other arrays in these two congruency conditions. Occipital N1 modulation was also reversed for arrays with images mismatched on either threat type or arousal level, effects that reached statistical significance in the incongruent arousal condition. These results correspond to one EEG study in which high-arousing images (e.g., human injury, erotica) evoked more negative

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posterior N1 than low-arousing images (e.g., everyday household objects; Lithari et al., 2010). It is possible the mismatch between arousal level or threat type in incongruent arrays drove occipital N1 modulation as these pairings were more ambiguous than arrays with congruent or incongruent both distractors.

The results from Experiment 3 further highlight the need to consider how the semantic categorisation of highly aversive images impact the investigation of sex differences in picture processing. By itself, state anxiety is not explicitly associated with negative emotion, as this "trait" is context-dependant rather than stable (Bishop, 2007; Endler & Parker, 1990). The association between state anxiety and modulation of the CRN, the anterior N1, and the EPN in the current study raises questions about the role of social relevance in picture processing for male and female individuals. Similar to the N1 and EPN modulation observed in Experiment 1, this discrepancy had resolved by the time frame of the LPP. Most intriguing is the connection between neuroticism and occipital N1 amplitude, as this relationship was also observed in Experiment 2. This finding indicates that visual processing indexed by the posterior N1 is indeed separate from that denoted by the anterior N1 (Smit et al., 2007; Vogel & Luck, 2000) and that this processing is uniquely tied to a man or woman's predisposition to negative emotionality in picture processing.

Physical differences between scenes of severe injury and other images may have impacted findings from Experiment 3. It is possible the presence of male and female victims among scenes of severe injury affected ERP modulation differently for male and female individuals, despite the absence of injured humans who were obviously feminine or masculine in appearance. ERP activity is shown to index the greater sensitivity of women to the physical characteristics of human faces including gender (Oliver-Rodríguez et al., 1999; Sun et al., 2010), familiarity (Wang, Kitayama, & Han, 2011)

and emotional expression (Choi et al., 2015; Orozco & Ehlers, 1998) compared to men. Combined this evidence suggests women are more responsive to contextual cues in faces than men, a difference that could extend to other aspects of the human body (e.g., male or female physicality). Another image property that may moderate ERP activity is the predominance of blood and gore in scenes of human injury. Red-toned features in affective images are shown to moderate behavioural and ERP measures (e.g., Kuniecki, Pilarczyk, & Wichary, 2015). Select EEG studies have also demonstrated that image colouring contributes to P3 and LPP modulation (Cano, Class, & Polich, 2009; Codispoti, De Cesarei, & Ferrari, 2012).

Attention allocation towards an image naturally involves the context in which the stimulus is viewed, and by extension this factor also impacts the threat value of an aversive stimulus. Results from Experiment 3 align with the findings of Kveraga et al. (2014) in showing the action disposition of humans in aversive images contributes to the threat value of unpleasant images. The present study extends upon these findings by showing that this process is influenced by an individual's biological sex. Moreover, the use of the modified Flanker task in the current research indicates that sex differences in picture processing are tied to the threat value of aversive images featuring humans. The findings of Kveraga et al. also indicate that scenes of injured animals and humans overlap in self-referential and empathic processing. This implies the present findings could be replicated with images of animals. However, distinguishing between active and passive forms of threat may be specific to members of our own species, as the emotional salience of severe injury to animals may not match that of injured humans. This conundrum again highlights the need to explicitly integrate the physical properties of stimuli, such as their perceived threat value, into current theories of emotional salience in picture processing.

Chapter 7 - GENERAL DISCUSSION

Sex differences in the motivational relevance of highly aversive images were examined in the preceding research. It was hypothesised that the threat value of these negative stimuli would moderate sex-specific variation in picture processing. Findings from the three EEG studies support the existence of a relationship between an individual's biological sex, the attribution of threat value to a stimulus and attention allocation towards negative stimuli, while also providing guidance for the future investigation of sex differences in picture processing. In the current chapter, results related to sex-specific variation in the processing of action disposition will be reviewed first, followed by a discussion of the use of human injury in negative scenes. Attention will then shift to the use of personality traits to index stress reactivity in the investigation of sex-specific variation in response to unpleasant images. The chapter will conclude with a reflection on the future investigation of sex differences in picture processing and the implications for the role of stress reactivity in defensive motivation.

In the present research similarities between men and women in ERP modulation indicate the influence of threat value on perceptual processing, response selection and task demands is similar between male and female individuals in some respects (Bradley, Codispoti, Cuthbert, et al., 2001). For brevity, the current chapter will focus on instances in which men and women differed in ERP activity evoked by highly aversive or neutral images. Given that sex-specific variation in EPN or MPN amplitude was rarely linked to specific image content these two ERP components will not be discussed in detail. Participant sex was also found to interact with electrode position in ERP activity throughout the picture processing stream. The influence of hemispheric location on sex differences in ERP modulation was not a focus of the present thesis, and therefore, the effect of electrode position on sex-specific variation will not be discussed.

Sex differences in brain physiology which affect picture processing in men and women have also been addressed with fMRI measures elsewhere (Stevens & Hamann, 2012; Whittle et al., 2011).

Experiment 1: The motivational relevance of attack intent

As demonstrated in Chapter 2, images of attack intent are often included alongside other unpleasant images in EEG studies that investigate sex differences in picture processing (Gardener et al., 2013; Groen et al., 2013; Lithari et al., 2010; Rozenkrants & Polich, 2008). In the present research, evidence was found that attack intent with high biological relevance is processed differently by male and female individuals. In Experiment 1 scenes of attacking snakes evoked larger LPP activity in men with above average levels of trait anxiety in comparison to other participants, male and female included. For the male grouping attacking snakes were also differentiated from non-attacking snakes in N1, N2 and P3b amplitude, a result that did not occur for female participants bar one exception. Luteal phase women exhibited a significant reduction in N2 amplitude for attacking snakes compared to turtles or non-attacking snakes. This differentiation in N2 activity for females concurs with Masataka and Shibasaki's (2012) visual search study in which luteal phase women responded to snake targets among flower distractors faster than women in the follicular phase of their ovarian cycle.

The N2 modulation observed for luteal phase women in relation to snakes is consistent with findings that emotional processing is enhanced in women during this stage of the ovarian cycle (e.g., Lusk et al., 2015; Wassell, Rogers, Felmingam, Pearson, & Bryant, 2015; Wu et al., 2014). It has been suggested that snakes pose a higher survival cost to women than men due to the role women have traditionally played in protecting their children from biologically-relevant threats (Öhman et al., 2012; Rakison, 2009; Van Strien, Franken, et al., 2014). To date, this hypothesis has not been consistently supported by empirical data (Tierney & Connolly, 2013). Men and women are reported to diverge in responses towards disgust-eliciting stimuli (Caseras et al., 2007; Olatunji, Sawchuk, Arrindell, & Lohr, 2005; Rohrmann, Hopp, & Quirin, 2008; Schienle et al., 2005; Skolnick, 2013; Skolnick, Bascom, & Wilson, 2013); threats which are likely to be contaminative rather than predatory in nature. Other physical characteristics of snakes unrelated to attack intent could conceivably modulate ERP activity in females but not males (e.g., scaled skin, slithering movements). Predatory behaviour in snakes may be more salient for women when progesterone levels are relatively high, or in other words, when pregnancy is most likely to occur during the female ovarian cycle.

Sex-specific variation was also evident in early perceptual processing for images of attack intent. N1 amplitude was reduced for images of aimed handguns compared to unarmed handguns, but the same differentiation between attacking and non-attacking snakes was only found for male and not female participants in response to reptile images. These results indicate N1 modulation observed in Experiment 1 was affected by the threat value of snake and handgun images to men and women. Sex differences were also found in ERP activity for handgun stimuli specifically, a threat with low biological relevance (e.g., Blanchette, 2006; Brosch & Sharma, 2005; Fox et al., 2007). Images of handguns that were aimed or unarmed were differentiated for female but not male participants in activity for the N2. Aimed handguns also evoked greater levels of P3b activity than unarmed handguns for men and birth control females in Experiment 1, but not for women in the follicular or luteal stage of their ovarian cycle. Sex-specific variation in N2 and P3 modulation for negative stimuli with varying levels of unpleasantness is not without precedent (Li et al., 2008; Yuan et al., 2009). Results from

the present research indicate that sex-specific variation found for unpleasant images in prior EEG studies may have been influenced by the evolutionary significance of images that show attack intent (see Chapter 2).

Sex differences in N1, N2, P3b and LPP modulation for reptile images indicates that men prioritise threats with high biological relevance. These findings are consistent with the idea that men are more alert to cues of attack and aggression than women (Kring & Gordon, 1998; Schienle et al., 2005; Sulikowski & Burke, 2014). The same type of sex-specific variation was not evident for handguns, as differentiation between images of aimed or unarmed handguns was found for women but not men in N2 modulation. Gender socialisation is thought to contribute to the higher levels of emotional reactivity observed in women compared to men (Craske, 2003; Kret & De Gelder, 2012; Vigil, 2009). In this instance, women may have been more sensitised than men to the action disposition of the handgun due to the attack position of the weapon, and this awareness may be driven by a learned need to rapidly identify potential threats with low biological relevance. It is also possible the relationship found between neuroticism and N2 activity drove the female ERP response to handguns as the association of attack with this stimulus is assumedly learned throughout one's lifetime. Individual variation in worry may have also influenced sex differences observed in late positivity, including the association found between LPP amplitude and trait anxiety for men in response to images of attacking snakes.

Experiments 2 and 3: Stimulus congruency, attack intent and arousal level

Highly aversive images are more arousing than other unpleasant images due to the threat value nature of image content such as attack intent. Due to this, moderately threatening versions of aversive images may not be an adequate match for the emotional saliency of highly aversive images. In Experiments 2 and 3 this inconsistency was addressed by examining the effect of stimulus congruency on responses by men and women towards aversive and neutral images. Activity for the anterior N1 was moderated by arrays with high-arousing distractors mismatched to low-arousing targets for women, whereas for men the anterior N1 was modulated by arrays with mismatched high-arousing images (e.g., aimed handguns/attacking snakes, human injury/men with aimed handguns). Participant sex also affected the amplitude of the occipital N1 in Experiment 2, but not Experiment 3. For women, occipital N1 activity was reduced for arrays featuring congruent or incongruent attacking snake or aimed handgun images compared to other arrays in the same congruency conditions, an effect not found for men in Experiment 2. Women with below average levels of trait anxiety also responded with more positive LPP amplitude than men in the same trait anxiety grouping when arrays featured distractors that were aimed handguns or attacking snakes.

The results from Experiment 2 provide evidence that stimulus congruency moderates the effect of threat value on sex-specific variation in picture processing. Unlike Experiment 1, the presence of attack intent in images appeared to be the main driver of N1 and LPP modulation rather than biological relevance. In Experiment 3 the aim was to test whether the presence of humans in highly aversive images contributes to sex differences in ERP activity. At central electrodes, anterior N1 amplitude was reduced for congruent aimed handguns compared to other congruent arrays for women, but not men. For men, CRN activity was of lesser magnitude for arrays with aimed handgun distractors in comparison to those with injury distractors, an effect not found for female participants. This CRN modulation may have been driven by arrays with images mismatched on active and passive dispositions. Amplitude reduction in the N1 and the CRN may indicate more efficient processing of particular Flanker combinations, suggesting that attack intent is prioritised differently by men as opposed to women

during early picture processing.

The deployment of attentional resources in contextual paradigms, such as the visual search, oddball and Flanker tasks, is more akin to real-world circumstances compared to passively viewing an image. Results from Experiments 2 and 3 indicate the effect of context on attention allocation towards images of attack intent is different for male and female individuals. Moreover, ERP modulation in Experiments 2 and 3 provided support for disassociation between anterior and posterior N1 activity in visual processing (Smit et al., 2007; Vogel & Luck, 2000). Activity for the anterior N1 appeared more susceptible to sex-specific variation, particularly in Experiment 3. It must also be noted that ERP modulation observed for females in Experiments 1, 2 and 3 for images of aimed handguns is intriguing given that men are more likely than women to be exposed to weapon use as children (i.e., toys) and later as adults (see Sulikowski & Burke, 2014). This discrepancy suggests the social relevance of potential threats moderates sex differences in the emotional salience of highly aversive images.

The motivational relevance of human injury

The present findings support sex-specific variation in responses towards attack intent in aversive images, suggesting that these sex differences in the threat value of these stimuli are influenced by biological relevance and stimulus congruency. In contrast, many similarities were found between male and female individuals in EPN, N2, P3b and LPP activity for scenes of injured humans in Experiment 1. These results contrast with EEG studies that have found sex-specific variation in P3 or LPP activity for images of humans in pain or distress (Gonzalez-Liencres et al., 2016; Han et al., 2008; Luo et al., 2014). Categorising severe and non-severe injury as high and moderate threat stimuli may have led to this inconsistency with previous research in Experiment 1. There were two instances in which sex differences were observed for human injury in
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late positive ERP activity, neither of which reached statistical significance. Scenes of severe injury elicited more positive P3b amplitude than other human images in grand average waveforms for male but not female participants. LPP activity for follicular phase women was also reduced compared to other female participants and men for images of human injury.

Due to the association of late positive modulation with task demands (Kok, 1997; Polich, 2007), scenes of severe injury may have been more task relevant for males at the stage of the P3b compared to other human stimuli, whereas lower than average progesterone levels could have acted to decrease the motivational relevance of injured humans for women in the follicular phase of their ovarian cycle. Alternatively, the lack of sex-specific ERP modulation by way of human injury in Experiment 1 may have originated from the absence of other aversive images with humans present. This limitation was rectified in Experiment 3 with the inclusion of aimed handgun images with an explicit human presence alongside scenes of human injury. Unlike males, CRN modulation for females indicated that action disposition influenced response selection towards Flanker arrays. Unarmed men distractors with an aimed handgun target elicited the most negative CRN activity in the incongruent arousal condition, whereas in the incongruent threat condition this occurred for sleeping men distractors paired with an injury target. For females, arrays with mismatched sleeping men and aimed handgun images also evoked more negative CRN amplitude than those with mismatched injury and unarmed men images.

Reports of CRN modulation by way of images are scarce (e.g., Moser et al., 2008). The relationship of this ERP component to the ERN suggests the magnitude of the CRN is related to individual variation in anxiety (Hajcak, 2012). Anxiety may also attenuate attention allocation towards the action disposition of a threat (Riskind, 1997;

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Riskind & Williams, 2005). Several personality traits are linked to individual variation in the expression of negative emotion (Eysenck & Eysenck, 1985; Watson & Clark, 1984). This dynamic, however, has been linked primarily to the experience of emotion by individuals rather than emotion as an action disposition. Responses towards the threat value of a stimulus could also require sex-specific strategies in resource allocation that begin at the pre-attentive stage. For instance, expected and unexpected images with pleasant or unpleasant valence are differentiated in N2 activity for women and in LPP amplitude for men (Lin et al., 2014). The predictability of distractor images with unpleasant or neutral valence is also shown to moderate N1 and P2 amplitude differently in men and women (Jin et al., 2013).

Social relevance is often implicated in the emotional salience of unpleasant images to men and women in picture processing (see Chapter 2). Results from the present research indicate the types of action dispositions exhibited by humans in unpleasant images contributes to this dynamic. A common element shared by dysphoric scenes of humans and those showing injured humans is the depiction of another human in a vulnerable state. Women are thought to engage in affiliative behaviours to a greater extent than men in response to stress (S. E. Taylor, 2006, 2011; S. E. Taylor et al., 2000), which suggests that images of humans in distress are more stress-eliciting for women compared to men. A range of brain-based evidence indicates that men and women vary in responses towards sadness in several forms (George, Ketter, Parekh, Herscovitch, & Post, 1996; Lee et al., 2002; Schneider, Habel, Kessler, Salloum, & Posse, 2000; Verkuil et al., 2015), however these sex differences are likely due to other sources of individual variation in brain activation and environmental factors (Côté et al., 2007; Eugène et al., 2003). Known differences between men and women in responses towards disgust-eliciting stimuli, mentioned previously, also indicate the risk of

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exposure to contaminative threats moderates the emotional salience of unpleasant human images to men and women (e.g., human injury, disease, poor hygiene).

The effect of stress reactivity on sex differences in motivational relevance

In the present research, individual variation in neuroticism, trait anxiety, worry and alexithymia were measured. Though the observed relationships between ERP modulation and these four personality traits do not capture the full complexity of the stress response, these findings do indicate an individual's physiological reaction to the threat value of stimuli impacts the processing of highly aversive images. Levels of neuroticism, trait anxiety, worry and alexithymia were also found to overlap to varying degrees in the present research; a finding consistent with the breadth of behaviours associated with negative emotionality (Eysenck & Eysenck, 1985; Watson & Clark, 1984). Regarding the earlier stages of picture processing, it was evident that state or trait anxiety was most strongly associated with modulation of the anterior N1 and the CRN, while the EPN was related to either state anxiety or neuroticism. These relationships appeared dependent on the inclusion of human images as stimuli. State anxiety scores were most strongly correlated with anterior N1, CRN and EPN modulation in Experiments 1 and 3, the two studies in which images of injured and non-injured humans featured.

