Emotional Specificity of Early Startle Reflex Potentiation

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Abstract

This thesis investigated the emotional processing of photographic stimuli. The startle blink reflex was used to index emotional processing, in line with a model predicting that this reflex should be larger in magnitude when elicited during negative emotional processing, and smaller in magnitude during positive processing, relative to reflexes during emotionally neutral material. The studies were based on a discrepancy between phobic and non-phobic individuals for startle elicited shortly after picture onset.

In Study 1, participants rated the emotional characteristics of photographic stimuli. These ratings were used to select pictures for subsequent experiments.

Study 2 tested whether early emotional startle modification was specific to phobic/high-fear participants by measuring blink reflexes in an unselected sample during emotionally positive pictures, neutral pictures, and two types of threatening pictures — threatening animal pictures, similar to those used for phobic participants, and threatening human pictures. Startle was elicited with a 95 dB white noise stimulus, either 300 ms or between 2 and 5 seconds after onset; this was a between-subjects manipulation. Blink magnitude results showed early startle potentiation for human threat but not animal threat pictures.

In Study 3a probe time was manipulated within-subjects, and reflexes were compared between positive, neutral, threat, and mutilation (e.g., dead bodies) pictures. Early startle potentiation was observed only for high-fear participants viewing threat pictures. Study 3b was an attempt to replicate Study 3a with a different picture set. To ensure participants viewed each picture from onset, a fixation cross was presented for 500 ms prior to picture onset. The absence of late probe time startle modification or skin conductance response (SCR) enhancement suggested that the picture set was not emotionally engaging, and hence unsuitable for assessing startle modification.

Study 4 retained the fixation cross, with emotional categories similar to Study 3 being subdivided into high and low arousal examples. Startle modification was consistent across probe times; potentiation was observed for both threat subgroups, and for high-arousal mutilation stimuli. Low-arousal mutilation stimuli blinks were never different from neutral blinks.

In Study 5 a picture complexity manipulation was used to investigate emotional startle modification 150 ms after picture onset. Half of the pictures in each of three emotional categories (positive, neutral, and negative) were full-colour photographs; the remainder were monotone silhouettes of the target stimulus (e.g., a banana, a spider). The negative category consisted entirely of spider pictures, and the participant sample was limited to females with some spider fear. The results offered limited evidence for startle potentiation at 150 ms by spider pictures, in low general-fear participants (data averaged over complexity conditions). SCR enhancement for spider contents was not consistent across participants, suggesting the pictures were not emotionally engaging.

The conclusions were that identification of picture emotional content is possible by 300 ms (to the extent of modifying the startle reflex) when attention is directed to the picture at onset, as indicated by significant startle potentiation for some negative picture contents, and that previously observed differences in responding between high and low fear participants may represent differences in attentional engagement.

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List of Common Abbreviations

BDI	Beck Depression Inventory
EMG	Electromyography
FSS	Fear Survey Schedule
HSD	Tukey's Honest Significant Difference test
IAPS	International Affective Picture System
ITI	Intertrial interval
MQ	Mutilation Questionnaire
PPI	Prepulse inhibition
RMS	Root-Mean-Square transformation function
SAM	Self Assessment Manikin
SCR	Skin Conductance Response
SNAQ	Snake Questionnaire
SPQ	Spider Questionnaire
STAI-S	State-Trait Anxiety Inventory – State Anxiety scale
STAI-T	State-Trait Anxiety Inventory – Trait Anxiety scale

Chapter 1
Emotion

Any work that purports to address issues regarding emotion should start by providing the framework in which emotion will be discussed. This thesis is primarily concerned with modification of the startle reflex by different types of emotional experience. Before discussing the startle reflex (Chapter 2) and the influence of emotional processing on this reflex (Chapter 3), this chapter covers several aspects of emotion.

The first section introduces a functional perspective on emotion. This is followed by a consideration of the levels at which emotion can be described, from a very general motivational description (to approach or avoid a situation) to patterns of responding that are specific to discrete emotional states, such as fear, joy, sadness, and disgust. The majority of studies on emotional modification of the startle reflex modification consider emotion at the very basic motivation level; the chapter therefore concludes by detailing descriptors of emotional experience at the level of motivational disposition.

A Functional Perspective on Emotion

Darwin (1872/1998) proposed three principles on the expression of emotion, the first and third of which provide a solid basis for emotional theory. The first principle declares that emotions are "serviceable associated habits" (p. 34); that is, some components of emotional responding are, or have been, of adaptive use to survival of the individual and/or species. As a corollary of this, certain other aspects of emotional expression may be vestigial remains of previously adaptive behaviours that have generalised to or appear in situations where they are of no adaptive value (Darwin, 1872/1998). For instance, the communicative function of facial expression was viewed by Darwin as an evolutionary 'bonus', rather than an adaptive function per se. Likewise, LeDoux (1998) notes that the conscious or subjective experience of emotion is a consequence of

an emotional event rather than the event itself — an update on William James' famous statement that "bodily changes follow directly the perception of the [emotion] exciting fact, and that our feeling of the same changes as they occur IS the emotion" (James, 1890/1952, p. 743).

The third principle is concerned with the physiological changes during an emotional episode as precursors to action — "when movements are excited [by an emotion], their nature is, to a large extent, determined by those which have often and voluntarily been performed for some definite end under the same emotion" (Darwin, 1872/1998, p. 75). In his discussion of anger and fear, increased heart rate and muscle tension were taken as evidence of a propensity to engage in physical exertion when these emotions are elicited. Darwin emphasised that it was anticipation of such behaviour as fighting or fleeing that is responsible for such body changes, rather than the behaviour itself. This conception is of emotion as action disposition — the emotional experience prepares the body to allow action in an appropriate manner. Although the quotation given above suggests that learning plays a primary role in organising emotional responding, it seems more likely that general patterns of emotional responding are innate.

Taking these two principles — that some parts of emotional expression are preparations for action, and other parts are formed through association with previously adaptive behaviour — provides a useful framework for the discussion of specific emotional states. Thus, emotions can be similar in some respects (e.g., fear and anger both associated with increased blood flow), yet differ in terms of behavioural outputs such as facial expression and action disposition (e.g., increased cardiovascular activity in fear prepares primarily for escape, while in anger it prepares for aggressive engagement).

Distinguishing Between Emotional States

Perhaps the most basic distinction between emotional states is that between positive and negative emotion. At a simple level, positive and negative emotion can be conceived of as internal states associated with subjective feelings of pleasantness and unpleasantness. This is a strategic level of emotion, where the antecedents of emotional experience (e.g., food, or an aggressive

predator) are associated with either approach or withdrawal tendencies that do not specify any particular response set. At a tactical level of emotion, different emotional antecedents (within the basic approach/avoid dichotomy) can produce distinct combinations of physiological, cognitive, and behavioural responding that are meant to enable the most suitable response to the situation. Thus, the tactical disposition of an organism faced by an emotion eliciting stimulus may differ depending on other circumstances: For a rat faced by a predator, either escape or attack may be the most suitable response. The tendency to approach or avoid activated at the strategic level is also described as the organism's motivational disposition, while the tactical level is homologous to the action disposition described above, and dictates or prepares the appropriate response to the situation.

The theoretical distinctions outlined above are not incompatible, but provide different levels of description for emotion. Discrete categories of emotional experience (e.g., fear, happiness, disgust) exist at the levels of subjective experience and action dispositions, while the basic approach/avoid disposition is simultaneously evident. Within the motivational disposition, discrete emotions can theoretically be described as "subordinate organizations of behavior" (Lang, Greenwald, Bradley, & Hamm, 1993, p. 268).

The work in this thesis will consider emotions both as discrete programmes and as strategic dispositions, with later experiments addressing conflict between these two levels of description with regard to the startle reflex. In the following sections, consideration is restricted to the strategic level of emotion, this being the level at which most experiments on startle modification describe emotional stimuli.

A Two-dimensional Model of Emotion

As a formulation of the relationship between the various levels of emotional processing described above, Lang (1985) proposed

> A three-level hierarchical organization in emotion, ascending from specific context bound acts (e.g., subroutines for attack, vigilance, or escape), to larger emotional programs, such as fear or anger, that may vary in the specific acts included, but still show relative response stereotypy across situations, to broad dimensional dispositions (the parameters of intensity, direction, and control), that apply descriptively to all emotional behavior. (p. 141)

In this model, the action disposition (or tactical responding) is nested within the specific emotional state (e.g., fear), which is nested within descriptors common to all emotion: intensity, direction, and control. These descriptors, which have been developed from studies of semantic differentials in emotional language (Osgood, Suci, & Tannenbaum, 1957), will now be discussed.

Emotional Descriptors: Direction/valence

The direction, or valence (after Lewin, 1936), of an emotional state is usually described on the basis of subjective ratings of pleasantness. The direction of emotion is conceived of as a description of motivational disposition, to approach or avoid, although this motivational disposition does not always map neatly onto notation of the direction of emotion as pleasant or unpleasant. The best example of this is the case of anger, a negative emotional state (in terms of valence) which is nonetheless associated with a tendency to approach or engage a situation, as indicated by both subjective reports and measures of brain activation (Harmon-Jones & Allen, 1998).

A change of terminology can clarify this discrepancy between motivational disposition and valence. Konorski (1967) classified reflexes into two categories on the basis of biological function, distinguishing preservative from protective reflexes. Preservative reflexes are those necessary for the survival of the individual (and by extension the species) in the absence of adverse circumstances — reflexes involved with breathing, eating, sleeping, and reproduction. Protective reflexes are those whose function becomes apparent in adverse circumstances, such as threat

from a predator or following ingestion of a noxious substance. Those protective reflexes involved with withdrawal from noxious and dangerous stimuli are defensive reflexes. Protective reflexes which involve engagement with a noxious or dangerous situation, usually in an attempt to destroy it, are classified as offensive reflexes (Konorski, 1967).

Discussing emotion in terms of preservative or protective roles intuitively corresponds more closely to the pleasant/unpleasant valence dimension of emotion than does the approach/avoid dichotomy. As an alternative description of motivational disposition, this distinction could be more useful in discussions of emotion where it is equated with the notion of valence — although of course the distinction between approach and avoidance tendencies in some emotions still needs to be made, as this distinction will be pertinent to certain issues in emotional research. This is described in the introduction to Study 3, in the case of anger.

The terms positive and negative valence are used throughout this thesis to note emotional stimuli or experiences that are subjectively pleasant or unpleasant.