The influence of anxiety-related traits was evident later in the picture processing stream for male and female individuals. As mentioned, N2 modulation observed in Experiment 1 was related to neuroticism. Worry and trait anxiety, rather than neuroticism or alexithymia, were most strongly related to LPP and P3b modulation in the present research. This coincides with other EEG studies that have found similar relationships for late positive activity in response to unpleasant images (Burkhouse et al., 2015; MacNamara, Ferri, & Hajcak, 2011; MacNamara & Hajcak, 2009; Mocaiber

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et al., 2009; Pedersen & Larson, 2016). Given that late positivity is linked to the allocation of attentional resources (Kok, 1997; Polich, 2007), these findings imply that anxiety traits are connected to motivational relevance for non-clinical populations. This connection may have also driven previous reports of late positivity modulation by participant levels of alexithymia (Franz, Schaefer, Schneider, Sitte, & Bachor, 2004; Pollatos & Gramann, 2011; Walker, O'Connor, & Schaefer, 2011; L. Zhang et al., 2012) or neuroticism (K. W. Brown, Goodman, & Inzlicht, 2013; W. Zhang, Zhao, & Liu, 2013, 2015).

Alexithymic traits were not as strongly related to sex differences in ERP modulation evoked by aversive images compared with other personality traits measured in the present research. Sex-specific variation in alexithymia may not directly influence picture processing due to similarities between this personality trait and anxious arousal. Anxious arousal refers to the visceral aspects of the anxiety state, including somatic tension and physiological hyper-arousal (Moser et al., 2012). Anxious arousal is closely related to more transitory forms of anxious psychopathology, such as state anxiety (Nitschke, Heller, & Miller, 2000). In contrast, trait anxiety, worry and neuroticism are more akin to anxious apprehension, which denotes the more cognitive aspects of anxiety and is characterised by rumination, agitation, fatigue, and muscular tension with a psychosomatic basis (Nitschke et al., 1999). Categorising personality traits in terms of anxious apprehension and arousal, rather than negative emotionality, in future research may shed light on sex-specific variation in ERP activity towards unpleasant images. For instance, Moran et al. (2012) reported that ERN and CRN activity correlates with worry in women, but not men, in response to a standard Flanker task.

Implications and conclusions

The measurement of personality traits associated with stress reactivity was a

strength of the present research. Characterising the influence of these individual-level factors on motivational relevance also sheds light on the relationship between internal states and external cues in picture processing. Personality traits associated with negative emotionality represent one way in which the deployment of attentional resources to support subsequent behaviour in men and women can be examined. For instance, the greater prevalence of anxiety and mood disorders in women compared to men worldwide (Baxter et al., 2013; Ferrari et al., 2013; Steel et al., 2014) may be more indicative of sex-specific strategies related to stress reactivity rather than a female negativity bias per se. Negative emotionality may simply manifest differently in men and women, a premise supported by the proposed existence of male-type depression (Martin, Neighbors, & Griffith, 2013; Nejtek, 2014). Results from the present research also indicate the effect of hormonal contraceptives on picture processing in women requires further investigation, specifically whether different types of birth control medications exert similar effects on brain-based measures (Toffoletto, Lanzenberger, Gingnell, Sundström-Poromaa, & Comasco, 2014; Warren et al., 2014).

The connection between attention allocation and response selection is heavily implied in theories of emotional salience (Frijda, 2010; James, 1884; Lang & Bradley, 2013). Defining the influence of individual-level factors that affect picture processing will assist in determining the exact nature of the relationship between attention and behaviour in defensive motivation. Sex differences in defensive motivation are assumedly linked to those behaviours of most benefit to men and women in encounters with highly aversive stimuli. Though these defensive strategies are largely consistent across men and women, findings from the present research suggest that men and women differ in the prioritisation of stimulus-level factors that denote threat. The avoidance evoked by a negative stimulus could depend upon how that threat is appraised by the

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male or female individual (Elliot et al., 2013). Given that responses towards threat can be categorised as self-protective or disease-avoidant (Neuberg et al., 2011), sex differences in the motivational relevance of highly aversive images could reflect sexspecific variation in the onset of self-protective behaviours during pre-attentive processing.

Valence and arousal serve as adequate descriptors of emotional salience in picture processing. However, to deepen current understandings of motivational relevance the other stimulus- and individual-level factors that influence attention allocation towards images with high emotional salience must also be considered. This premise was demonstrated throughout the preceding research by investigating sex differences in the threat value of highly aversive images. Threat is not simply the attribution of danger, but the summation of the individual- and stimulus-level factors that contribute to the emotional salience of many negative stimuli. This process, termed threat value in the present research, was shown to support pre-attentive processing related to perception, semantic categorisation, resource allocation, task demands and response selection. Stating that men or women are biased towards specific stimuli does not capture the full scope of sex-specific variation in motivational relevance. Highly aversive images are emotionally-salient for men and for women; it is the response to the stimulus that differs between the sexes, and it is this process that is reflected by sex differences in ERP activity for unpleasant images.

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APPENDIX A: General medical questionnaire

General Medical Questionnaire: University of Newcastle, Ourimbah Campus
School of Psychology, Faculty of Science and Information Technology
Experiment Code Date/
Age
Handedness: Left / Right
Part 1: 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?
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 experienced phobia? Yes No
If yes, please specify:
Does your phobia extend to/include viewing
pictures containing snakes, guns or human injury?
Yes No
Part 2: Drinking and Smoking History
1. On how many days last week did you drink alcohol? None

None One-two days Three-four days Five-six days Every day Never

2. Do you usually drink...

		During weekdays
		Friday night
		Weekends
3.	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
4.	How often do you get drunk?	Never
		Rarely
		Once a month
		Once a week
		More frequently
5.	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

- 6. 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

Part 3: Vision

Do you have any difficulties with vision? (please specify)
If yes, are these difficulties corrected (i.e. glasses/contacts)

Part 4: Menstrual Cycle (Females Only)

Are you pregnant? Yes No If yes, how long

for?.....days

When did you experience your last period? Tick or circle the most appropriate option/s:

I have my period now

For how long?daysOne week ago (est. 2-4 weeks until next period)Two weeks ago (est. Day 10-18 of cycle)Three weeks ago (est. 1-3 weeks since last period)Four weeks ago (est. period due within a week)Hormonal birth control (e.g., the pill, arm-implant)

 Type of birth control? Please include

 details

 Other

 Please give details (i.e. length of average cycle, health

 condition, etc.)....

 AND/OR Specify number of days since end of last period

.....days

Disclaimer: The information provided in this questionnaire will be kept confidential to protect your privacy, as required by the Human Ethics Research Committee of the University of Newcastle (New South Wales, Australia). This information will be available only to the principal researchers and not to any other party, and will be stored at a secure location at the Ourimbah campus at the University of Newcastle. The questionnaire will be destroyed once individuals are accepted as participants or not.

Thank you for your participation!

APPENDIX B: Analysis of Goldberg marker scores for Experiments 1, 2 and 3

Scores from the agreeableness dimension of the IPIP5F-100 did not follow a normal distribution nor possess equal variance for Experiments 1, 2 and 3. Therefore non-parametric methods were employed to analyse scores from the IPIP5F-100. Spearman rank correlation coefficients were calculated to compare relationships between scores from the five IPIP5F-100 dimensions and those from the PSWQ, TAS-20 and the two STAI subscales. Five 4[Participant sex: male, birth control female, luteal phase female, follicular phase female] Kruskal-Wallis one-way ANOVAs were computed for extraversion, agreeableness, conscientiousness, emotional stability and imagination scores in Experiment 1. The epsilon-squared estimate was used to index effect size for each Kruskal-Wallis ANOVA (Tomczak & Tomczak, 2014). Post hoc comparisons for relevant IPIP5F-100 dimensions were performed using Mann-Whitney U tests with Bonferroni corrections ($\alpha = .008$). For Experiments 2 and 3 five separate 2[Participant sex: male, female] Mann-Whitney U tests were performed for each of the IPIP5F-100 dimensions.

Experiment 1

The internal reliability of scores from the Extraversion ($\alpha = .93$), Agreeableness ($\alpha = .94$), Conscientiousness ($\alpha = .91$), Emotional stability ($\alpha = .92$) and Imagination ($\alpha = .9$) dimensions of the IPIP5F-100 were very good. Participants scored more highly on the Agreeableness ($M = 78.66 \pm 1.7$; Mdn = 82, IQR = 73.88) and Imagination ($M = 78.66 \pm 1.7$; Mdn = 76, IQR = 67.82) dimensions of the IPIP5F-100 compared to the Conscientiousness ($M = 67.77 \pm 1.53$; Mdn = 68.5, IQR = 60.78), Emotional stability ($M = 66.69 \pm 1.6$; Mdn = 67, IQR = 57.75) and Extraversion ($M = 67.53 \pm 1.63$; Mdn = 67.5, IQR = 59.77) dimensions. The scores of females for Extraversion and Agreeableness tended to be higher than those reported by males (Table B.1), however non-parametric

			Females	
	Males Birth control		Follicular phase	Luteal phase
Means (±SE)				
EXTRA	63 (±3.53)	68.32 (±2.9)	68.4 (±3.67)	71.56 (±2.57)
AGREE	72.14 (±3.65)	81.72 (±3.01)	79.67 (±4.16)	82.06 (±1.88)
CONSC	62.9 (±3.41)	72.96 (±2.24)	66.33 (±2.84)	61.21 (±3.36)
EMOSTAB	73.57 (±2.6)	61.82 (±2.87)	65.4 (±4.15)	65.56 (±3)
IMAG	77 (±2.04)	72.91 (±2.58)	72.6 (±3.3)	74.44 (±2.96)
Medians (with IQR)				
EXTRA	66 (50-73)	68.5 (59-78)	65 (57-83)	69.5 (66-77.5)
AGREE	76 (67-82)	83.5 (76-91)	85 (72-90)	83 (75.5-89.5)
CONSC	67 (51-73)	73.5 (67-81)	63 (60-76)	67 (57.5-80.5)
EMOSTAB	72 (66-79)	61 (52-70)	67 (53-78)	65.5 (56-73.5)
IMAG	78 (70-82)	74.5 (68-82)	71 (62-83)	74 (65-79.5)

Table B.1. Means (top) and medians (bottom) for the extraversion, agreeableness, conscientiousness, emotional stability and imagination dimensions of the IPIP5F-100 in Experiment 1, grouped by male and female groupings (2 d.p.).

testing indicated these differences were non-significant for Extraversion (H (3, N = 74) = 2.81, p = .42, E_R^2 = .04) and Agreeableness (H (3, N = 74) = 5.96, p = .11, E_R^2 = .08) scores. Mean scores for Conscientiousness were highest for birth control females, followed by follicular phase females, and then scores for males and luteal phase females. Again though the main effect of Participant sex was not significant, H (3, N = 74) = 5.64, p = .13, E_R^2 = .08. The Emotional stability and Imagination scores of males tended to be higher than those reported by females, particularly for birth control females in Emotional stability scores and follicular phase females in Imagination scores (Table B.1). The main effect of Participant sex reached significance for the Emotional stability dimension (H (3, N = 74) = 8.43, p = .04, E_R^2 = .12), but not for the Imagination dimension (H(3, N = 74) = 1.54, p = .67, E_R^2 = .02). Emotional stability scores for birth control females were significantly lower compared to those for males, U = 67.5, n_1 = 22, n_2 = 21, p = .004, r = -.43. This same difference occurred between Emotional stability scores for males and other females, however was non-significant for follicular phase females (U = 106.5, $n_1 = 21$, $n_2 = 15$, p = .1, r = .27) and a trend occurred for luteal-phase females (U = 104.5, $n_1 = 16$, $n_2 = 21$, p = .05, r = .32).

Correlations. Positive and significant correlations were found between Imagination scores and those for Extraversion, Agreeableness and Emotional stability, with the strength of these relationships ranging from moderate to strong (Table B.1). A positive, moderate and significant association also occurred between Agreeableness and Conscientiousness scores. Extraversion scores were significantly and positively related to those for Emotional stability and Agreeableness, with the former being weak and the latter being strong. Scores from the five IPIP5F-100 dimensions each shared negative and significant relationships with scores from the TAS-20 and the two STAI subscales (Table B.2). A majority of these associations were weak to moderate in nature, excluding two. A strong inverse correlation was found between Agreeableness and TAS-20 scores, as well as between Emotional stability and trait anxiety scores. Regarding the PSWQ, negative and significant relationships occurred between these scores and those for Emotional stability and Imagination, with the former correlation being strong and the latter moderate.

Experiment 2

As found in Experiment 1, Cronbach alpha values indicated the internal reliability of scores Extraversion ($\alpha = .94$), Agreeableness ($\alpha = .88$), Conscientiousness ($\alpha = .9$), Emotional stability ($\alpha = .94$) and Imagination ($\alpha = .87$) scores were very good. Scores for Agreeableness and Imagination were again larger than those recorded for Extraversion, Emotional stability and Imagination (Table B.3). Conscientiousness scores were on par with those reported in Experiment 1, while scores for Extraversion and Emotional stability were on average lower. Scores for Agreeableness Table B.2. Spearman rank correlation coefficients for Experiment 1 between scores from the extraversion, agreeableness, conscientiousness, emotional stability and imagination dimensions of the IPIP5F-100, as well as with PSWQ, TAS-20 and STAI scores.

	IPIP5F-100				
-	EXTRA	AGREE	CONSC	EMOSTAB	IMAG
Experiment 1					
EXTRA	1				
AGREE	.49***	1			
CONSC	.11	.39***	1		
EMOSTAB	0.23*	.14	.14	1	
IMAG	.63***	.38***	.09	.42***	1
PSWQ	16	.08	.18	64***	37**
TAS-20	33**	51***	41***	29*	31**
State anxiety	3*	35**	-29*	4***	31**
Trait anxiety	32**	39***	28*	61***	41***

 $p < .05 \ast, p < .01 \ast \ast, p < .001 \ast \ast \ast$

Table B.3. *Means (top) and medians (bottom) for the extraversion, agreeableness, conscientiousness, emotional stability and imagination dimensions of the IPIP5F-100 in Experiment 2, grouped by total, male and female groupings (2 d.p.).*

	IPIP5F-100				
	EXTRA	AGREE	CONSC	EMOSTAB	IMAG
Means					
Total	63.86 (±2.29)	77.69 (±1.52)	68.6 (±1.98)	62.57 (±2.36)	73.74 (±1.56)
BC females	60.48 (±3)	78.33 (±1.45)	69 (±2.37)	56.05 (±2.67)	70.57 (±1.95)
Males	67.24 (±3.38)	77.05 (±2.7)	68.79 (±3.23)	69.1 (±3.38)	76.9 (±2.29)
Medians					
Total	61 (54-74)	78.5 (71-85)	68 (62-76)	62.5 (51-74)	74.5 (64-81)
BC females	58 (51-70)	80 (71-83)	68 (64-75)	60 (48-64)	70 (64-77)
Males	68 (55-77)	78 (69-85)	68 (62-79)	72 (62-77)	79 (73-82)

 $(U = 219.5, n_1 = n_2 = 21, p = .99, r = .002)$ and Conscientiousness $(U = 215.5, n_1 = n_2 = 21, p = .91, r = .02)$ were of similar magnitude between male and female participants. For the other three IPIP5F-100 dimensions the scores of males tended to be higher than those reported by females. This main effect of Participant sex reached significance for the Emotional stability $(U = 114.5, n_1 = n_2 = 21, p = .18, r = .41)$ and Imagination $(U = 138, n_1 = n_2 = 21, p = .007, r = .32)$ dimensions, but not for the Extraversion dimension $(U = 219.5, n_1 = n_2 = 21, p = .18, r = .2)$.

Correlations. As found in Experiment 1, scores for Imagination were positively and significantly associated with scores for Extraversion, Agreeableness and Emotional

Table B.4. Spearman rank correlation coefficients for Experiment 2 between scores from the extraversion, agreeableness, conscientiousness, emotional stability and imagination dimensions of the IPIP5F-100, as well as with PSWQ, TAS-20 and STAI scores.