Emotional Descriptors: Intensity/Arousal

The intensity or arousal dimension of emotion can be conceptualised as the degree of activation of an emotional system (Hebb, 1949; Konorski, 1967). Early conceptions of arousal proposed that arousal or drive mechanisms existed independently from specific appetitive or aversive motivational systems (e.g., Schachter & Singer, 1962). More recent formulations of the nature of arousal view it as the intensity of activation within the appetitive or aversive motivational system — or both (Lang, Bradley, & Cuthbert, 1998). Intensity and arousal are used interchangeably in this thesis to describe the subjective experience of intensity during an emotional state.

Emotional Descriptors: Control

Control, also referred to as dominance, represents an individual's autonomy during an emotional episode, or the amount of control they feel over their emotional response. Lang (1985) described

how this dimension can discriminate between emotions that occupy similar positions in the two-dimensional space defined by valence and arousal — fear and anger, for instance, occupy similar locations in this two-dimensional space, but fear is low on dominance ratings while anger is relatively high.

Russell (1980) excluded control (among other factors) from his two-dimensional model of emotion because it explained little variance in subjective descriptions of emotional words. Furthermore, control and the other excluded dimensions were not considered as suitable components of this model because they were "interpreted as referring to … the antecedents or consequences of the emotion described, rather than as referring to the emotion per se" (Russell, 1978, as cited in Russell, 1980, p. 1163).

We are left, then, with a two-dimensional model of affective space (Russell, 1980; Lang, 1985), with valence (from pleasant to unpleasant) and arousal (from sleepy to high arousal) as separate bipolar axes. The arousal dimension does not have to be conceived as bipolar, as one of the endpoints (calm or sleepy) seems to indicate the absence of arousal (i.e., a neutral status) rather than indicating the opposite of arousal. For the purposes of describing affective space, this distinction only influences the point at which arousal would be defined as neutral (i.e., at the bottom of a unipolar scale; at the midpoint of a bipolar scale).

Relating Emotional Descriptors to Emotional Responses

So far, these emotional descriptors have only been considered as semantic information, the mapping of ratings of valence and arousal (measured by self-report) onto subjective consciousness of emotional experience. How well do these emotional descriptors correspond to other areas of emotional experience? Two experiments have looked at different aspects of responding to emotional pictures, using a standardised set of photographs developed specifically for research on emotion, the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999a). This picture set has been developed over several years, and emotional ratings of the pictures have been standardised across a large number of studies, mainly in the United States.

In the first of these studies looking at semantic dimensions and other aspects of emotional responding, Lang et al. (1993) examined affective ratings of pictures, autonomic activation (skin conductance, heart rate), facial muscle activity, and behavioural activity (amount of free viewing time looking at each picture, in a session following the initial exposure). Factor analysis of these different measures revealed groupings onto two major factors. The first, labelled valence, correlated positively with ratings of pleasantness, peak heart rate, and zygomatic muscle activity (the muscle responsible for pulling the corner of the mouth up and back during a smile). This factor was also negatively correlated with corrugator muscle tension (the muscle that knits the eyebrow during a frown). The second factor, labelled arousal, correlated positively with arousal and interest ratings for the pictures, skin conductance, and free viewing times for the pictures. This factor analysis provided evidence for the validity of the two-dimensional model for describing emotion at the motivational level (Lang et al., 1993).

The second study, conducted by Lane et al. (1997), found differential brain activation for positive and negative emotional pictures defined by this two-dimensional affective space, suggesting that the brain structures involved in these two processes are separable, and yet common to specific emotions within the general motivational disposition. This second assumption will be addressed at the start of Study 3, with regard to emotional modification of startle.

One final characteristic to note regarding this model is that arousal ratings tend to increase as valence ratings move away from neutral (i.e., with increasing subjective pleasantness or unpleasantness). This is shown in Figure 1, where standardised valence and arousal ratings are plotted for all 716 of the IAPS pictures for which ratings were given by Lang, Bradley, and Cuthbert (1999b). Picture ratings were collected using the Self-Assessment Manikin (SAM), which is described in the method of Study 1, as well as being included in Appendix A. It can be seen that there are very few emotionally neutral pictures (a score of around 5 on valence) that are associated with high arousal ratings. The overall distribution of picture ratings thus approximates a V shape rotated 90 degrees clockwise, extending from low-arousal neutral pictures towards extremely arousing pleasant and unpleasant emotional experiences (Lang, 1995).

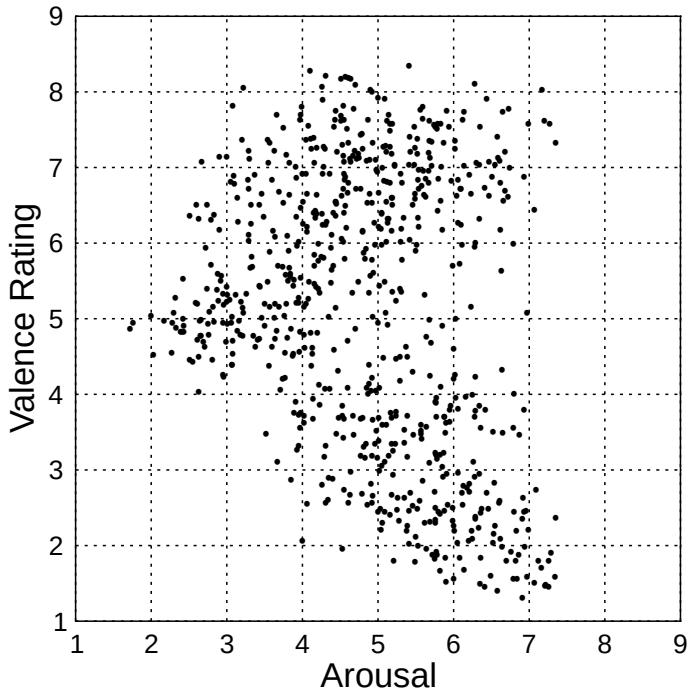


Figure 1. Distribution of valence and arousal ratings for IAPS pictures, adapted from Lang (1995). Valence ratings range from 1 (extremely unpleasant) to 9 (extremely pleasant), while arousal ratings range from 1 (calm) to 9 (highly aroused). Each point represents the ratings for a single picture.