	IPIP5F-100				
-	EXTRA	AGREE	CONSC	EMOSTAB	IMAG
IPIP5F-100					
EXTRA	1				
AGREE	.43**	1			
CONSC	.42**	.44**	1		
EMOSTAB	0.23	.24	.07	1	
IMAG	.36*	.32*	.1	.32*	1
PSWQ	13	13	.05	7***	31*
TAS-20	48**	41**	56***	18*	32*
STAI					
STAI-S	11	17	26	39*	06
Trait anxiety	25	32*	36*	68***	23

p < .05*, p < .01 **, p < .001***

particularly for Extraversion scores (Table B.4). Again, a moderate, significant and stability; however, the magnitude of these relationships was smaller, positive correlation was found between scores for Conscientiousness and Agreeableness. Moderate, positive and significant associations also occurred between Extraversion scores and those from the Conscientiousness and Agreeableness dimensions. Similar to Experiment 1, TAS-20 scores were negatively and significantly related to scores from each IPIP5F-100 dimension, and again the magnitude of these relationships varied from weak to strong (Table B.4). In contrast, state anxiety scores shared a negative, moderate and significant correlation with Emotional stability scores, but not scores from the remaining four IPIP5F-100 dimensions. In relation to trait anxiety, scores from this personality trait were again negatively, significantly and strongly related to Emotional stability scores. This same relationship occurred between trait anxiety scores and those for Agreeableness and Conscientiousness, but these relationships were of reduced magnitude compared to Emotional stability. Finally, as found for Experiment 1 negative and significant correlations were found between PSWQ scores and those for Emotional stability or Imagination, but the former scores led to a much stronger relationship compared to those for Imagination.

Experiment 3

Similar to Experiments 1 and 2, internal reliability was very good for scores from the Extraversion ($\alpha = .93$), Agreeableness ($\alpha = .89$), Conscientiousness ($\alpha = .86$), Emotional stability ($\alpha = .9$) and Imagination ($\alpha = .85$) dimensions of the IPIP5F-100. Once again scores for Imagination and Agreeableness were on average greater than those reported for the other three IPIP5F-100 dimensions (Table B.5). The mean scores for Conscientiousness and Emotional stability were on par with those from the same dimensions in Experiment 1. In contrast, the magnitude of Extraversion scores was

conscientiousness, emotional stability and imagination dimensions of the IPIP5F-100 in Experiment 3, categorised by male and female groupings (2 d.p.). IPIP5F-100

Table B.5. Mean (top) and median (bottom) scores for the extraversion, agreeableness,

			IPIP5F-100		
	EXTRA	AGREE	CONSC	EMOSTAB	IMAG
$M(\pm SE)$					
Total	61.78 (±2.36)	79.45 (±1.6)	70.45 (±1.72)	67.2 (±1.98)	74.65 (±1.39)
BC females	65.2 (±2.6)	81.8 (±1.82)	73.1 (±2.37)	61.6 (±2.39)	74.9 (±1.56)
Males	58.35 (±3.86)	77.1 (±2.56)	62.78 (±2.4)	72.8 (±2.66)	74.4 (±2.33)
Mdn (IQR)					
Total	63 (51.5-73)	80.5 (75.5-86.5)	71.5 (64-78.5)	67.5 (58.5-75.5)	75.5 (71-79)
BC females	66 (43.5-71.5)	81 (77-87)	75.5 (69-81)	62.5 (51.5-75.5)	75 (72-78)
Males	60 (43.5-71.5)	79 (68.5-85)	66 (63-73)	73.5 (63.5-82.5)	76.5 (68.5-80)

lower, and of similar magnitude, to those found for Extraversion in Experiment 2. Average scores for Agreeableness (U = 162.5, $n_1 = n_2 = 20$, p = .32, r = .16) and Imagination (U = 175.5, $n_1 = n_2 = 20$, p = .52, r = .1) were comparable between male and female participants. Birth control females scored more highly than males in the Extraversion dimension, however the Participant sex main effect did not reach significance, U = 147.5, $n_1 = n_2 = 20$, p = .16, r = .22. A trend occurred for the same difference in Conscientiousness scores, U = 131.5, $n_1 = n_2 = 20$, p = .07, r = .29. Similar to Experiments 1 and 2, the Emotional stability scores of females were significantly lower than those of males, U = 97.5, $n_1 = n_2 = 20$, p = .006, r = .44.

Correlations. One significant correlation was found to occur amongst the five IPIP5F-100 dimensions in Experiment 3, which was a positive and strong association between Agreeableness and Imagination scores (Table B.6). TAS-20 scores were significantly and negatively related to scores from the Extraversion, Agreeableness and Conscientiousness dimensions, with the strength of these correlations ranging from moderate to strong. Once again, there were strong, negative and significant associations between Emotional stability scores and those from the PSWQ and the STAI-T. Scores

Table B.6. Spearman rank correlation coefficients for Experiment 3 between scores from the extraversion, agreeableness, conscientiousness, emotional stability and imagination dimensions of the IPIP5F-100, as well as with PSWQ, TAS-20 and STAI scores.

	IPIP5F-100				
	EXTRA	AGREE	CONSC	EMOSTAB	IMAG
IPIP5F-100					
EXTRA	1				
AGREE	.24	1			
CONSC	.2	17	1		
EMOSTAB	0.28	.006	11	1	
IMAG	.25	.51***	.14	.22	1
PSWQ	05	.2	4*	65***	.03
TAS-20	38*	44**	59***	12	28
STAI					
STAI-S	05	14	22	22	07
Trait anxiety	38*	12	31*	56***	33*

p < .05*, p < .01 **, p < .001***

for Conscientiousness were also moderately, negatively and significantly related to PSWQ and trait anxiety scores. Finally, there were negative and significant relationships between trait anxiety scores and those for Extraversion and Imagination, with the former being moderate and the latter weak.



APPENDIX C: Visual scales used to collect affective ratings during Experiment 1

Six-point scales for valence, arousal, threat and disgust that were used to collect ratings during Experiment 1, and during initial rating of images selected for Experiment 3. The original SAM pictures for valence and arousal are not shown, but were included during data collection. Scale numbering was reversed, such that a higher rating for valence indicated greater unpleasantness for valence, and a lower rating signalled greater arousal, threat or disgust.

APPENDIX D: Initial affective ratings of images selected for Experiments 1 and 2

Mean valence, arousal, threat and disgust ratings for firearm, reptile and human images employed Experiment 1 or 2, rounded to 2 or fewer decimal places. Images are categorised by stimulus type and threat level. All ratings have been modified to reflect greater levels of unpleasantness, arousal or threat with higher ratings (1 = low, 6 =high). For valence lower ratings indicate increasing levels of pleasantness. Stimuli from the IAPS database are denoted by a single asterisk beside the image code.

	Image code	Valence (<i>M</i> ±SE)	Arousal (M±SE)	Threat (M±SE)
Firearms				
Aimed handguns	fht1001	5.57 (±0.29)	5.86 (±0.25)	5.64 (±0.40)
Ex 1: High threat	fht1004	5.50(±0.40)	5.86 (±0.23)	6.21 (±0.30)
Ex 2: Attack	fht1005	5.71 (±0.29)	6.07 (±0.27)	6.29 (±0.30)
	fht1007	5.93 (±0.25)	6.21 (±0.21)	6.43 (±0.17)
	fht1010	5.64 (±0.29)	5.93 (±0.22)	6.43 (±0.20)
	fht1012	6.08 (±0.21)	6.38 (±0.14)	6.62 (±0.14)
	fht1015	5.64 (±0.27)	5.86 (±0.29)	6.14 (±0.29)
	fht6230*	5.36 (±0.36)	5.86 (±0.27)	6.14 (±0.25)
	fht6260*	5.69 (±0.29)	5.85 (±0.30)	6.31 (±0.21)
	fht6263*	5.57 (±0.31)	5.93 (±0.29)	6.36 (±0.17)
Unarmed handguns	fmt2001	4.43 (±0.27)	4.5 (±0.23)	4.64 (±0.25)
Ex 1: Moderate threat	fmt2002	4.77 (±0.28)	4.69 (±0.29)	4.85 (±0.22)
	fmt2003	4.67 (±0.33)	4.5 (±0.29)	4.83 (±0.27)
	fmt2004	4.57 (±0.29)	4.57 (±0.25)	4.43 (±0.27)
	fmt2005	4.93 (±0.30)	4.43 (±0.36)	4.5 (±0.39)
	fmt2006	4.36 (±0.31)	4.36 (±0.25)	4.57 (±0.25)
	fmt2011	4.5 (±0.25)	4.43 (±0.29)	4.43 (±0.31)
	fmt2014	4.86 (±0.29)	4.57 (±0.23)	4.79 (±0.21)
	fmt2016	4.86 (±0.25)	4.71 (±0.24)	4.86 (±0.23)
	fmt2018	4.57 (±0.31)	4.79 (±0.24)	4.79 (±0.24)
Water pistols	fn13001	2.93 (±0.30)	3.14 (±0.31)	2.07 (±0.38)
Ex 1: Neutral	fn13002	3.14 (±0.35)	3.57 (±0.29)	2.14 (±0.38)
Ex 2: Neutral	fn13007	3.15 (±0.27)	3.69 (±0.33)	2.15 (±0.34)

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	Image code	Valence (M±SE)	Arousal (M±SE)	Threat (M±SE)
	fn13009	3.14 (±0.27)	3.36 (±0.27)	1.93 (±0.34)
	fn13012	3.07 (±0.29)	3.21 (±0.28)	2.07 (±0.35)
	fn13013	2.71 (±0.32)	3.07 (±0.34)	1.93 (±0.32)
	fn13015	3.08 (±0.33)	3.38 (±0.33)	1.85 (±0.39)
	fn13016	2.71 (±0.34)	3.14 (±0.29)	2.07 (±0.35)
	fn13017	3.07 (±0.29)	3.5 (±0.29)	2.07 (±0.34)
	fn13019	2.79 (±0.30)	3.5 (±0.33)	2 (±0.31)
Reptiles				
Attacking snakes	rht1003	5.86 (±0.31)	6.21 (±0.19)	6.43 (±0.20)
Ex 1: High threat	rht1006	5.5 (±0.34)	5.86 (±0.21)	6.14 (±0.23)
Ex 2: Attack	rht1007	5.57 (±0.27)	5.86 (±0.23)	6 (±0.26)
	rht1008	5.21 (±0.28)	5.5 (±0.23)	5.57 (±0.25)
	rht1050*	5.36 (±0.34)	6 (±0.23)	6 (±0.33)
	rht1051*	5.29 (±0.30)	5.57 (±0.27)	5.43 (±0.37)
	rht1052*	5.07 (±0.25)	5.57 (±0.20)	5.64 (±0.36)
	rht1070*	5.29 (±0.27)	5.5 (±0.23)	5.71 (±0.24)
	rht1114*	5.36 (±0.25)	5.86 (±0.21)	6.07 (±0.22)
	rht1120*	5.43 (±0.31)	5.43 (±0.39)	6 (±0.31)
Passive snake	rmt1040	4.43 (±0.42)	4.86 (±0.35)	4.64 (±0.39)
Ex 1: Moderate threat	rmt1101	4.79 (±0.37)	4.43 (±0.25)	4.71 (±0.34)
	rmt2001	3.57 (±0.47)	3.86 (±0.36)	3.86 (±0.44)
	rmt2002	4.5 (±0.39)	4.43 (±0.31)	4.57 (±0.40)
	rmt2011	4.57 (±0.34)	5 (±0.23)	4.36 (±0.43)
	rmt2015	3.86 (±0.36)	4.5 (±0.17)	4.14 (±0.33)
	rmt2016	4.5 (±0.36)	5.07 (±0.25)	4.79 (±0.30)
	rmt2017	4.57 (±0.34)	4.79 (±0.28)	4.43 (±0.34)
	rmt2023	4.43 (±0.34)	4.64 (±0.23)	4.64 (±0.36)
	rmt2024	3.79 (±0.35)	4.29 (±0.24)	4.14 (±0.39)
Turtles	rn13002	2.43 (±0.25)	2.79 (±0.33)	1.93 (±0.27)
Ex 1: Neutral	rn13004	2 (±0.35)	2.79 (±0.45)	2.21 (±0.38)
Ex 2: Neutral	rn13005	2.71 (±0.35)	3.14 (±0.38)	2.5 (±0.43)
	rn13006	2.71 (±0.35)	2.79 (±0.33)	1.71 (±0.34)

	Image code	Valence (M±SE)	Arousal (M±SE)	Threat (M±SE)
	rn13007	2.29 (±0.29)	3 (±0.36)	1.71 (±0.24)
	rn13008	2.57 (±0.40)	3.21 (±0.39)	1.86 (±0.27)
	rn13010	2.64 (±0.36)	2.93 (±0.37)	1.86 (±0.31)
	rn13011	2.36 (±0.27)	2.79 (±0.35)	1.93 (±0.29)
	rn13014	2.07 (±0.32)	3.07 (±0.53)	1.93 (±0.37)
	rn13016	2 (±0.26)	2.79 (±0.45)	1.79 (±0.3)
Humans				
Severe injury	hht2001	6.64 (±0.13)	6.21 (±0.19)	5.29 (±0.34)
Ex 1: High threat	hht2003	6.71 (±0.13)	6.29 (±0.24)	4.29 (±0.42)
	hht3015	6.86 (±0.10)	6.57 (±0.14)	5.14 (±0.40)
	hht3016	6.64 (±0.13)	6.21 (±0.21)	5.14 (±0.25)
	hht3120*	6.79 (±0.11)	6.14 (±0.18)	5 (±0.35)
	hht3130*	6.57 (±0.14)	6.21 (±0.24)	4.93 (±0.32)
	hht3140*	6.71 (±0.13)	6.21 (±0.21)	5.14 (±0.27)
	hht3213*	6.50 (±0.20)	6.07 (±0.25)	4.71 (±0.41)
	hht3261*	6.79 (±0.11)	6.29 (±0.22)	4.71 (±0.51)
	hht3400*	6.86 (±0.10)	6.43 (±0.23)	4.86 (±0.47)
Non-severe injury	hmt1023	6.64 (±0.13)	6.21 (±0.19)	5.29 (±0.34)
Ex 1: Moderate threat	hmt1024	6.71 (±0.13)	6.29 (±0.24)	4.29 (±0.42)
	hmt1025	6.50 (±0.14)	6.50 (±0.14)	4.79 (±0.43)
	hmt1027	5.93 (±0.22)	6.00 (±0.21)	5.14 (±0.23)
	hmt1029	6.64 (±0.13)	6.64 (±0.17)	4.93 (±0.46)
	hmt1034	6.43 (±0.17)	6.21 (±0.21)	5.21 (±0.33)
	hmt1041	6.07 (±0.13)	5.71 (±0.22)	4.43 (±0.31)
	hmt1046	6.64 (±0.13)	6.14 (±0.21)	4.71 (±0.34)
	hmt2001*	6.57 (±0.14)	6.00 (±0.26)	5.21 (±0.42)
	hmt2003*	6.93 (±0.07)	6.64 (±0.17)	5.07 (±0.44)
Non-injured humans	hnl2026	3.50 (±0.27)	3.21 (±0.28)	1.93 (±0.29)
Ex 1: Neutral	hnl2036	2.71 (±0.24)	2.93 (±0.29)	1.86 (±0.29)
	hnl2102*	3.36 (±0.25)	3.00 (±0.26)	1.93 (±0.25)
	hnl2359*	2.93 (±0.32)	2.86 (±0.31)	1.79 (±0.30)
	hnl2381*	2.79 (±0.24)	3.29 (±0.22)	2.14 (±0.25)

Code	Valence (M±SE)	Arousal (M±SE)	Threat (M±SE)
hnl2382*	2.21 (±0.19)	3.21 (±0.43)	1.64 (±0.23)
hnl2383*	3.64 (±0.27)	3.64 (±0.25)	2.07 (±0.32)
hn12390*	2.71 (±0.35)	2.43 (±0.23)	1.86 (±0.27)
hn12593*	2.36 (±0.32)	2.79 (±0.33)	1.93 (±0.34)
hnl2594*	2.64 (±0.23)	2.93 (±0.37)	2.14 (±0.36)

APPENDIX E: Analysis of initial affective ratings for Experiments 1 and 2

Assumption checks indicated that initial affective ratings collected for Experiments 1 and 2 did not follow a normal distribution (Digital Appendix B). Nonparametric methods were used to analyse these affective ratings. Three separate 3(Stimulus type: firearm, reptile, human) x 3(Threat level: high threat, moderate threat, neutral) Friedman ANOVAs was performed on valence, arousal and threat ratings. Kendall's Coefficient of Concordance (W) indexed the effect size of the relevant test. Wilcoxon signed-rank tests with Bonferroni-corrections ($\alpha = .002$) were utilised for posthoc comparisons between image conditions. The Friedman ANOVAs for valence $(\chi^2 (8) = 99.95, p < .001, W = .89)$, arousal $(\chi^2 (8) = 92.9, p < .001, W = .83)$ and threat $(\chi^2 (8) = 94.35, p < .001, W = .84)$ ratings each reached significance. Within their respective stimulus categories attacking snakes and aimed handguns were rated as the most unpleasant, arousing and threatening reptiles and firearms, followed by moderate threat stimuli (i.e., non-attacking snakes, unarmed handguns), and then neutral stimuli (i.e., turtles, water pistols; Figure E.1). Ratings of valence, arousal and threat were approximately equal for images of severely injured humans and humans with nonsevere injury. Both types of human injury were also rated as significantly more unpleasant, arousing and threatening than non-injured humans.

Injury images for Experiment 1

Initial ratings were used to determine the most appropriate stimuli for denoting high and moderate threat for images of injured humans in Experiment 1. Twenty images from four injury categories were included in the initial image task; sports injuries, conscious people with obvious injuries, injury to specific body parts, and severely injured people who were dead or unconscious. Ratings of these stimuli by the 14 volunteers were analysed in a similar manner to firearm, reptile and human stimuli



Figure E.1. Initial ratings of valence, arousal and threat for 30 firearm, 30 reptile and 30 human images. Colourings for high threat, moderate threat and neutral images are shown to the right. Differences below the Bonferroni-corrected level of significance (α = .002) are indicated by double asterisks.

(Bonferroni-corrected $\alpha = .01$). Three non-parametric 4(Injury type: Sports-related, Alert/awake, Body-part, Severe) Friedman ANOVAs were performed on valence, arousal and threat ratings for the 80 injury images. The Friedman ANOVAs for valence (χ^2 (3) = 39.56, *p* < .001, *W* = .94), arousal (χ^2 (3) = 15.52, *p* < .001, *W* = .44) and threat $(\chi^2 (3) = 39.17, p < .001, W = .93)$ ratings each reached significance. The images of severe injury was rated as the most unpleasant and arousing type of injury, followed by injured body parts and alert injured humans, and then images of sport-related injuries (Table E.1, all *p*s < .001). Images of severe injury were also judged as significantly more threatening than images of injured body parts, alert injured humans and sports injuries (all *p*s = .002). Images of alert injured humans (*p* = .03) and injured body parts (*p* = .05) were both rated as more threatening than those showing sports injuries as well, however neither difference reached the Bonferroni-corrected level of significance.

Table E.1. Mean and median ratings of valence, arousal and threat for the four types of injury images shown to volunteers during initial ratings of images selected for *Experiment 1 (2 d.p.)*.

	Injury type				
-	Sports injury	Non-severe,	Body-parts	Severe,	
	Sports injury	conscious injury		unconscious injury	
Valence					
$M(\pm SE)$	5.35 (±0.11)	6.03 (±0.1)	6.28 (±0.12)	6.68 (±0.08)	
Mdn (IQR)	5.23 (5.05-5.65)	6.1 (5.85-6.25)	6.23 (6.05-6.7)	6.78 (6.6-6.85)	
Arousal					
$M(\pm SE)$	5.23 (±0.11)	5.71 (±0.13)	5.96 (±0.16)	6.38 (±0.13)	
Mdn (IQR)	5.1 (4.9-5.65)	5.68 (5.2-6.15)	5.88 (5.55-6.5)	6.55 (6.05-6.8)	
Threat					
$M(\pm SE)$	4.15 (±0.17)	4.53 (±0.21)	4.59 (±0.28)	5.22 (±0.25)	
Mdn (IQR)	4.08 (3.9-4.6)	4.68 (4-4.95)	4.63 (4.15-5.4)	5.23 (4.4-5.95)	

APPENDIX F: Average ERP waveforms for overall, female and male groupings in Experiments 1, 2 and 3



- Non-injured humans
- **Water pistols —** Turtles














Experiments 2 and 3: Stimulus-locked ERP components

















Experiments 2 and 3: The CRN



- Aimed HGs/Unarmed
- Aimed HGs/Injury
- = Aimed HGs/Sleeping
- Unarmed/Sleeping
- Unarmed/Injury
- Injury/Sleeping
- Injury/Aimed HG Injury/Unarmed
- Sleeping/Injury
- Sleeping/Unarmed
- Sleeping/Aimed HG





Experiment 2, 21 Birth control females,











APPENDIX G: Linear mixed effects analysis procedure

In psychological research the use of statistical methods that incorporate random factors has increased in recent years (Baayen, Davidson, & Bates, 2008; Judd, Westfall, & Kenny, 2012; Kahn, 2011; Tremblay & Newman, 2015). An advantage of linear mixed effects analysis for EEG data is that normal individual variation in ERP modulation can be allowed for by classifying participants as a random factor. This is particularly relevant in the present research given the focus on sex-specific variation. The default lmer unstructured covariance was left on for all analyses in the present research. To confirm the necessity of the random intercept the rand function from lmerTest was applied to the base and final model for each dataset (Kuznetsova et al., 2016). This function tests the difference between the designated model and one without a random intercept, the null model, with a chi-square statistic. P-values are not provided in lmer output due to the unreliability of the resultant degrees of freedom. These degrees of freedom, however, can be estimated using Satterthwaite or Kenward-Roger approximations with the R package lmerTest (Kuznetsova et al., 2016). The Kenward-Roger approximation is more conservative and generally more appropriate for repeatedmeasures design (Arnau, Bendayan, Blanca, & Bono, 2014; Kenward & Roger, 2009; Kowalchuk, Keselman, Algina, & Wolfinger, 2004), however this method is prone to dramatic inflations in computation time. All parameter information during model estimation was calculated using the Satterthwaite approximation, excluding that for the final model in behavioural and ERP data. This approximation method was also applied during the use of the step function to expedite computation times during backwards elimination (Kuznetsova et al., 2016).

APPENDIX H: Comparison of null and base models for reaction time and ERP data in Experiments 1, 2 and 3

Values for the AIC, BIC and loglikelihood of each null and base model are rounded to the nearest whole number.

	AIC	BIC	loglikelihood	Chi-square statistic and <i>p</i> -value
The N1				
Null model	16365	16378	-8181	
Base model	11046	11064	-5520	vs. null: $\chi^2(1) = 5325, p < .001$
The EPN				
Null model	15537	15549	-7767	
Base model	14119	14137	-7057	vs. null: $\chi^2(1) = 1423, p < .001$
The N2				
Null model	21107	21119	-10551	
Base model	18213.6	18232.5	-9104	vs. null: $\chi^2(1) = 2898, p < .001$
The P3b				
Null model	27941	27954	-13968	
Base model	25807	25827	-12901	vs. null: $\chi^2(1) = 2139, p < .001$
The LPP				
Null model	17985	17997	-8990	
Base model	15763	15782	-7879	vs. null: $\chi^2(1) = 1781, p < .001$

Experiment 1

Experiment 2

	AIC	BIC	loglikelihood	Chi-square statistic and <i>p</i> -value
Reaction times				
Null model	-460	-451	232	
Base model	-1069	-1056	538	vs. null: $\chi^2(1) = 614, p < .001$
The anterior N1				
Null model	14974	14886	-7485	
Base model	10628	10646	-5311	vs. null: $\chi^2(1) = 4352, p < .001$
The occipital N1				
Null model	7056	7066	-3526	
Base model	5559	5575	-2776	vs. null: $\chi^2(1) = 1502, p < .001$
The EPN				
Null model	14085	114097	-7040	

	AIC	BIC	loglikelihood	Chi-square statistic and <i>p</i> -value
Base model	13307	13325	-6651	vs. null: $\chi^2(1) = 783, p < .001$
The MPN				
Null model	14473	14485	-7235	
Base model	14146	14164	-7070	vs. null: $\chi^2(1) = 332, p < .001$
The LPP				
Null model	17356	17369	-8676	
Base model	15509	15527	-7751	vs. null: $\chi^2(1) = 1853, p < .001$
The CRN				
Null model	11748	11761	-5872	
Base model	8742	8760	-4368	vs. null: $\chi^2(1) = 3013, p < .001$

Experiment 3

	AIC	BIC	loglikelihood	Chi-square statistic and <i>p</i> -value
Reaction times				
Null model	-251	-242	127	
Base model	-766	-752	386	vs. null: $\chi^2(1) = 520, p < .001$
The anterior N1				
Null model	15869	15882	-7933	
Base model	10122	10141	-5058	vs. null: $\chi^2(1) = 5651, p < .001$
The occipital N1				
Null model	6928	6938	-3462	
Base model	5384	5399	-2689	vs. null: $\chi^2(1) = 1508, p < .001$
The EPN				
Null model	12903	12915	-6450	
Base model	12119	12137	-6157	vs. null: $\chi^2(1) = 789, p < .001$
The MPN				
Null model	13609	13620	-6802	
Base model	12880	12898	-6437	vs. null: $\chi^2(1) = 733, p < .001$
The LPP				
Null model	15702	15714	-7849	
Base model	14475	14493	-7234	vs. null: $\chi^2(1) = 1233, p < .001$
The CRN				
Null model	10963	10976	-5480	
Base model	8001	8020	-3997	vs. null: $\chi^2(1) = 2968, p < .001$

Experiment 1: The N1

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	11046	11064	-5520	
Model 1				
Full model	10813	12182	-5189	vs. base: $\chi^2(215) = 662.34^{***}$
Reduced model	10527	10803	-5219	vs. base: $\chi^2(41) = 600.77 ***$
Model 2				
Full (Neuroticism)	10968	13693	-5050	vs. full: $\chi^2(216) = 227.13^{**}$
Full (TAS-20)	10953	13678	-5042	vs. full: $\chi^2(216) = 292.43^{***}$
Full (STAI-S)	10935	13660	-5033	vs. full: $\chi^2(216) = 310.44^{***}$
Reduced (TAS-20)	10374	10989	-5089	vs. reduced: $\chi^2(54) = 260.87^{***}$
Reduced (STAI-S)	10363	10979	-5084	vs. reduced: $\chi^2(54) = 271.29^{***}$
Model 3				
Full (TAS-20, STAI-S)	11291	16729	-4780	vs. TAS-20: $\chi^2(432) = 525.66^{**}$
				vs. STAI-S: $\chi^2(432) = 507.66^{**}$
Reduced (TAS-20, STAI-S)	10281	10990	-5027	vs. TAS-20: $\chi^2(29) = 144.76^{***}$
				vs. STAI-S: $\chi^2(15) = 112.63^{***}$
Final model				
TAS-20, STAI-T scores + REML	10886	11595	-5330	

p < .05*, p < .01 **, p < .001***

Experiment 1: The EPN

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	14119	14137	-7057	
Model 1				
Full model	12105	12963	-5907	vs. base: $\chi^2(143) = 2300.1^{***}$
Reduced model	11933	12145	-5931	vs. base: $\chi^2(33) = 2251.9^{***}$
Model 2				
Full (PSWQ)	12184	13888	-5802	vs. full: $\chi^2(144) = 208.69^{**}$
Full (STAI-T)	12189	13893	-5805	vs. full: $\chi^2(144) = 203.74 * * *$
Full (STAI-S)	12179	13882	-5800	vs. full: $\chi^2(144) = 214.05^{***}$
Reduced (PSWQ)	11817	12076	-5865	vs. reduced: $\chi^2(8) = 131.92^{***}$
Reduced (STAI-T)	11807	12065	-5859	vs. reduced: $\chi^2(8) = 142.62^{***}$
Reduced (STAI-S)	11817	12075	-5864	vs. reduced: $\chi^2(8) = 132.63^{***}$

	AIC	BIC	loglikelihood	Chi-square statistic
Model 3				
Full (STAI-S, PSWQ)	12448	15844	-5646	vs. STAI-S: $\chi^2(288) = 306.47$, $p = .21$
Full (STAI-S, STAI-T)	12345	15740	-5595	vs. STAI-S: $\chi^2(288) = 409.85^{***}$
Final model				
STAI-S scores + REML	11901	12160	-5907	

 $p < .05^*, p < .01^{**}, p < .001^{***}$

Experiment 1: The N2

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	18214	18233	-9104	
Model 1				
Full model	14150	15521	-6857	vs. base: $\chi^2(215) = 4494.1^{***}$
Reduced model	13893	14258	-6888	vs. base: $\chi^2(55) = 4430.9^{***}$
Model 2				
Full (Neuroticism)	14308	17039	-6720	vs. full: $\chi^2(216) = 273.45^{**}$
Full (TAS-20)	14329	17060	-6730	vs. full: $\chi^2(216) = 252.65^*$
Reduced (Neuroticism)	13756	14511	-6758	vs. reduced: $\chi^2(74) = 283.78^{***}$
Final model				
Neur scores + REML	14288	15043	-7024	

 $p < .05^*, p < .01^{**}, p < .001^{***}$

Experiment 1: The P3b

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	25807	25827	-12901	
Model 1				
Full model	22865	24294	-11215	vs. base: $\chi^2(215) = 3371.8^{***}$
Reduced model	22620	23039	-11246	vs. base: $\chi^2(61) = 3309^{***}$
Model 2				
Full (PSWQ)	23012	25857	-11072	vs. full: $\chi^2(216) = 284.74^{**}$
Reduced (PSWQ)	22506	23358	-11123	vs. reduced: $\chi^2(66) = 245.56^{***}$
Final model				
PSWQ scores + REML	22451	23451	-11315	
. 05* . 01 ** . 001***				

 $p < .05^*, p < .01^{**}, p < .001^{***}$

Experiment 1: The LPP

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	15763	15782	-7879	

	AIC	BIC	loglikelihood	Chi-square statistic
Model 1				
Full model	14210	15578	-6887	vs. base: $\chi^2(215) = 1983.2^{***}$
Reduced model	13942	14319	-6911	vs. base: $\chi^2(57) = 1935^{***}$
Model 2				
Full (PSWQ)	14340	17065	-6736	vs. full: $\chi^2(216) = 302.39^{***}$
Full (Neuroticism)	14358	17084	-6745	vs. full: $\chi^2(216) = 283.37^{**}$
Full (STAI-T)	14324	17049	-6728	vs. full: $\chi^2(216) = 318.34^{***}$
Reduced (PSWQ)	13792	14433	-6794	vs. reduced: $\chi^2(42) = 233.61^{***}$
Reduced (STAI-T)	13784	14374	-6798	vs. reduced: $\chi^2(34) = 226.53^{***}$
Model 3				
Full (STAI-T, PSWQ)	14525	19963	-6396	vs. STAI-T: $\chi^2(432) = 662.84^{***}$
Full (STAI-T, Neuroticism)	14644	20083	-6456	vs. STAI-T: $\chi^2(432) = 543.05^{***}$
Reduced (STAI-T, PSWQ)	13437	14643	-6527	vs. STAI-T: $\chi^2(98) = 542.41^{***}$
Final model				
STAI-T, PSWQ scores + REML	14627	15833	-7122	

p < .05*, p < .01 **, p < .001***

Experiment 2: Reaction times

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	-460	-451	232	
Model 1				
Full model	-1669	-1516	868	vs. base: $\chi^2(31) = 661.5^{***}$
Reduced model	-1676	-1541	868	vs. base: $\chi^2(27) = 660.43^{***}$
Model 2				
Full (Neuroticism)	-1656	-1360	894	vs. full: $\chi^2(32) = 51.14^*$
Full (TAS-20)	-1663	-1367	898	vs. full: $\chi^2(32) = 58.54^{**}$
Reduced (TAS-20)	-1697	-1527	887	vs. reduced: $\chi^2(8) = 37.58^{***}$
Model 3				
Full (TAS-20, Neur)	-1631	-1048	946	vs. TAS-20: $\chi^2(64) = 96.04 **$
				vs. Neur: $\chi^2(64) = 103.45^{**}$
Reduced (TAS-20, Neur)	-1709	-1539	893	vs. TAS-20: χ2(35) = 51.43*
Final model				
TAS-20, Neur scores + REML	-1369	-1198	722	
<i>p</i> < .05*, <i>p</i> < .01 **, <i>p</i> < .001***				

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	10628	10646	-5311	
Model 1				
Full model	10575	11793	-5094	vs. base: $\chi^2(191) = 434.13^{***}$
Reduced model	10311	10225	-5117	vs. base: $\chi^2(36) = 388.06^{***}$
Model 2				
Full (PSWQ)	10734	13157	-4981	vs. full: $\chi^2(192) = 225.34^*$
Full (STAI-T)	10714	13137	-4971	vs. full: $\chi^2(192) = 245.31^{**}$
Full (STAI-S)	10713	13136	-4971	vs. full: $\chi^2(192) = 246.09^{**}$
Reduced (STAI-T)	10166	10593	-5015	vs. reduced: $\chi^2(24) = 175.47^{***}$
Reduced (STAI-S)	10184	10580	-5029	vs. reduced: $\chi^2(29) = 203.33^{***}$
Final model				
STAI-T scores + REML	10535	10962	-5199	
STAI-T scores + REML	10535	10962	-5199	