Chapter 2
The Startle Reflex

The startle reflex is a response to sudden, intense sensory stimulation, and consists of several involuntary muscular contractions, cardiovascular reaction, and phasic increase in sweat gland activation (Landis & Hunt, 1939). Graham (1979) posits that the function of the reflex is as "an interrupt system" (p. 151), stopping motor activity and cognitive processing, so that resources can be reallocated toward the potentially threatening cause of the intense stimulus. The response has been characterised (Ekman, Friesen, & Simons, 1985) as a reflex rather than an emotion on the basis of several observations, including: (a) reliability of elicitation across participants; (b) a very short latency to onset (similar to that for other reflexes) and a duration much shorter than emotional experiences (excluding surprise); and, (c) inability of participants to suppress the response.

The use of the startle reflex as a tool that can test an individual's processing of emotional stimuli is covered in the next chapter. The purpose of this chapter is to describe response components of the startle reflex, as well as conditions necessary for the elicitation and recording of the reflex in humans.

Although not the first to extensively describe the startle reflex, Landis and Hunt (1939) reported many of the skeletomuscular and physiological components of the reflex, as triggered by an intense acoustic stimulus. High-speed cinematographic footage was taken of bodily movements in response to a gunshot. In their book "The Startle Pattern" the movement components of the startle reflex were reported, in temporal sequence, as

> Blinking of the eyes, head movement forward, a characteristic facial expression, raising and drawing forward of the shoulders, abduction of the upper arms, bending of the elbows, pronation of the lower arms, flexion of the fingers, forward movement of the trunk, contraction of the abdomen, and bending of the knees... The

> first and most noticeable feature of the facial pattern is the immediate closing of the eyes. (Landis & Hunt, 1939, p. 21)

Not all of the participants in their study showed this exact pattern of whole-body startle (i.e., the entire pattern described above from blink to knee bend), with some participants only showing the eyeblink and head movement components. The variability of response expression was also apparent over repeated presentations of the pistol shot stimulus. Some participants still displayed whole-body startle after 17 consecutive presentations of the stimulus, while the responses of other participants habituated after only a few presentations. Interestingly, the eyeblink component of the response persevered over all the trials, for all participants, independent of the presence or absence of the other response components (Landis & Hunt, 1939). Thirteen of the 15 participants also showed eyeblink responses (with or without other muscle activation) to a less intense acoustic stimulus, an automobile horn. Subsequent studies examining the startle reflex in humans have generally used this eyeblink component as an indicative measure of the startle reflex, although the activity of other muscles involved in the whole-body response have also been measured on occasion (Anthony, 1985).

Most contemporary studies incorporating the startle reflex use less intense stimuli than a pistol shot to elicit the response, such as a short burst of white noise in the range of 90-120 dB (A). The startle reflex produced by a stimulus of this intensity typically consists of bilateral eyeblink, with other involuntary muscle contractions absent from the response (Lang, Bradley, & Cuthbert, 1990). Individual differences in responding to stimuli in this intensity range mean that some other aspects of the whole-body response (e.g., forward movement of the head) are seen with some frequency. The advantages of using a less intense eliciting stimulus are both ethical and practical, reducing participant discomfort as well as minimising artefacts on physiological recordings that can be caused by movement.

Non-muscular physiological components of the startle reflex also occurred in the putatively task-free context of Landis and Hunt (1939). The electrical resistance of the skin (an indirect measure of sweat gland activation) decreased in a phasic response following presentation of the

startling stimulus, indicating an increase in sweat gland activation. The conductance of the skin is now more commonly recorded than skin resistance: although resistance and conductance are reciprocal, skin conductance is more simply and directly related to the physiological change in sweat gland activity than skin resistance (Lykken & Venables, 1971). Furthermore, the measurement of a phasic skin conductance response (SCR) to an event does not depend on the tonic, ongoing skin conductance level (SCL), a condition which is not true of the skin resistance response (SRR) in relation to the tonic skin resistance level (SRL — for an in-depth discussion of the merits of recording skin conductance over resistance, see p. 657-660 of Lykken & Venables, 1971). Following presentation of a startling stimulus, skin conductance increases in a phasic response (the SCR), and begins to return toward baseline levels after a few seconds.

Cardiovascular components of the startle response in Landis and Hunt (1939) consisted of an increase in systolic blood pressure as well as increased heart rate (HR) in the period following startle elicitation. The authors hesitated to attribute these changes to the startle response itself, arguing that they could be concomitant changes that are instead dependent on secondary (i.e., non-reflexive) components of the participant's response to the pistol shot. Gautier and Cook (1997) measured heart rate change patterns to both sustained loud noises and a 50 ms burst of white noise, presented at 100 dB (A), both in the absence of any specific task. Initial heart rate acceleration produced a peak in HR a couple of seconds after stimulus presentation, followed by a return to baseline levels. As participants were seated during this procedure, it is unlikely that the HR changes seen were the consequence of any secondary, non-reflexive behaviours. A similar pattern of heart-rate changes was observed in another task-free context with a slightly longer duration (1 s) white noise stimulus with a short latency (5 ms) to peak intensity (Turpin, Schaefer, & Boucsein, 1999).