Experiment 2: The anterior N1

 $p < .05^*, p < .01^{**}, p < .001^{***}$

Experiment 2: The occipital N1

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	5559	5575	-2777	
Model 1				
Full model	5276	5617	-2572	vs. base: $\chi^2(63) = 408.74^{***}$
Reduced model	5248	5433	-2588	vs. base: $\chi^2(33) = 377.5^{***}$
Model 2				
Full (PSWQ)	5299	5969	-2520	vs. full: $\chi^2(64) = 105.14^{***}$
Full (Neuroticism)	5226	5896	-2483	vs. full: $\chi^2(64) = 178.26^{***}$
Full (STAI-T)	5317	5987	-2529	vs. full: $\chi^2(64) = 87.27^*$
Reduced (Neuroticism)	5119	5475	-2490	vs. reduced: $\chi^2(33) = 194.85^{***}$
Final model				
Neur scores + REML	5338	5694	-2600	

p < .05*, p < .01 **, p < .001***

Experiment 2: The EPN

AIC	BIC	loglikelihood	Chi-square statistic
13307	13325	-6651	
11898	12665	-5819	vs. base: $\chi^2(127) = 1662.8^{***}$
11719	11861	-5836	vs. base: $\chi^2(21) = 1629.8^{***}$
	AIC 13307 11898 11719	AIC BIC 13307 13325 11898 12665 11719 11861	AIC BIC loglikelihood 13307 13325 -6651 11898 12665 -5819 11719 11861 -5836

	AIC	BIC	loglikelihood	Chi-square statistic
Model 2				
Full (Neuroticism)	11921	13442	-5703	vs. full: $\chi^2(128) = 233.16^{***}$
Reduced (Neuroticism)	11578	11849	-5743	vs. reduced: $\chi^2(22) = 16.32^{***}$
Final model				
Neur scores + REML	11754	12055	-5826	
p < .05*, p < .01 **, p < .001***				

Experiment 2: The MPN

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	14146	14164	-7070	
Model 1				
Full model	13062	13828	-6401	vs. base: $\chi^2(127) = 1338.4^{***}$
Reduced model	12898	13063	-6421	vs. base: $\chi^2(25) = 1298^{***}$
Model 2				
Full (TAS-20)	13138	14659	-6311	vs. full: $\chi^2(128) = 179.99^{**}$
Full (Neuroticism)	13153	14674	-6318	vs. full: $\chi^2(128) = 165^*$
Reduced (TAS-20)	12760	12949	-6348	vs. reduced: $\chi^2(4) = 146^{***}$
Final model				
TAS-20 scores + REML	12817	13006	-6377	

 $p < .05^*, p < .01^{**}, p < .001^{***}$

Experiment 2: The LPP

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	15509	15527	-7751	
Model 1				
Full model	13778	15000	-6695	vs. base: $\chi^2(191) = 2113^{***}$
Reduced model	13515	13723	-6725	vs. base: $\chi^2(30) = 2053.4^{***}$
Model 2				
Full (PSWQ)	13783	16216	-6506	vs. full: $\chi^2(192) = 378.46^{***}$
Full (Neuroticism)	13843	16275	-6535	vs. full: $\chi^2(192) = 318.86^{***}$
Full (STAI-T)	13864	16296	-6546	vs. full: $\chi^2(192) = 297.69^{***}$
Full (STAI-S)	13922	16654	-6575	vs. full: $\chi^2(192) = 239.94^*$
Reduced (PSWQ)	13278	13637	-6582	vs. reduced: $\chi^2(24) = 285.3^{***}$
Reduced (Neur)	13309	13700	-6593	vs. reduced: $\chi^2(29) = 263.95^{***}$
Reduced 1 (STAI-T)	13315	13788	-6583	vs. reduced: $\chi^2(42) = 283.64^{***}$
Model 3				
Full (PSWQ, STAI-T)	14010	18862	-6235	vs. reduced: $\chi^2(384) = 622.08^{***}$

	AIC	BIC	loglikelihood	Chi-square statistic
Reduced (PSWQ, STAI-T)	2785	3023	-1347	vs. reduced: $\chi^2(28) = 77.03^{***}$
Final model				
PSWQ scores, STAI-T scores + REML	13724	14442	-6748	
<i>p</i> < .05*, <i>p</i> < .01 **, <i>p</i> < .001***				

Experiment 2: The CRN

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	8742	8760	-4368	
Model 1				
Full model	8664	9882	-4138	vs. base: $\chi^2(191) = 459.3^{***}$
Reduced model	8409	8729	-4154	vs. base: $\chi^2(48) = 428.69^{***}$
Model 2				
Full (Neuroticism)	8776	11199	-4002	vs. full: $\chi^2(192) = 272.51^{***}$
Full (TAS-20)	8755	11178	-3992	vs. full: $\chi^2(192) = 293.16^{***}$
Full (STAI-T)	8703	11126	-3966	vs. full: $\chi^2(192) = 345.23^{***}$
Full (STAI-S)	8765	11189	-3997	vs. full: $\chi^2(192) = 282.85^{***}$
Reduced (STAI-T)	8409	8729	-4154	vs. reduced: $\chi^2(48) = 291.02^{***}$
Final model				
STAI-T scores + REML	8769	9390	-4285	
0.54 04.44 004.444				

 $p < .05 \ast, p < .01 \ \ast \ast, p < .001 \ast \ast \ast$

Experiment 3: Reaction times

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	-766	-752	386	
Model 1				
Full model	-1435	-1283	752	vs. base: $\chi^2(31) = 731.21^{***}$
Reduced model	-1441	-1326	748	vs. base: $\chi^2(23) = 721.64^{***}$
Model 2				
Full (PSWQ)	-1382	-1087	757	vs. full: $\chi^2(32) = 10.77, p = .99$
Full (Neuroticism)	-1400	-1106	766	vs. full: $\chi^2(32) = 29.28, p = .61$
Full (TAS-20)	-1409	-1115	771	vs. full: $\chi^2(32) = 38.22, p = .21$
Full (STAI-T)	-1340	-1106	766	vs. full: $\chi^2(32) = 28.87, p = .63$
Full (STAI-S)	-1397	-1103	765	vs. full: $\chi^2(32) = 26.19, p = .76$
Final model				
REML	-1281	-1165	667	

 $p < .05^{*}, p < .01^{**}, p < .001^{***}$

Experiment 3: The anterior N1

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	10122	10141	-5058	
Model 1				
Full model	9907	11119	-4759	vs. base: $\chi^2(191) = 586.07^{***}$
Reduced model	9665	10021	-4776	vs. base: $\chi^2(54) = 552.57^{***}$
Model 2				
Full (STAI-S)	10013	12425	-4620	vs. full: $\chi^2(192) = 287.31^{***}$
Reduced (STAI-S)	9487	9974	-4665	vs. reduced: $\chi^2(19) = 226.01^{***}$
Final model				
STAI-S scores + REML	9817	10305	-4830	

p < .05*, p < .01 **, p < .001***

Experiment 3: The occipital N1

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	5384	5399	-2689	
Model 1				
Full model	5169	5509	-2519	vs. base: $\chi^2(63) = 340.4^{***}$
Reduced model	5129	5315	-2529	vs. base: $\chi^2(33) = 320.33^{***}$
Model 2				
Full (PSWQ)	5200	5870	-2470	vs. full: $\chi^2(64) = 97.14^*$
Full (Neuroticism)	5201	5871	-2471	vs. full: $\chi^2(64) = 95.77^*$
Reduced (Neuroticism)	5080	5363	-2485	vs. reduced: $\chi^2(19) = 87.56^{***}$
Final model				
Neur scores + REML	5222	5506	-2556	

 $p = 0.05^{*}, p < .01^{**}, p < .001^{***}$

Experiment 3: The EPN

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	12119	12137	-6157	
Model 1				
Full model	10710	11466	-5225	vs. base: $\chi^2(127) = 1663.6^{***}$
Reduced model	10567	10794	-5245	vs. base: $\chi^2(36) = 1624.3^{***}$
Model 2				
Full (PSWQ)	10772	12274	-5128	vs. full: $\chi^2(128) = 193.48^{***}$
Full (TAS-20)	10800	12302	-5142	vs. full: $\chi^2(128) = 165.33^*$
Full (STAI-S)	10662	12163	-5073	vs. full: $\chi^2(128) = 303.89^{***}$
Reduced (PSWQ)	10480	10986	-5153	vs. reduced: $\chi^2(7) = 258.12^{***}$

	AIC	BIC	loglikelihood	Chi-square statistic
Reduced (STAI-S)	10323	10591	-5116	vs. reduced: $\chi^2(48) = 182.99^{***}$
Model 3				
Full (STAI-S, PSWQ)	10930	13921	-4951	vs. STAI-S: $\chi^2(36) = 384.71^{***}$
Reduced (STAI-S, PSWQ)	10192	10448	-5052	vs. STAI-S: $\chi^2(36) = 384.71^{***}$
Final model				
STAI-S, PSWQ scores + REML	10325	10581	-5119	

p < .05*, p < .01 **, p < .001***

Experiment 3: The MPN

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	12880	12898	-6437	
Model 1				
Full model	11406	12143	-5577	vs. base: $\chi^2(123) = 1719.9^{***}$
Reduced model	11347	11587	-5633	vs. base: $\chi^2(38) = 1609^{***}$
Model 2				
Full (STAI-S)	11490	12951	-5495	vs. full: $\chi^2(124) = 164.17^{**}$
Reduced (STAI-S)	11161	11412	-5538	vs. reduced: $\chi^2(2) = 190.29^{***}$
Final model				
STAI-S scores + REML	11219	11470	-5566	
n < 05* $n < 01 ** n < 001***$				

p < .05*, p < .01 **, p < .001***

Experiment 3: The LPP

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	14475	14493	-7234	
Model 1				
Full model	12240	13453	-5926	vs. base: $\chi^2(191) = 2616.3^{***}$
Reduced model	12032	12363	-5963	vs. base: $\chi^2(50) = 2543.1^{***}$
Model 2				
Full (PSWQ)	12386	14798	-5807	vs. full: $\chi^2(192) = 238.92^*$
Full (STAI-T)	12317	14730	-5773	vs. full: $\chi^2(192) = 307.46^{***}$
Full (STAI-S)	12371	14784	-5800	vs. full: $\chi^2(192) = 253.34^*$
Reduced (STAI-T)	11811	12248	-5835	vs. reduced: $\chi^2(17) = 254.92^{***}$
Final model				
STAI-T scores + REML	12075	12513	-5968	
$p < .05^*, p < .01^{**}, p < .001^{***}$				

Experiment 3: The CRN

	AIC	BIC	loglikelihood	Chi-square statistic
Base model	8001	8020	-3997	
Model 1				
Full model	7859	9071	-3735	vs. base: $\chi^2(191) = 524.08^{***}$
Reduced model	7623	7923	-3763	vs. base: $\chi^2(45) = 468.29^{***}$
Model 2				
Full (STAI-S)	7970	10383	-3599	vs. full: $\chi^2(192) = 272.33^{***}$
Model 3				
Reduced (STAI-S)	7457	7957	-3648	vs. reduced: $\chi^2(32) = 229.57^{***}$
Final model				
STAI-S scores + REML	7870	8370	-3855	

 $p < .05^*, p < .01^{**}, p < .001^{***}$

	Malas	Females		
	Males	Birth control	Follicular phase	Luteal phase
Firearms				
Aimed handguns	4.66 (±0.14)	4.67 (±0.14)	4.83 (±0.21)	4.72 (±0.2)
Unarmed handguns	3.7 (±0.13)	3.77 (±0.15)	4.03 (±0.19)	4.3 (±0.18)
Water pistols	2.49 (±0.18)	2.3 (±0.16)	2.81 (±0.2)	2.81 (±0.23)
Reptiles				
Attacking snakes	3.81 (±0.24)	4.3 (±0.19)	4.58 (±0.24)	4.52 (±0.2)
Non-attacking snakes	3.18 (±0.24)	3.57 (±0.2)	4 (±0.28)	3.98 (±0.24)
Turtles	1.98 (±0.17)	1.76 (±0.15)	2.22 (±0.15)	1.94 (±0.2)
Humans				
Severe injury	5.44 (±0.11)	5.51 (±0.1)	5.31 (±0.19)	5.59 (±0.11)
Non-severe injury	5.09 (±0.1)	5.22 (±0.12)	5.15 (±0.2)	5.38 (±0.12)
Non-injured humans	2.5 (±0.2)	1.93 (±0.13)	2.45 (±0.2)	2.42 (±0.19)

APPENDIX J: Descriptive statistics of affective ratings for male and female groupings in Experiment 1 (*M*±*SE*)

Valence

Arousal

	Malas		Females	
	Wales	Birth control	Follicular phase	Luteal phase
Firearms				
Aimed handguns	4.31 (±0.22)	4.35 (±0.18)	4.19 (±0.21)	4.19 (±0.19)
Unarmed handguns	3.08 (±0.17)	3.64 (±0.14)	3.41 (±0.27)	3.35 (±0.22)
Water pistols	2.45 (±0.22)	3.12 (±0.21)	3.06 (±0.26)	3.26 (±0.26)
Reptiles				
Attacking snakes	3.94 (±0.25)	4.25 (±0.17)	4.31 (±0.22)	3.89 (±0.28)
Non-attacking snakes	3.05 (±0.25)	3.7 (±0.13)	3.82 (±0.26)	3.54 (±0.24)
Turtles	2.63 (±0.32)	2.87 (±0.25)	2.88 (±0.26)	2.96 (±0.25)
Humans				
Severe injury	4.72 (±0.2)	4.94 (±0.2)	4.51 (±0.32)	4.75 (±0.26)
Non-severe injury	4.5 (±0.18)	4.68 (±0.2)	4.27 (±0.27)	4.55 (±0.18)
Non-injured humans	1.97 (±0.17)	2.55 (±0.2)	2.67 (±0.28)	2.95 (±0.19)

	Malor	Females		
	wrates	Birth control	Follicular phase	Luteal phase
Firearms				
Aimed handguns	5.08 (±0.15)	4.91 (±0.15)	5.1 (±0.19)	5.06 (±0.15)
Unarmed handguns	3.4 (±0.25)	3.89 (±0.2)	4.15 (±0.29)	4.16 (±0.26)
Water pistols	1.47 (±0.14)	1.57 (±0.17)	1.54 (±0.14)	1.66 (±0.16)
Reptiles				
Attacking snakes	4.46 (±0.22)	4.67 (±0.21)	5.08 (±0.14)	4.71 (±0.26)
Non-attacking snakes	3 (±0.24)	3.61 (±0.25)	4.16 (±0.26)	3.98 (±0.29)
Turtles	1.29 (±0.11)	1.42 (±0.1)	1.48 (±0.2)	1.5 (±0.18)
Humans				
Severe injury	4.87 (±0.25)	5.45 (±0.11)	5.34 (±0.13)	5.36 (±0.25)
Non-severe injury	4.61 (±0.23)	5.04 (±0.15)	5.06 (±0.17)	5.17 (±0.24)
Non-injured humans	1.39 (±0.13)	1.36 (±0.12)	1.31 (±0.11)	1.42 (±0.13)

Disgust

	Molos	Females		
	Males	Birth control	Follicular phase	Luteal phase
Firearms				
Aimed handguns	4.66 (±0.2)	4.63 (±0.17)	4.99 (±0.18)	4.79 (±0.19)
Unarmed handguns	3.22 (±0.22)	3.78 (±0.21)	4.06 (±0.27)	4.07 (±0.24)
Water pistols	1.55 (±0.14)	1.65 (±0.17)	1.58 (±0.14)	1.67 (±0.16)
Reptiles				
Attacking snakes	3.69 (±0.3)	4.38 (±0.21)	4.88 (±0.16)	4.41 (±0.3)
Non-attacking snakes	2.75 (±0.25)	3.49 (±0.24)	4.09 (±0.25)	3.82 (±0.33)
Turtles	1.44 (±0.14)	1.47 (±0.11)	1.5 (±0.19)	1.53 (±0.18)
Humans				
Severe injury	5.36 (±0.14)	5.53 (±0.11)	5.49 (±0.11)	5.64 (±0.1)
Non-severe injury	4.97 (±0.13)	5.22 (±0.11)	5.21 (±0.12)	5.38 (±0.11)
Non-injured humans	1.6 (±0.15)	1.47 (±0.13)	1.43 (±0.12)	1.44 (±0.14)

APPENDIX K: Parameter information and inferential statistics for select final models in Experiments 1, 2 and 3

Parameter information for significant main effects and interactions in select final models from Experiments 1, 2 and 3. The reference parameter and estimates (β) are provided for each main effect and interaction. F-statistics are located at the top of the parameter column for each main effect and interaction.

	Parameter	β [95% CI]
Stimulus type	<i>F</i> (2, 3771) = 25.59***	
ref. Firearms	Humans	-0.02 [0.19, -0.23]
	Reptiles	0.38 [0.59, 0.18]***
Threat level	<i>F</i> (2, 3771) = 42.19***	
ref. High threat	Moderate threat	-0.38 [-0.17, -0.58]***
	Neutral	0.37 [0.57, 0.17]***
TAS-20 scores	F(1, 60) = 4.14*	
	TAS-20 scores	0.04 [0.16, -0.07]
Stim*Thr	<i>F</i> (4, 3771) = 29.66***	
ref. Firearm: High threat	Human: Moderate threat	0.36 [0.64, 0.07]*
	Human: Neutral	-0.27 [0.01, -0.56]
	Reptile: Moderate threat	0.18 [0.46, -0.11]
	Reptile: Neutral	-0.92 [-0.63, -1.2]***
Stim*Sex	<i>F</i> (6, 3771) = 3.46**	
ref. Firearm: BC female	Human: Male	-0.51 [-0.21, -0.8]***
	Human: Follicular phase	-0.05 [0.28, -0.37]
	Human: Luteal phase	-0.47 [-0.15, -0.79]**
	Reptile: Male	-0.37 [-0.08, -0.67]*
	Reptile: Follicular phase	-0.03 [0.3, -0.35]
	Reptile: Luteal phase	-0.08 [0.24, -0.4]
Thr*Sex	<i>F</i> (6, 3771) = 3.61**	
ref. High threat: BC female	Moderate threat: Male	-0.44 [-0.15, -0.73]**
	Moderate threat: Follicular	-0.14 [0.18, -0.47]
	Moderate threat: Luteal	-0.23 [0.09, -0.55]
	Neutral: Male	-0.77 [-0.48, -1.06]***
	Neutral: Follicular	-0.03 [0.29, -0.36]
	Neutral: Luteal	-0.72 [-0.4, -1.03]***

Experiment 1: The N1

	Parameter	β [95% CI]
Stim*Thr*Sex	<i>F</i> (12, 3771) = 3.88***	
ref. Firearm: HT: BC female	Human: MT: Male	0.64 [1.05, 0.23]**
	Human: MT: Follicular phase	0.07 [0.53, -0.39]
	Human: MT: Luteal phase	0.22 [0.67, -0.23]
	Human: Neutral: Male	1.07 [1.48, 0.66]***
	Human: Neutral: Follicular phase	0.27 [0.73, -0.19]
	Human: Neutral: Luteal phase	0.91 [1.35, 0.46]***
	Reptile: MT: Male	0.24 [0.65, -0.17]
	Reptile: MT: Follicular phase	0.01 [0.47, -0.45]
	Reptile: MT: Luteal phase	0.23 [0.68, -0.22]
	Reptile: Neutral: Male	0.99 [1.4, 0.58]***
	Reptile: Neutral: Follicular phase	0.44 [0.89, -0.02].
	Reptile: Neutral: Luteal phase	0.79 [1.23, 0.34]***
Stim*Thr*STAI-S	<i>F</i> (4, 3771) = 6.94***	
ref. Firearm: High threat	Human: Moderate threat	-0.05 [-0.01, -0.09]*
	Human: Neutral	0.01 [0.05, -0.03]
	Reptile: Moderate threat	-0.04 [0, -0.08]*
	Reptile: Neutral	0.04 [0.08, 0.004]*
Stim*Sex*STAI-S	<i>F</i> (6, 3771) = 7.42***	
ref. Firearm: BC female	Human: Male	-0.004 [0.04, -0.05]
	Human: Follicular phase	-0.09 [-0.04, -0.13]***
	Human: Luteal phase	0.04 [0.08, -0.01].
	Reptile: Male	-0.03 [0.01, -0.07]
	Reptile: Follicular phase	-0.05 [-0.01, -0.09]*
	Reptile: Luteal phase	0.02 [0.06, -0.02]
Thr*Sex*STAI-S	<i>F</i> (6, 3771) = 4.83***	
ref. High threat: BC female	Moderate threat: Male	-0.05 [-0.01, -0.09]*
	Moderate threat: Follicular	-0.05 [-0.01, -0.09]**
	Moderate threat: Luteal	-0.04 [-0.003, -0.08]*
	Neutral: Male	0.001 [0.04, -0.04]
	Neutral: Follicular	0.01 [0.04, -0.03]
	Neutral: Luteal	0.02 [0.06, -0.02]
Stim*Sex*TAS-20	<i>F</i> (6, 3771) = 13.24***	
ref. Firearm: BC female	Human: Male	0.04 [0.06, 0.01]**
	Human: Follicular phase	0.1 [0.13, 0.08]***
	Human: Luteal phase	0.06 [0.08, 0.03]***
	Reptile: Male	0.04 [0.07, 0.02]***
	Reptile: Follicular phase	0.1 [0.13, 0.07]***
	Parameter	β [95% CI]
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	Reptile: Luteal phase	0.05 [0.07, 0.03]***
Stim*STAI-S*TAS-20	<i>F</i> (2, 3771) = 8.15***	
ref. Firearm	Humans	0.002 [0.002, 0.001]***
	Reptiles	0.001 [0.002, -0.00005].
Stim*Thr*Sex*STAI-S	<i>F</i> (12, 3771) = 5.19***	
ref. Firearm: HT: BC female	Human: MT: Male	-0.01 [0.05, -0.06]
	Human: MT: Follicular phase	0.06 [0.11, 0.01]*
	Human: MT: Luteal phase	-0.05 [0.01, -0.1]
	Human: Neutral Male	-0.05 [0.004, -0.1].
	Human: Neutral Follicular phase	0.05 [0.1, -0.004].
	Human: Neutral Luteal phase	-0.08 [-0.02, -0.14]**
	Reptile: MT: Male	0.01 [0.06, -0.05]
	Reptile: MT: Follicular phase	0.05 [0.1, 0.004]*
	Reptile: MT: Luteal phase	0.05 [0.11, -0.002].
	Reptile: Neutral: Male	-0.05 [0.01, -0.1].
	Reptile: Neutral: Follicular phase	-0.05 [-0.002, -0.1]*
	Reptile: Neutral: Luteal phase	-0.05 [0.01, -0.11].
.1 , $p < .05$ *, $p < .01$ **, $p < .001$ ***	Stim: Stimulus type Thr: Threat level (H	HT = High threat, MT = Moderate threat)

-	-	-	-		-
				STAI-S = state anxiety scores	TAS-20 = alexithymia scores

Experiment 1: The N2

	Parameter	β [95% CI]
Stimulus type	<i>F</i> (2, 3812) = 1788.82***	
ref. Firearms	Humans	-2.409 [-2.04, -2.78]***
	Reptiles	0.04 [0.4, -0.33]
Threat level	<i>F</i> (2, 3812) = 230.09***	
ref. High threat	Moderate threat	0.98 [1.31, 0.65]***
	Neutral	-0.09 [0.24, -0.42]
Sex	F(3, 66) = 3.86*	
ref. BC females	Males	3.32 [4.93, 1.71]***
	Follicular phase	1.54 [3.18, -0.1].
	Luteal phase	1.94 [3.56, 0.33]*
Stim*Thr	<i>F</i> (4, 3812) = 41.78***	
ref. Firearm: High threat	Human: Moderate threat	-0.71 [-0.25, -1.18]**
	Human: Neutral	-1.43 [-0.96, -1.89]***
	Reptile: Moderate threat	-1.23 [-0.76, -1.69]***
	Reptile: Neutral	-0.68 [-0.21, -1.14]**

	Parameter	β [95% CI]
Stim*Sex	<i>F</i> (6, 3812) = 5.75***	
ref. Firearm BC female	Human: Male	-0.21 [0.28, -0.7]
	Human: Follicular phase	-0.29 [0.21, -0.78]
	Human: Luteal phase	0.02 [0.51, -0.47]
	Reptile: Male	-0.38 [0.11, -0.87]
	Reptile: Follicular phase	0.24 [0.74, -0.26]
	Reptile: Luteal phase	-0.05 [0.44, -0.54]
Thr*Sex	<i>F</i> (6, 3812) = 4.07***	
ref. High threat: BC female	Moderate threat: Male	-1.46 [-0.97, -1.94]***
	Moderate threat: Follicular phase	-0.08 [0.41, -0.58]
	Moderate threat: Luteal phase	-0.37 [0.12, -0.86]
	Neutral: Male	-0.96 [-0.47, -1.45]***
	Neutral: Follicular phase	-0.06 [0.44, -0.56]
	Neutral: Luteal phase	-0.35 [0.14, -0.84]
Stim* Sag	<i>F</i> (2, 3812) = 7.34***	
ref. Firearm: Central	Human: Central-parietal	0.37 [0.56, 0.17]***
	Reptile: Central-parietal	0.1 [0.3, -0.09]
Stim*Cor	<i>F</i> (4, 3812) = 3.59**	
ref. Firearm: Left hemisphere	Human: Midline	-0.34 [-0.1, -0.57]**
	Human: Right hemisphere	0.06 [0.3, -0.17]
	Reptile: Midline	-0.04 [0.19, -0.28]
	Reptile: Right hemisphere	0.14 [0.38, -0.1]
Stim*Neur	<i>F</i> (2, 3812) = 8.66***	
ref. Firearms	Humans	-0.02 [-0.002, -0.05]*
	Reptiles	-0.01 [0.02, -0.03]
Stim*Thr*Sex	<i>F</i> (12, 3812) = 2.57**	
ref. Firearm: HT: BC female	Human: MT: Male	1.49 [2.18, 0.8]***
	Human: MT: Follicular phase	0.005 [0.71, -0.7]
	Human: MT: Luteal phase	0.17 [0.86, -0.52]
	Human: Neutral: Male	0.68 [1.37, -0.01].
	Human: Neutral: Follicular phase	0.27 [0.97, -0.43]
	Human: Neutral: Luteal phase	0.39 [1.09, -0.3]
	Reptile: MT: Male	0.97 [1.66, 0.28]**
	Reptile: MT: Follicular phase	-0.06 [0.65, -0.76]
	Reptile: MT: Luteal phase	-0.01 [0.68, -0.7]
	Reptile: Neutral: Male	0.84 [1.53, 0.15]*
	Reptile: Neutral: Follicular phase	-0.06 [0.64, -0.76]
	Reptile: Neutral: Luteal phase	0.22 [0.91, -0.48]

	Parameter	β [95% CI]
Stim*Thr*Neur	<i>F</i> (4, 3812) = 3.48**	
ref. Firearm: High threat	Human: Moderate threat	0.01 [0.04, -0.02]
	Human: Neutral	0.04 [0.07, 0.01]*
	Reptile: Moderate threat	-0.03 [0.01, -0.06]
	Reptile: Neutral	-0.03 [0.01, -0.06]
Stim*Sex*Neur	<i>F</i> (6, 3812) = 8.56***	
ref. Firearm BC female	Human: Male	-0.02 [0.02, -0.06]
	Human: Follicular phase	0.03 [0.06, -0.01]
	Human: Luteal phase	0.02 [0.05, -0.02]
	Reptile: Male	-0.02 [0.02, -0.05]
	Reptile: Follicular phase	-0.02 [0.01, -0.06]
	Reptile: Luteal phase	-0.01 [0.03, -0.05]
Stim*Thr*Sex*Neur	<i>F</i> (12, 3812) = 2.74**	
ref. Firearm: Attack: CON	Human: MT: Male	0.06 [0.11, 0.01]*
	Human: MT: Follicular phase	0.03 [0.08, -0.02]
	Human: MT: Luteal phase	-0.02 [0.03, -0.08]
	Human: Neutral Male	0.02 [0.07, -0.03]
	Human: Neutral Follicular phase	-0.01 [0.04, -0.06]
	Human: Neutral Luteal phase	-0.06 [-0.01, -0.12]*
	Reptile: MT: Male	0.09 [0.14, 0.04]***
	Reptile: MT: Follicular phase	0.03 [0.07, -0.02]
	Reptile: MT: Luteal phase	0.06 [0.11, 0.002]*
	Reptile: Neutral: Male	0.06 [0.11, 0.01]*
	Reptile: Neutral: Follicular phase	0.04 [0.09, -0.01]
	Reptile: Neutral: Luteal phase	0.01 [0.06, -0.05]

.1 , <math>p < .05, p < .01 **, p < .01 **, p < .001 *** Stim: Stimulus type Cor: Coronal site Neur = neuroticism score Thr: Threat level (HT = High threat, MT = Moderate threat) Sag: Sagittal location (CP = Central-parietal)

	Parameter	β [95% CI]
Threat level	<i>F</i> (2, 5168) = 35.99***	
ref. High threat	Moderate threat	-0.29 [0.2, -0.77]
	Neutral	-0.71 [-0.23, -1.19]**
Stim*Thr	<i>F</i> (4, 5168) = 36.87***	
ref. Firearm: High threat	Human: Moderate threat	-0.11 [0.48, -0.7]
	Human: Neutral	-0.66 [-0.07, -1.25]*
	Reptile: Moderate threat	0.69 [1.28, 0.1]*
	Reptile: Neutral	0.78 [1.37, 0.19]*

Experiment 1: The P3b

	Parameter	β [95% CI]
Stim*Sex	<i>F</i> (6, 5168) = 8.9***	
ref. Firearm BC female	Human: Male	0.9 [1.31, 0.49]***
	Human: Follicular phase	-0.08 [0.4, -0.56]
	Human: Luteal phase	1.06 [1.48, 0.64]***
	Reptile: Male	0.74 [1.15, 0.33]***
	Reptile: Follicular phase	0.34 [0.82, -0.13]
	Reptile: Luteal phase	0.3 [0.72, -0.12]
Thr*Sex	<i>F</i> (6, 5168) = 2.45*	
ref. High threat: BC female	Moderate threat: Male	-0.28 [0.13, -0.68]
	Moderate threat: Follicular phase	0.73 [1.2, 0.25]**
	Moderate threat: Luteal phase	0.1 [0.52, -0.32]
	Neutral: Male	-0.08 [0.33, -0.49]
	Neutral: Follicular phase	0.31 [0.78, -0.17]
	Neutral: Luteal phase	0.03 [0.45, -0.39]
Stim*Sag	<i>F</i> (2, 5168) = 117.97***	
ref. Firearm: Parietal	Human: Parietal-occipital	1.85 [2.34, 1.36]***
	Reptile: Parietal-occipital	-0.43 [0.06, -0.92].
Thr* Sag	$F(2, 5168) = 14.66^{***}$	
ref. High threat: Parietal	Moderate threat: Parietal-occipital	-0.41 [0.08, -0.9]
	Neutral: Parietal-occipital	-0.36 [0.14, -0.85]
Stim*Cor	<i>F</i> (4, 5168) = 20.37***	
ref. Firearm: Left hemisphere	Human: Midline	-1.41 [-0.79, -2.02]***
	Human: Right hemisphere	0.3 [0.84, -0.25]
	Reptile: Midline	-0.13 [0.48, -0.74]
	Reptile: Right hemisphere	0.5 [1.05, -0.04].
Thr*Cor	F(4, 5168) = 6.77 * * *	
ref. Firearm: Left hemisphere	Moderate threat: Midline	-0.41 [0.2, -1.03]
	Moderate threat: Right hemisphere	-0.19 [0.36, -0.73]
	Neutral: Midline	-1.05 [-0.43, -1.66]***
	Neutral: Right hemisphere	-0.49 [0.05, -1.03].
Stim*Thr*Sag	<i>F</i> (4, 5168) = 5.99***	, [,].
ref. Firearm: HT: Parietal	Human: Moderate threat: PO	-0.12 [0.58, -0.81]
	Human: Neutral: PO	0.9 [1.59, 0.2]*
	Reptile: Moderate threat: PO	0.38 [1.08, -0.31]
	Reptile: Neutral: PO	1.68 [2.37, 0.98]***
Stim*Thr*Cor	<i>F</i> (8, 5168) = 3.23**	
ref. Firearm: HT: Left	Human: Moderate threat: Midline	0.58 [1.44, -0.29]
	Human: Neutral: Midline	0.31 [1.18, -0.55]

	Parameter	β [95% CI]
	Reptile: Moderate threat: Midline	-0.75 [0.12, -1.61].
	Reptile: Neutral: Midline	0.16 [1.03, -0.71]
	Human: Moderate threat: Right	0.4 [1.17, -0.37]
	Human: Neutral: Right	0.42 [1.19, -0.35]
	Reptile: Moderate threat: Right	-1.24 [-0.47, -2.01]**
	Reptile: Neutral: Right	0.21 [0.98, -0.56]
Stim*Sex*PSWQ	<i>F</i> (6, 5168) = 3.14**	
ref. Firearm BC female	Human: Male	-0.0001 [0.03, -0.03]
	Human: Follicular phase	0.02 [0.06, -0.02]
	Human: Luteal phase	0.04 [0.09, 0]*
	Reptile: Male	-0.02 [0.02, -0.05]
	Reptile: Follicular phase	-0.05 [-0.01, -0.09]*
	Reptile: Luteal phase	-0.04 [0, -0.08].
Thr*Sex*PSWQ	<i>F</i> 6, 5168) = 2.81**	
ref. High threat: BC female	Moderate threat: Male	-0.02 [0.01, -0.05]
	Moderate threat: Follicular phase	-0.06 [-0.02, -0.1]**
	Moderate threat: Luteal phase	0.02 [0.06, -0.02]
	Neutral: Male	-0.03 [0.01, -0.06]
	Neutral: Follicular phase	-0.03 [0.01, -0.07]
	Neutral: Luteal phase	0.03 [0.07, -0.02]
.1 < p < .05., p < .05*, p < .01 **, p < .001***	Stim: Stimulus type Cor: Coronal	site PSWQ = worry scores