Elicitation of the Startle Reflex

The preceding description of the output of the startle reflex is based on a response elicited by a sudden, loud auditory stimulus. The nature of the startle reflex is such that sudden, intense stimuli in any sensory modality should be capable of eliciting the response. The two most

important factors (Turpin et al., 1999) of the eliciting stimulus are (a) intensity and (b) rise-time, this being the latency between stimulus onset and peak intensity.

Landis and Hunt (1939) tested this assumption by using several different eliciting stimuli in addition to the pistol shot: Visual stimulation by firing magnesium photographic flash lamps, and cutaneous stimulation by (a) a jet of cold water directed between the shoulder blades, (b) electric shock to the hand, and (c) a pinprick to the thigh. The visual stimulation was less successful than acoustic stimulation, with only 10 of the 15 participants showing blink responses to it. Leaving aside the ethical considerations involved with the three methods of cutaneous stimulation (the authors suggested the pinprick may have failed to elicit startle because "the pin was not jabbed in hard enough", Landis & Hunt, 1939, p. 49), these seemed less effective at eliciting startle, although this may have been due to the stimuli being less intense than the acoustic stimulus, as was reported by the participants.

Most contemporary methods of startle elicitation include the use of white noise auditory stimuli, usually presented over headphones (e.g., Vrana, Spence, & Lang, 1988), as a practical and more easily standardised analogue to the pistol shot. Visual elicitation of startle is still achieved through multiple synchronised camera flash units (e.g., Witvliet & Vrana, 2000), and several tactile stimuli are used which are again more practical than those used by Landis and Hunt (1939). A puff of air directed to the participant's temple reliably elicits eyeblink (e.g., Hawk & Cook, 1997), as does electrical stimulation of the opthalmic branch of the trigeminal nerve or a mechanical tap to the glabellar region of the forehead, which also stimulates the trigeminal nerve (Berg & Balaban, 1999).

Of these methods, acoustic stimuli are used in the vast majority of studies on emotional modification of the startle reflex, and are the most simple and cost effective manner of eliciting startle. The acoustic stimulus itself is most effective (Berg & Balaban, 1999) when it is of intense volume, contains a wide range of frequencies (i.e., white noise as compared to a pure tone), and has a fast risetime (the latency from stimulus onset to peak intensity). These characteristics are easy to both standardise between laboratories and manipulate in order to test how varying these

characteristics affects the startle reflex.

Although startle can be elicited by lower intensity stimuli (e.g., 50 or 60 dB for a white-noise acoustic stimulus), the probability of a response occurring at these intensities is relatively low, occurring on approximately 45-50% of trials (Blumenthal & Goode, 1991, Experiment 1). More intense stimuli (70 dB) were associated with higher response probability and greater response amplitude (measured from the orbicularis oculi muscle, which is responsible for blinking of the eye: see the section on recording the startle reflex, below), while faster stimulus rise time is associated with larger amplitude responses, but has no effect on response probability (Blumenthal & Goode, 1991, Experiment 3). For white noise stimuli at higher intensities (comparing 95 dB and 100 dB stimuli), changes in rise time had no effect on response probability or amplitude, but the higher intensity stimulus was associated with greater response amplitude (Blumenthal & Berg, 1986). Blink response probability for white noise stimuli in this intensity range is above 90%.

Visual startle elicitation has been used less frequently than acoustic elicitation in studies of emotional processing. Anthony and Graham (1985) and Bradley, Cuthbert, and Lang (1990) used camera flash units to elicit the startle reflex in order to test the differential attentional effects of presenting a startle stimulus and a foreground (i.e., task) stimulus in the same or a different sensory modality. Visual startle stimuli were also cleverly used in a test of startle reflex modification during emotion evoking acoustic stimuli (Bradley & Lang, 2000). All three of these experiments are discussed in detail in Chapter 3.

Blink reflexes elicited by a puff of air directed toward the temple have been used in psychology experiments ranging from classical conditioning in animals to startle modification in humans (e.g., Haerich, 1994). The mechanism of airpuff presentation can be complex, requiring acoustic isolation of valves to prevent noise contamination at the time of stimulus presentation. It has been suggested (Hawk & Cook, 1997) that airpuff-elicited startle allows better testing of laterality effects and startle due to greater hemispheric lateralisation of processing for tactile information compared to acoustic or visual information. The two final methods of tactile startle

elicitation, by electrical stimulation of the trigeminal nerve or glabellar tap, will not be discussed here as they have not been used in studies of emotional modulation of the startle reflex.

Finally, the three modalities of startle elicitation (acoustic, visual, and tactile) produce different expressions of blink response. Cutaneous and acoustic startle stimuli produce larger magnitude (the size of electrical activity associated with muscle activation: see section below on recording startle) blink responses, with shorter stimulus to response onset latencies, than visually evoked startle (van Boxtel, Boelhouwer, & Bos, 1998). Cutaneous elicitation of the startle reflex also shows two response components on electrical recordings of orbicularis oculi activity; an initial response component (R1) from the muscle site ipsilateral to the site of stimulation, and a second, later component (R2) occurring at a latency comparable to that of the acoustically evoked startle blink (Anthony, 1985). Only R2 is related to eyelid closure (Anthony, 1985), and it is this component that is used in studies of the emotional modification of cutaneous startle (e.g., Hawk & Cook, 1997).

Discussion of the startle reflex so far has concentrated largely on a context-free description of the reflex. Landis and Hunt's participants were not asked to perform any other tasks while the startle reflex was elicited, although anticipation of the startle stimulus should be considered as a task in itself, capable of modifying the startle response (Landis & Hunt, 1939; Ekman et al., 1985).When the reflex is elicited in the context of a separate task (e.g., viewing emotional pictures or performing a reaction-time task), the eliciting stimulus is termed the startle probe. This terminology carries the implication that the startle reflex is being recorded as an index of other, ongoing psychological or physiological processes (Dawson, Schell, & Böhmelt, 1999).

Measuring the Startle Reflex

Experiments measuring startle in animals usually quantify startle as the force of cage displacement upon presentation of the startle stimulus (e.g., Brown, Kalish, & Farber, 1951). Some more recent experiments have measured the amount of electrical activity associated with neck muscle activation as an index of startle in the rat (e.g., Cassella, Harty, & Davis, 1986), which can detect

startle potentiation that is unobservable at the level of gross bodily movement (Davis, 1986). Given that most experiments involving human participants involve startle reflexes elicited below the threshold for whole-body responses, quantification of the size of the reflex has concentrated on the first component of the response, the eyeblink.

Four different techniques used for measuring eyeblink have been neatly summarised by Anthony (1985). The force of eyelid closure can be measured by attaching a thread (or similar connective material) to the upper lid which is then connected to a potentiometer. A blink can also be measured by recording changes in reflectance of a light source shining on the eyeball, with reflectance decreasing as the eyelid obscures the eyeball (Anthony, 1985). The blink response may also be quantified by recording the electrical activity associated with the firing of the orbicularis oculi muscle, which is responsible for reflexive and voluntary closure of the eyelid. The electrical activity associated with the muscle firing can be observed through two different recording techniques. A blink appears as an initially positive going wave on the vertical electro-oculogram (EOG), representing electrical activity from the muscle contracting.

The electrical activity concomitant with activation of the orbicularis oculi muscle can be measured more directly by electromyographic (EMG) recordings. Two electrodes are placed on the skin over the muscle, and the differential between these two electrodes is recorded and compared to a reference electrode. Most experiments record orbicularis oculi activity from the orbital section of the muscle (underlying the orbital bone around the lower periphery of the eye), although recordings can be taken from the palpebral section of the muscle by utilising minute electrodes placed on the upper eyelid (see Silverstein & Graham, 1978, for a description). The palpebral section of orbicularis oculi is more closely concerned with reflexive blinking than the orbital section, allowing greater sensitivity in recording startle eyeblink EMG (Berg & Balaban, 1999).

Blink magnitude is calculated from EMG recordings by rectifying the alternating-currentsignal (so that it is rendered entirely positive) and calculating the difference between peak amplitude following stimulus presentation and prestimulus baseline levels. The exact procedure for this is

described in some detail in the method section of Study 2. As the blink component of the startle reflex occurs bilaterally, and there is no lateral difference in expression of the blink (Bradley, Cuthbert, & Lang, 1991, 1996), EOG and EMG measures need only be recorded from one eye. Anthony (1985) reports that EMG has a higher correlation with potentiometric recordings of blink magnitude than EOG. For the remaining discussions of blink reflexes, EMG recordings of activity from the orbital section of the orbicularis oculi are taken as standard — any exceptions will be duly noted in the text.

A final note on recording blink as a measure of the startle reflex should mention a second attribute of the blink reflex that is of psychological interest. The latency of the blink response is the length of time that passes between presentation of the startle stimulus and either the onset of the blink response (referred to as blink latency to onset) or the time at which the electrical activity concurrent with muscle activation reaches it's peak level (referred to as blink latency to peak). The magnitude and latency components of the startle blink reflex are discussed with relation to emotional processing in Chapter 3.

Chapter 3
The Use of the Startle Reflex in Studies of Emotion

Early hopes that investigating the startle reflex would provide "an entirely new approach to a wide variety of problems in the field of emotion" (Landis & Hunt, 1939, p. 4) proved unfulfilled for some time. Early indications that the startle reflex could be modified by emotional experience were provided by experiments looking at fear conditioning and the startle in rats. As measured by a mechanical device that quantified the force of whole-body movements, the startle reflex in the rat was enhanced when elicited in the presence of a conditioned stimulus previously paired with electric shock, compared to startle elicited in rats for whom shock had not been contingent on the presence of these cues (rats were matched between groups on preconditioning startle levels; Brown et al., 1951). From this point, investigations into the properties of startle in humans generally considered the effects of attentional factors on the reflex.

It was research on attentional modulation of startle that perhaps inadvertently led to the rediscovery of startle modification by emotional context. Examining infants and adults respectively, Anthony and Graham (1983) and Simons and Zelson (1985) found that the eyeblink component of the startle response was inhibited when the participant was viewing interesting as compared to dull pictorial stimuli. Both infants and adults also showed enhanced startle blink magnitude when the probe stimulus was in the same sensory modality as the interesting foreground stimulus (Anthony & Graham, 1983, 1985). These results were taken as evidence in favour of a modality matching hypothesis of stimulus processing, where the processing of an incoming stimulus (in this case, the startle probe) is enhanced if attention is already allocated to the sensory modality in which the probe stimulus occurs, and inhibited if there is a modality mismatch between the foreground and the probe stimuli (Simons & Zelson, 1985).