(H = High threat, MT = Moderate threat)Sag: Sagittal location (PO = Parietal-occipital)

Experiment 1: The LPP

	Parameter	β [95% CI]
Stimulus type	<i>F</i> (2, 3695) = 53.5***	
ref. Firearms	Humans	0.22 [0.71, -0.27]
	Reptiles	0.17 [0.66, -0.31]
Threat level	<i>F</i> (2, 3695) = 158.63***	
ref. High threat	Moderate threat	-0.92 [-0.45, -1.4]***
	Neutral	-1.23 [-0.75, -1.71]***
Stim*Thr	$F(4, 3695) = 38.43^{***}$	
ref. Firearm: High threat	Human: Moderate threat	0.46 [1.14, -0.21]
	Human: Neutral	-1.56 [-0.88, -2.23]***
	Reptile: Moderate threat	0.46 [1.14, -0.21]
	Reptile: Neutral	0.5 [1.17, -0.18]
Stim*Sex	<i>F</i> (6, 3695) = 4.1***	
ref. Firearm BC female	Human: Male	-0.69 [-0.07, -1.32]*

	Parameter	β [95% CI]
	Human: Follicular phase	-0.52 [0.17, -1.21]
	Human: Luteal phase	-0.13 [0.61, -0.88]
	Reptile: Male	0.32 [0.94, -0.3]
	Reptile: Follicular phase	0.59 [1.28, -0.09].
	Reptile: Luteal phase	0.23 [0.98, -0.52]
Thr*Sex	$F(6, 3695) = 3.06^{**}$	
ref. High threat: BC female	Moderate threat: Male	0.49 [1.24, -0.26]
	Moderate threat: Follicular phase	-0.52 [0.17, -1.21]
	Moderate threat: Luteal phase	-0.95 [-0.33, -1.58]**
	Neutral: Male	-0.39 [0.24, -1.01]
	Neutral: Follicular phase	-0.3 [0.45, -1.05]
	Neutral: Luteal phase	0.56 [1.25, -0.12]
Stim*Sag	<i>F</i> (2, 3695) = 62.69***	
ref. Firearm: Central-parietal	Human: Parietal	0.98 [1.17, 0.79]***
	Reptile: Parietal	0.08 [0.27, -0.12]
Stim*Thr*Sex	<i>F</i> (12, 3695) = 3.04***	
ref. Firearm: HT: BC female	Human: Moderate: Male	1.35 [2.23, 0.46]**
	Human: Moderate: Follicular	0.75 [1.73, -0.22]
	Human: Moderate: Luteal	1.06 [2.12, 0]*
	Human: Neutral Male	0.75 [1.63, -0.13].
	Human: Neutral Follicular phase	1.07 [2.05, 0.1]*
	Human: Neutral Luteal phase	0.59 [1.65, -0.47]
	Reptile: Moderate Male	1.49 [2.37, 0.61]***
	Reptile: Moderate Follicular phase	0.91 [1.88, -0.07].
	Reptile: Moderate Luteal phase	0.65 [1.71, -0.41]
	Reptile: Neutral Male	-0.1 [0.78, -0.98]
	Reptile: Neutral Follicular phase	-0.79 [0.19, -1.76]
	Reptile: Neutral Luteal phase	-0.57 [0.49, -1.62]
Stim*Sex*STAI-T	<i>F</i> (6, 3695) = 6.05***	
ref. Firearm BC female	Human: Male	-0.14 [-0.06, -0.23]***
	Human: Follicular phase	-0.13 [-0.03, -0.23]**
	Human: Luteal phase	-0.13 [-0.03, -0.23]*
	Reptile: Male	0.05 [0.13, -0.04]
	Reptile: Follicular phase	-0.03 [0.07, -0.13]
	Reptile: Luteal phase	0.06 [0.16, -0.04]
Stim*Sex*PSWQ	<i>F</i> (6, 3695) = 5.66***	
ref. Firearm BC female	Human: Male	0.07 [0.12, 0.01]*
	Human: Follicular phase	0.06 [0.13, -0.02]

	Parameter	β [95% CI]
	Human: Luteal phase	0.07 [0.15, -0.01].
	Reptile: Male	-0.04 [0.01, -0.09]
	Reptile: Follicular phase	-0.02 [0.05, -0.09]
	Reptile: Luteal phase	-0.08 [0, -0.16]*
Thr*Sex*STAI-T	$F(6, 3695) = 6.49^{***}$	
ref. High threat: BC female	Moderate threat: Male	-0.08 [0.02, -0.18]
	Moderate threat: Follicular phase	-0.06 [0.04, -0.16]
	Moderate threat: Luteal phase	-0.07 [0.01, -0.15]
	Neutral: Male	-0.1 [-0.02, -0.18]*
	Neutral: Follicular phase	-0.05 [0.05, -0.15]
	Neutral: Luteal phase	0.002 [0.1, -0.1]
Thr*Sex*PSWQ	<i>F</i> (6, 3695) = 2.91**	
ref. High threat: BC female	Moderate threat: Male	0.01 [0.09, -0.07]
	Moderate threat: Follicular phase	0.05 [0.12, -0.03]
	Moderate threat: Luteal phase	-0.02 [0.03, -0.08]
	Neutral: Male	-0.03 [0.02, -0.08]
	Neutral: Follicular phase	0.04 [0.12, -0.04]
	Neutral: Luteal phase	-0.02 [0.05, -0.1]
Thr*STAI-T*PSWQ	<i>F</i> (2, 3695) = 10.62***	
ref. High threat	Moderate threat	-0.004 [0.001, -0.01]
	Neutral	-0.002 [0.003, -0.01]
Stim*Thr*Sex*STAI-T	<i>F</i> (12, 3695) = 3.06***	
ref. Firearm: HT: BC female	Human: MT: Male	0.08 [0.2, -0.04]
	Human: MT: Follicular phase	0.09 [0.23, -0.06]
	Human: MT: Luteal phase	0.02 [0.16, -0.12]
	Human: Neutral Male	0.08 [0.2, -0.04]
	Human: Neutral Follicular phase	0.23 [0.37, 0.09]**
	Human: Neutral Luteal phase	0.09 [0.23, -0.05]
	Reptile: MT: Male	0.22 [0.34, 0.1]***
	Reptile: MT: Follicular phase	0.27 [0.41, 0.13]***
	Reptile: MT: Luteal phase	0.21 [0.35, 0.07]**
	Reptile: Neutral: Male	0.01 [0.13, -0.11]
	Reptile: Neutral: Follicular phase	0.12 [0.26, -0.02].
	Reptile: Neutral: Luteal phase	0.06 [0.2, -0.08]
Stim*Sex*PSWQ*STAI-T	F(6, 3695) = 2.51*	
ref. Firearm: BC female	Human: Male	0.01 [0.01, 0.002]*
	Human: Follicular phase	0.01 [0.02, 0.01]***
	Human: Luteal phase	0.01 [0.02, -0.004]

	Parameter	β [95% CI]
	Reptile: Male	-0.002 [0.004, -0.01]
	Reptile: Follicular phase	0.01 [0.02, 0.003]**
	Reptile: Luteal phase	-0.003 [0.01, -0.01]
Thr*Sex*PSWQ*STAI-T	<i>F</i> (6, 3695) = 4.48***	
ref. High threat: BC female	Moderate threat: Male	-0.01 [0.002, -0.02]
	Moderate threat: Follicular phase	0.003 [0.01, -0.004]
	Moderate threat: Luteal phase	0.001 [0.01, -0.01]
	Neutral: Male	-0.004 [0.003, -0.01]
	Neutral: Follicular phase	-0.001 [0.01, -0.01]
	Neutral: Luteal phase	-0.001 [0.01, -0.01]
Stim*Thr*Sex*STAI-T*PSWQ	<i>F</i> (12, 3695) = 2.77***	
ref. Firearm: HT: BC female	Human: MT: Male	-0.004 [0.01, -0.01]
	Human: MT: Follicular phase	-0.003 [0.01, -0.01]
	Human: MT: Luteal phase	0.001 [0.01, -0.01]
	Human: Neutral Male	-0.002 [0.01, -0.01]
	Human: Neutral Follicular phase	-0.01 [-0.002, -0.02]*
	Human: Neutral Luteal phase	0.001 [0.01, -0.01]
	Reptile: MT: Male	-0.01 [0.002, -0.02]
	Reptile: MT: Follicular phase	-0.02 [-0.01, -0.03]**
	Reptile: MT: Luteal phase	-0.01 [0.01, -0.02]
	Reptile: Neutral: Male	0.004 [0.01, -0.005]
	Reptile: Neutral: Follicular phase	-0.01 [-0.001, -0.02]*
	Reptile: Neutral: Luteal phase	0.01 [0.02, -0.01]

.1 , <math>p < .05, p < .01**, p < .001***Stim: Stimulus typePSWQ = worry scoresSTAI-T = trait anxiety scoresThr: Threat level (HT = High threat, MT = Moderate threat)Sag: Sagittal location (CP = Central-parietal)

Experiment 2: The LPP

	Parameter	β [95% CI]
Threat level	$F(1, 3886) = 8.08^{**}$	
ref. Attack	Neutral	-1.66 [-0.8, -2.53]***
Congruency	$F(3, 3886) = 6.01^{***}$	
ref. CON	THR	0.16 [1.12, -0.81]
	STIM	-0.75 [0.21, -1.72]
	BOTH	-0.53 [0.44, -1.5]
Stim*Thr	F(1, 3886) = 9.17 **	
ref. Firearm: Attack	Reptile: Neutral	1.28 [1.88, 0.68]***
Stim*Cong	<i>F</i> (3, 3886) = 4.19**	
ref. Firearm: CON	Reptile: THR	0.45 [0.74, 0.17]**

	Parameter	β [95% CI]
	Reptile: STIM	0.97 [1.25, 0.68]***
	Reptile: BOTH	0.28 [0.57, -0.01].
Thr*Cong	<i>F</i> (3, 3886) = 5.91***	
ref. Attack: CON	Neutral: THR	1.81 [2.75, 0.86]***
	Neutral: STIM	0.97 [1.91, 0.03]*
	Neutral: BOTH	1.49 [2.43, 0.54]**
Stim*Sag	<i>F</i> (1, 3886) = 10.29**	
ref. Firearm: Central-parietal	Reptile: Parietal	0.23 [0.38, 0.09]**
Cor*Cong	<i>F</i> (6, 3886) = 3.74**	
ref. Left hemisphere: CON	Midline: THR	-0.06 [0.18, -0.31]
	Midline: STIM	0.18 [0.43, -0.07]
	Midline: BOTH	0.23 [0.47, -0.02].
	Right hemisphere: THR	0.06 [0.3, -0.19]
	Right hemisphere: STIM	0.45 [0.7, 0.2]***
	Right hemisphere: BOTH	0.43 [0.68, 0.18]***
Cong*PSWQ	<i>F</i> (3, 3886) = 14.13***	
ref. CON	THR	-0.02 [-0.005, -0.04]*
	STIM	-0.01 [0.01, -0.03]
	BOTH	-0.01 [0.01, -0.03]
Stim*Thr*Cong	<i>F</i> (3, 3886) = 19.46***	
ref. Firearm: Attack: CON	Reptile: Neutral: THR	-0.52 [-0.11, -0.92]*
	Reptile: Neutral: STIM	-1.32 [-0.91, -1.72]***
	Reptile: Neutral: BOTH	0.09 [0.49, -0.32]
Stim*Thr*PSWQ	<i>F</i> (1, 3886) = 6.39*	
ref. Firearm: Attack	Reptile: Neutral	-0.01 [-0.003, -0.03]*
Stim*Cong*STAI-T	<i>F</i> (3, 3886) = 6.56***	
ref. Firearm: CON	Reptile: THR	-0.04 [-0.02, -0.06]***
	Reptile: STIM	-0.03 [-0.01, -0.05]**
	Reptile: BOTH	-0.001 [0.02, -0.02]
Thr*Cong*STAI-T	F(3, 3886) = 3.66*	
ref. Attack: CON	Neutral: THR	0.004 [0.09, -0.09]
	Neutral: STIM	0.13 [0.22, 0.04]**
	Neutral: BOTH	0.06 [0.15, -0.03]
Thr*Cong*PSWQ	<i>F</i> (3, 3886) = 3.12*	
ref. Attack: CON	Neutral: THR	-0.03 [-0.01, -0.05]**
	Neutral: STIM	-0.002 [0.02, -0.02]
	Neutral: BOTH	-0.02 [0, -0.04].

	Parameter	β [95% CI]	
Stim*Sex*STAI-T	<i>F</i> (1, 3886) = 9.43**		
ref. Firearm: BC female	Reptile: Male	0.02 [0.04, 0.01]**	
Thr*Sex*STAI-T	<i>F</i> (1, 3886) = 6.75**		
ref. Attack: BC female	Neutral: Male	-0.03 [-0.01, -0.05]**	
Thr*Sex*PSWQ	<i>F</i> (1, 3886) = 8.84**		
ref. Attack: BC female	Neutral: Male	-0.01 [-0.003, -0.03]*	
Sex*Cong*STAI-T	$F(3, 3886) = 4.4^{**}$		
ref. BC females: CON	Male: THR	0.19 [0.3, 0.08]***	
	Male: STIM	0.04 [0.15, -0.07]	
	Male: BOTH	0.1 [0.21, -0.01].	
Thr*Cong*STAI-T*PSWQ	F(3, 3886) = 4.8 **		
ref. Attack: CON	Neutral: THR	0.0001 [0.002, -0.002]	
	Neutral: STIM	-0.003 [-0.001, -0.005]**	
	Neutral: BOTH	-0.001 [0.001, -0.003]	
Sex*Cong*STAI-T*PSWQ	<i>F</i> (3, 3886) = 5.49***		
ref. BC females: CON	Male: THR	-0.004 [-0.002, -0.007]***	
	Male: STIM	-0.001 [0.002, -0.003]	
	Male: BOTH	-0.002 [0, -0.004].	
.1 < p < .05., p < .05*, p < .01 **, p < .001***	Stim: Stimulus type Cor: Coronal si	te STAI-T = trait anxiety scores	
Thr: Threat level	Sag: Sagittal location (CP = Central-parietal) PSWQ = worry scores		

Congruency: Cong, CON = Congruent, THR = Incongruent threat, STIM = Incongruent stimulus, BOTH = Incongruent both

Experiment 3: The anterior N1

	Parameter	β [95% CI]		
Congruency	F(3, 3716) = 5.34 * *			
ref. CON	ARO	0.34 [0.59, 0.09]**		
	THR	0.18 [0.43, -0.07]		
	BOTH	-0.08 [0.17, -0.33]		
Aro*Thr	<i>F</i> (1, 3716) = 12.1***			
ref. High arousal: Active	Low arousal: Passive -0.54 [-0.19, -0.9]**			
Aro*Cong	<i>F</i> (3, 3716) = 3.14*			
ref. High arousal: CON	Low arousal: ARO	-0.82 [-0.47, -1.18]***		
	Low arousal: THR	-0.51 [-0.16, -0.86]**		
	Low arousal: BOTH	0.1 [0.45, -0.25]		
Thr*Cong	<i>F</i> 3, 3716) = 14.51***			
ref. Active: CON	Passive: ARO	-0.63 [-0.28, -0.98]***		
	Passive: THR	-0.25 [0.1, -0.6]		
	Passive: BOTH	0.14 [0.49, -0.22]		