The results of the aforementioned studies, employing interesting and dull picture stimuli, can be reinterpreted in the light of subsequent research. Using an almost identical experimental paradigm, Vrana et al. (1988) compared startle reflexes that were elicited during three differ-

ent types of foreground picture stimuli, varying not only in terms of their interest levels, as in Anthony and Graham (1983, 1985) and Simons and Zelson (1985), but also in terms of the emotional valence of their content. These three categories varied along a continuum of emotional valence, starting with positive pictures (including erotic images, food, sports events), then moving to a neutral category (e.g., household furniture, abstract patterns) and finally a negative category (e.g., dead bodies, crying children, snakes and spiders, guns aimed at the viewer). The interesting categories of the previous experiments (Anthony & Graham, 1983, 1985; Simons & Zelson, 1985) had included pictures that would now fall into the positive emotional category in Vrana et al. (1988), and so the negative emotional category represents an addition to the original paradigm.

When startle was elicited by an acoustic probe during negative content pictures, blink magnitude was enhanced compared to startle during neutral and positive pictures. This study also replicated the finding of startle inhibition during positive content pictures (equivalent to the interesting pictures in the earlier studies), compared to neutral content pictures (Vrana et al., 1988). The difference in startle blink magnitude during positive and negative picture contents could not reasonably be ascribed to attentional differences — negative pictures received interest ratings from participants that were higher than those for neutral pictures, and participants viewed negative and positive pictures for similar periods of time in a free-viewing task, suggesting equivalence in subjective interest (Vrana et al., 1988). Taken as a whole, these results are not consistent with a modality matching model of startle modification, unless it is presumed that negative visual material engaged the participants' attention to a lesser degree than positive visual material; subjective interest rating reports and free-viewing times that were longer than for neutral stimuli suggest this was not the case.

The findings of Vrana et al. (1988) are consistent with the predictions of Lang's (1985) response matching model, where it is posited that elicited reflexes will be modulated depending on their congruency with the individual's ongoing motivational state. The startle probe elicits a defensive reflex, which should therefore be heightened if elicited during an aversive motivational state (e.g., viewing negative picture contents), and diminished if elicited during an appetitive

motivational state. Likewise, probe events that elicit an appetitive reflex should produce enhanced responding if the ongoing motivational state is appetitive, and diminished responding during an aversive state (Lang, 1985; Vrana et al., 1988).

Support for this model, and further evidence against the modality matching model, came from an experiment that used startle probes in two distinct sensory modalities, as had previously been done with infants and adults during dull and interesting foreground stimuli (Anthony & Graham, 1983, 1985). The modality matching model implies that the enhanced startle responding for an acoustic probe during a negative visual foreground is due to decreased attention to the attended sensory channel, and so increased attention to the non-attended modality in which the probe was presented. If this was the case, then presenting a startle probe that matches the foreground modality should produce decreased startle responding during negative picture contents, and conversely enhanced responding during positive picture contents, where attention is supposedly directed toward the visual modality (Bradley et al., 1990). Using this dual probe modality design during viewing of emotional photographs, blink magnitude for startle elicited both by acoustic (modality mismatched) and visual (modality matched) startle probes followed identical patterns to those obtained by Vrana et al. (1988) — enhanced blink magnitude during negative, and diminished magnitude during positive, relative to neutral, foregrounds (Bradley et al., 1990). These results added strong support to the response matching model of startle modification, and opened the way for startle probe methodologies to be used in research on emotion.

Further clarification of the validity of the response matching model is provided by testing other assumptions of the model. Firstly, a motivationally neutral reflexive response (i.e., specific to neither defensive nor appetitive motivational behaviours), specifically, the spinal tendinous or T-reflex, was not modified on the basis of foreground emotional valence (Bonnet, Bradley, Lang, & Requin, 1995). When elicited during the viewing of a variety of emotional pictures, the T-reflex was sensitive to differences in foreground arousal levels. Highly arousing foreground materials of both positive and negative emotional content led to augmentation of the reflex, thus demonstrating that the reflex modulation seen in the startle probe paradigm with emotional foregrounds is specific to the defensive nature of the startle reflex itself, rather than being common

to all reflexive systems (Bonnet et al., 1995).

A second and problematic issue with startle probe methodology and the response matching model lies with the emotional valence of the startle-eliciting probe. The model predicts the effects of a match (or mismatch) between the emotional valences of a foreground stimulus and an elicited reflex (Lang, 1985, 1995). At times, however, researchers (e.g., Bradley et al., 1990; Hawk & Cook, 1997) have interpreted the matching procedure as being between foreground valence and the valence of the probe stimulus, as opposed to the valence of the reflex elicited by the probe. This type of matching system is referred to as stimulus matching (Witvliet & Vrana, 2000). Bradley et al. (1990) found that the blink magnitude of startle reflexes to a visual probe were only modulated by foreground valence for participants who rated the visual probe as highly aversive, although the startle reflex itself was still reliably elicited in participants who did not rate the visual probe as aversive. During a different kind of emotional task, Witvliet and Vrana (2000) found significant emotional modification of startle by visual probes only for those participants who did not find the probes aversive. The method and results of this study are covered in more detail in the next section.