	Parameter	β [95% CI]
Aro*Sag	<i>F</i> (1, 3716) = 5.64*	
ref. High arousal: Frontal-central	Low arousal: Central	-0.9 [-0.61, -1.19]***
Sag*Cong	<i>F</i> (3, 3716) = 5.5***	
ref. Frontal-central: CON	Central: ARO	-0.99 [-0.7, -1.27]***
	Central: THR	-0.93 [-0.64, -1.21]***
	Central: BOTH	-0.93 [-0.65, -1.22]***
Aro*STAI-S	<i>F</i> (1, 3716) = 12.59***	
ref. High arousal	-0.04 [-0.02, -0.06]***	-0.04 [-0.02, -0.06]***
Cong*STAI-S	<i>F</i> (3, 3716) = 6.78***	
ref. CON	ARO	-0.001 [0.02, -0.02]
	THR	-0.03 [-0.01, -0.05]**
	BOTH	-0.01 [0.01, -0.03]
Aro*Thr*Cong	<i>F</i> (3, 3716) = 29.59***	
ref. High arousal: Active: CON	Low arousal: Passive: ARO	1.6 [2.1, 1.1]***
	Low arousal: Passive: THR	0.92 [1.41, 0.42]***
	Low arousal: Passive: BOTH	-0.25 [0.25, -0.75]
Thr*Sex*Cong	<i>F</i> (3, 3716) = 2.72*	
ref. Active: BC female: CON	Passive: Male: ARO	0.55 [0.97, 0.14]**
	Passive: Male: THR	-0.32 [0.09, -0.73]
	Passive: Male: BOTH	-0.25 [0.16, -0.66]
Aro*Thr*Sag	<i>F</i> (1, 3716) = 8.1**	
ref. High arousal: Active: FC	Low arousal: Passive: Central	0.88 [1.29, 0.47]***
Aro*Sag*Cong	<i>F</i> (3, 3716) = 4.97**	
ref. High arousal: FC: CON	Low arousal: Central: ARO	1.02 [1.43, 0.61]***
	Low arousal: Central: THR	0.73 [1.13, 0.32]***
	Low arousal: Central: BOTH	0.76 [1.17, 0.36]***
Thr*Sag*Cong	<i>F</i> (3, 3716) = 8.33***	
ref. Active: FC: CON	Passive: Central: ARO	0.96 [1.37, 0.55]***
	Passive: Central: THR	0.94 [1.34, 0.53]***
	Passive: Central: BOTH	1.01 [1.42, 0.61]***
Aro*Cong*STAI-S	<i>F</i> (3, 3716) = 2.76*	
ref. High arousal: CON	Low arousal: ARO	0.02 [0.05, 0]
	Low arousal: THR	0.02 [0.05, -0.01]
	Low arousal: BOTH	0.03 [0.06, -0.0004].
Aro*Thr*Sex*Cong	$F(3, 3716) = 5.56^{***}$	
ref. HA: Active: BC female: CON	LA: Passive: Male: ARO	-0.9 [-0.32, -1.49]**
	LA: Passive: Male: THR	0.08 [0.66, -0.51]
	LA: Passive: Male: BOTH	0.15 [0.74, -0.43]

	Parameter	β [95% CI]		
Aro*Thr*Sag*Cong	<i>F</i> (3, 3716) = 3.98**			
ref. HA: Active: FC: CON	LA: Passive: Central: ARO	-0.97 [-0.4, -1.55]***		
	LA: Passive: Central: THR	-0.68 [-0.11, -1.26]*		
	LA: Passive: Central: BOTH -0.7 [-0.12, -1.27]			
Aro*Thr*Cong*STAI-S	$F(3, 3716) = 6.6^{***}$			
ref. High arousal: Active: CON	Low arousal: Passive: ARO -0.08 [-0.04, -0.1			
	Low arousal: Passive: THR	-0.02 [0.02, -0.06]		
	Low arousal: Passive: BOTH	-0.06 [-0.02, -0.1]**		
.1 < p < .05., p < .05*, p < .01 **, p < .001***	Aro: Arousal level (HA = High arousal, LA = Low arousal) STAI-S = state anxiety sco			
Thr: Threat type	Sag: Sagittal location (FC = Frontal-central)			

Congruency: Cong, CON = Congruent, ARO = Incongruent arousal, THR = Incongruent threat, BOTH = Incongruent both

	Parameter	β [95% CI]	
Arousal level	$F(1, 2414) = 68.24^{***}$		
ref. High arousal	Low arousal	3.65 [4.05, 3.24]***	
Congruency	<i>F</i> (3, 2414.01) = 9.46***		
ref. CON	ARO	2.46 [2.95, 1.97]***	
	THR	2.32 [2.81, 1.83]***	
	BOTH	2.09 [2.58, 1.6]***	
Aro*Thr	<i>F</i> (1, 2414) = 49.49***		
ref. High arousal: Active	Low arousal: Passive	-3.48 [-2.92, -4.05]***	
Aro*Cong	$F(3, 2414) = 77.81^{***}$		
ref. High arousal: CON	Low arousal: ARO	-4.85 [-4.28, -5.41]***	
	Low arousal: THR	-2.85 [-2.28, -3.42]***	
	Low arousal: BOTH	-2.48 [-1.91, -3.05]***	
Aro*Thr*Cong	<i>F</i> (3, 2414) = 91.16***		
ref. High arousal: Active: CON	Low arousal: Passive: ARO	4.87 [5.68, 4.07]***	
	Low arousal: Passive: THR	4.83 [5.64, 4.03]***	
	Low arousal: Passive: BOTH	0.17 [0.97, -0.64]	
Thr*Cor*Cong	$F(3, 2414) = 4.05^{**}$		
ref. Active: Left hemisphere: CON	Passive: Right hemisphere: ARO 0.01 [0.81, -0.79]		
	Passive: Right hemisphere: THR	0.86 [1.67, 0.06]*	
	Passive: Right hemisphere: BOTH	1.12 [1.92, 0.32]**	
.1 , $p < .05$ *, $p < .01$ **, $p < .001$ ***	Aro: Arousal level Thr: Threat type	Cor: Coronal site	

Experiment 2: The EPN

Congruency: Cong, CON = Congruent, ARO = Incongruent arousal, THR = Incongruent threat, BOTH = Incongruent both

	Parameter	β [95% CI]
Arousal level	F(1, 3714) = 10.42 **	
ref. High arousal	Low arousal	-0.04 [0.13, -0.21]
Aro*Cong	F(3, 3714) = 24.48 * * *	
ref. High arousal: CON	Low arousal: ARO	-0.33 [-0.11, -0.55]**
	Low arousal: THR	-0.45 [-0.22, -0.67]***
	Low arousal: BOTH	0.43 [0.66, 0.21]***
Thr*Cong	$F(3, 3714) = 16.89^{***}$	
ref. Active: CON	Passive: ARO	0.26 [0.48, 0.04]*
	Passive: THR	0.12 [0.34, -0.11]
	Passive: BOTH	0.4 [0.62, 0.17]***
Aro*Sex	<i>F</i> (1, 3714) = 9.53**	
ref. High arousal: BC female	Low arousal: Male	-0.09 [0.13, -0.32]
Thr*Sex	F(1, 3714) = 8.21 **	
ref. Active: BC female	Passive: Male	0.05 [0.27, -0.18]
Aro*Sag	<i>F</i> (1, 3714) = 3.93*	
ref. High arousal: Frontal	Low arousal: Frontal-central	-0.08 [0, -0.16]*
Aro*Cor	$F(2, 3714) = 5.66^{**}$	
ref. High arousal: Left hemisphere	Low arousal: Midline	0.06 [0.16, -0.03]
	Low arousal: Right hemisphere	0.16 [0.26, 0.07]***
Sex*Cong	<i>F</i> (3, 3714) = 2.75*	
ref. BC female: CON	Male: ARO	0.01 [0.24, -0.21]
	Male: THR	-0.24 [-0.02, -0.47]*
	Male: BOTH	0.15 [0.37, -0.08]
Cor*Cong	F(6, 3714) = 3.68 **	
ref. Left hemisphere: CON	Midline: ARO	0.13 [0.26, -0.01].
	Midline: THR	0.09 [0.23, -0.04]
	Midline: BOTH	0.1 [0.23, -0.04]
	Right hemisphere: ARO	0.28 [0.41, 0.14]***
	Right hemisphere: THR	0.27 [0.41, 0.13]***
	Right hemisphere: BOTH	0.23 [0.37, 0.09]***
Cong*STAI-S	<i>F</i> (3, 3714) = 15.48***	
ref. CON	ARO	-0.02 [0.001, -0.03].
	THR	0.01 [0.02, -0.01]
	BOTH	-0.02 [0, -0.03]*

 $F(3, 3714) = 9.54^{***}$

Low arousal: Passive: ARO

0.29 [0.61, -0.02].

Experiment 3: The CRN

Aro*Thr*Cong

ref. High arousal: Active: CON

	Parameter	β [95% CI]	
	Low arousal: Passive: THR	-0.5 [-0.19, -0.82]**	
	Low arousal: Passive: BOTH	-0.79 [-0.47, -1.1]***	
Aro*Sex*Cong	<i>F</i> (3, 3623) = 4.95**		
ref. High arousal: BC female: CON	Low arousal: Male: THR	0.49 [0.81, 0.17]**	
	Low arousal: Male: STIM	0.55 [0.87, 0.23]***	
	Low arousal: Male: BOTH	-0.36 [-0.04, -0.68]*	
Thr*Sex*Cong	F(3, 3714) = 5.14 **		
ref. Active: BC female: CON	Passive: Male: ARO	-0.11 [0.21, -0.43]	
	Passive: Male: THR	-0.21 [0.11, -0.53]	
	Passive: Male: BOTH	-0.52 [-0.2, -0.84]**	
Aro*Thr*STAI-S	<i>F</i> (1, 3714) = 13.57***		
ref. High arousal: Active	Low arousal: Passive	-0.02 [0, -0.04]*	
Aro*Cong*STAI-S	<i>F</i> (3, 3714) = 3.56*		
ref. High arousal: CON	Low arousal: THR	-0.001 [0.02, -0.02]	
	Low arousal: STIM	-0.01 [0.01, -0.04]	
	Low arousal: BOTH	-0.01 [0.01, -0.03]	
Sex*Cong*STAI-S	<i>F</i> (3, 3714) = 3.56*		
ref. BC female: CON	Male: THR	0.02 [0.05, -0.003].	
	Male: STIM	-0.002 [0.03, -0.03]	
	Male: BOTH	-0.01 [0.02, -0.03]	
Aro*Thr*Sex*Cong	<i>F</i> 3, 3714) = 11.93***		
ref. HA: Active: BC female: CON	LA: Passive: Male: ARO	-0.67 [-0.23, -1.12]**	
	LA: Passive: Male: THR	0.09 [0.54, -0.36]	
	LA: Passive: Male: BOTH	0.69 [1.14, 0.24]**	
Aro*Thr*Cong*STAI-S	F(3, 3714) = 3.33*		
ref. High arousal: Active: CON	Low arousal: Passive: ARO	-0.01 [0.02, -0.04]	
	Low arousal: Passive: THR	-0.01 [0.02, -0.04]	
	Low arousal: Passive: BOTH	0.03 [0.06, -0.0003].	
Thr*Sex*Cong*STAI-S	$F(3, 3714) = 4.35^{**}$		
ref. Active: BC female: CON	Passive: Male: ARO	-0.07 [-0.03, -0.11]***	
	Passive: Male: THR	-0.03 [0.01, -0.06]	
	Passive: Male: BOTH	-0.04 [-0.01, -0.08]*	
.1 < p < .05, p < .05*, p < .01 **, p < .001***	Aro: Arousal level Thr: Threat type Sag: Sagittal location (FC = Frontal-central)	Cor: Coronal site STAI-S = state anxiety scores	

APPENDIX L: Initial affective ratings of images selected for Experiment 3

Mean valence, arousal, threat and disgust ratings for human images employed in the modified Flanker task, rounded to 2 or fewer decimal places. Images are categorised by threat type and arousal level. Ratings have been reverse-scored to reflect greater levels of arousal, threat or disgust with higher ratings (1 = low, 6 = high). For valence lower ratings indicate increasing levels of pleasantness. Stimuli from the IAPS or EmoMadrid databases are denoted by a single asterisk beside the image code.

	Image code	Valence (M±SE)	Arousal (M±SE)	Threat (M±SE)	Disgust (M±SE)
Active disposition					
Men with aimed	HAH_1031	5.1 (±0.18)	5.1 (±0.23)	5.4 (±0.27)	4 (±0.56)
handguns	HAH_1033	5.3 (±0.21)	5.4 (±0.22)	4.8 (±0.49)	3.5 (±0.58)
High arousal	HAH_1034	5.4 (±0.22)	5.4 (±0.22)	5.2 (±0.25)	4.1 (±0.5)
	HAH_1035	5.2 (±0.2)	5.1 (±0.23)	5.4 (±0.22)	4.2 (±0.51)
	HAH_1036	4.9 (±0.23)	5.3 (±0.26)	5 (±0.3)	4 (±0.52)
	HAH_1037	5.2 (±0.2)	5.1 (±0.18)	5.2 (±0.33)	4.1 (±0.5)
	HAH_1038	5.3 (±0.15)	5.2 (±0.2)	5.2 (±0.33)	4 (±0.58)
	HAH_1039	5 (±0.15)	5.1 (±0.23)	5.4 (±0.27)	4.1 (±0.5)
	HAH_1041	5.1 (±0.23)	5 (±0.37)	5.3 (±0.26)	4.1 (±0.53)
	HAH_1045	5.1 (±0.28)	5.2 (±0.2)	5.2 (±0.33)	4.1 (±0.53)
Unarmed men	HAL_2038*	2.7 (±0.4)	2.6 (±0.4)	1.4 (±0.31)	1.5 (±0.27)
Low arousal	HAL_2102*	3.1 (±0.35)	2.6 (±0.34)	1.5 (±0.31)	1.8 (±0.39)
	HAL_2191*	2.3 (±0.37)	2.5 (±0.43)	1.4 (±0.27)	1.6 (±0.31)
	HAL_2370*	2.7 (±0.47)	2.5 (±0.48)	1.4 (±0.27)	1.7 (±0.33)
	HAL_2382*	2.4 (±0.31)	2.6 (±0.54)	1.3 (±0.15)	1.3 (±0.21)
	HAL_2391*	2 (±0.26)	2.5 (±0.4)	1.8 (±0.42)	1.7 (±0.3)
	HAL_EM0504*	2.9 (±0.23)	2.6 (±0.4)	1.5 (±0.31)	2.1 (±0.46)
	HAL_EM0658*	2.6 (±0.31)	2 (±0.37)	1.5 (±0.34)	1.6 (±0.34)
	HAL_EM0672*	2.7 (±0.4)	2 (±0.33)	1.5 (±0.31)	1.3 (±0.15)
	HAL_EM0678*	2.9 (±0.31)	2.5 (±0.37)	1.9 (±0.35)	2.9 (±0.59)

	Image code	Valence (M±SE)	Arousal (M±SE)	Threat (M±SE)	Disgust (M±SE)
Passive disposition					
Severe injury	HPH_3016	5.7 (±0.15)	5.2 (±0.25)	4.9 (±0.46)	5.6 (±0.22)
High arousal	HPH_3017	5.3 (±0.26)	5.4 (±0.27)	5 (±0.39)	5.3 (±0.26)
	HPH_3019	5.6 (±0.22)	5.2 (±0.33)	4.8 (±0.51)	5.5 (±0.22)
	HPH_3080*	5.9 (±0.1)	5.3 (±0.5)	4.8 (±0.51)	5.9 (±0.1)
	HPH_3102*	5.8 (±0.2)	5.6 (±0.27)	5 (±0.42)	5.9 (±0.1)
	HPH_3120*	5.7 (±0.21)	5.7 (±0.21)	5 (±0.49)	5.6 (±0.22)
	HPH_3131*	5.8 (±0.2)	5.1 (±0.53)	4.8 (±0.47)	5.9 (±0.1)
	HPH_3140*	5.9 (±0.1)	5.1 (±0.48)	4.8 (±0.44)	5.8 (±0.13)
	HPH_3213*	5.6 (±0.22)	5.6 (±0.22)	4.5 (±0.52)	5.3 (±0.4)
	HPH_3250*	5.8 (±0.13)	5.5 (±0.27)	4.9 (±0.41)	5.7 (±0.21)
Sleeping men	HPL_4002	2.6 (±0.31)	2.3 (±0.45)	1.1 (±0.1)	1.3 (±0.21)
Low arousal	HPL_4007	2.6 (±0.34)	2.6 (±0.43)	1.4 (±0.31)	1.7 (±0.4)
	HPL_4011	2.6 (±0.37)	2.3 (±0.37)	1.2 (±0.13)	1.4 (±0.27)
	HPL_4012	2.5 (±0.27)	2.3 (±0.47)	1.3 (±0.21)	1.8 (±0.33)
	HPL_4016	2.4 (±0.4)	2.4 (±0.37)	1.4 (±0.22)	2.2 (±0.44)
	HPL_4020	2.4 (±0.34)	2.4 (±0.4)	1.1 (±0.1)	1.2 (±0.13)
	HPL_4021	2.9 (±0.38)	2.5 (±0.31)	1.2 (±0.13)	1.8 (±0.33)
	HPL_4026	3 (±0.37)	2.4 (±0.48)	1.8 (±0.42)	2.4 (±0.45)
	HPL_4028	2.6 (±0.37)	2.4 (±0.37)	1.4 (±0.27)	1.8 (±0.42)