Presentation of a tactile startle probe, a puff of air directed toward the participant's temple, also reliably elicited the startle reflex despite being rated as non-aversive by ninety-five percent of participating individuals (Hawk & Cook, 1997). Emotional modulation of startle blink magnitude by tactile startle probe stimuli was not entirely consistent with the incremental linear pattern predicted with increasing foreground unpleasantness, and although blink magnitude was greater for negative than for positive pictures, negative foreground blink magnitude was roughly equivalent to that obtained during neutral valence foregrounds (Hawk & Cook, 1997), indicating that startle modulation was occurring primarily with blink inhibition during positive foreground content, rather than this in combination with blink facilitation during negative foregrounds. The authors suggest an attentional explanation for the unexpectedly high blink magnitude during neutral pictures, in that reduced attention to the (non-engaging) visual foreground should leave more resources available to process the tactile startle probe. As the authors readily admit, it is not apparent why such an effect would occur when startle is elicited by a tac-

tile probe, but not when elicited by an acoustic probe, which should also show such increases for non-engaging neutral stimuli (Hawk & Cook, 1997). It is possible that this result is due to the non-aversive nature of the tactile airpuff probe, as observed with some participants with the visual startle probe in Bradley et al. (1990), rather than being a characteristic specific to tactile-probe elicited startle alone. Testing this hypothesis will be important both for the continued use of tactile startle probes in emotional research and also in addressing the inconsistency as to whether the response matching model requires a valence match between foreground and reflex or foreground and probe.

Imagery and Other Emotional Foregrounds

Before continuing discussion of the response matching model, a description of a different method of evoking emotion is needed. The startle probe, according to the response matching model, should produce the same pattern of emotional modulation equally well across all modalities of both probe and foreground stimulus. This section deals with the use of mental imagery to produce certain emotional states in the participant. A typical experiment (e.g., Vrana & Lang, 1990) gives the participant several scripted sentences, of varying emotional content, for which the participant is asked to form a vivid mental image in response to an acoustic (non-startling) cue tone. As with experiments using photographic stimuli, multiple types of emotional events can be scripted for according to the demands of the experimental hypotheses. Mental imagery is potentially a more ecologically valid method of emotion elicitation than picture viewing: physiological indicators of emotional activity such as heart rate tend to approximate the patterns of activity during actual emotional events more closely in imagery procedures than in picture viewing, so that forming a mental image of an emotional event produces an attenuated emotional response of the same nature as that which would occur if faced with the same event in reality (Vrana & Lang, 1990). It is possible that these differences may be due to task demands related to the imagery rather than the emotional states produced (Vrana, 1995).

Generally speaking, experiments using mental imagery to prime the startle reflex have found the same type of responding observed in picture viewing procedures — startle augmentation

during negative emotional states and inhibition of the reflex during positive states (Cook, Hawk, Davis, & Stevenson, 1991; Vrana, 1995; Vrana, Constantine, & Westman, 1992), although several experiments have found startle potentiation during highly-arousing positive imagery (Miller, Patrick, & Levenston, 2002; Witvliet & Vrana, 1995, 2000). These experiments and their implications are discussed in the section on emotional arousal and the startle reflex toward the end of the chapter. The importance of using different modality foregrounds to test models of emotional modulation need not be stressed further here.

Several further factors tested in some of these experiments do bear directly on the competing response, stimulus, and modality matching explanations of startle modification. Vrana (1995) attempted to manipulate the predominant sensory modality of mental imagery by emphasising either visual or auditory elements of the to-be-imagined emotional scripts. Startle, as elicited by an acoustic probe, was augmented during fear imagery relative to neutral and pleasant imagery, although the two latter categories were undifferentiated from one another. This pattern of blink magnitude was independent of whether the imagery scripts were primarily visual or auditory in nature (Vrana, 1995). Ratings of subjective pleasantness, arousal, and vividness of images formed were also the same for both acoustic and visual scripted imagery, although no reports were collected from the participants as to whether the images they formed were predominantly visual or auditory (it is recognised that the use of the term imagery to describe mental processes that may be primarily auditory seems somewhat antithetical). The absence of effects of sensory modality was taken as evidence against mental imagery being specific to sensory modality areas (Vrana, 1995), suggesting that emotional imagery is not a useful paradigm in which to test foreground modality effects.

Although most studies of startle modulation during imagery have used acoustic startle probes, Witvliet and Vrana (2000) used a visual probe to elicit the startle reflex in their participants. Using four emotional categories (both high and low arousal, positive and negative valence scripts), blink magnitude was greater during negative valence imagery than during positive valence imagery. The effects of varying arousal are discussed in the following section dealing with arousal and startle. Contrary to the findings of Bradley et al. (1990), dividing participants into two

groups by their ratings of visual probe aversiveness and arousal revealed that emotional modulation of startle was only present in the low-aversiveness group — the high-aversive group did not show any pattern of blink modulation by valence or arousal in response to the visual probe (Witvliet & Vrana, 2000). This emotional modulation of startle elicited by a non-aversive probe is clearly evidence for a response-matching rather than stimulus-matching account of emotional startle modification. The authors suggest that emotional modulation of startle did not occur in participants who found the visual probe highly aversive because anticipation of the subjectively aversive probe may have interfered with their ability to form vivid mental images (Witvliet & Vrana, 2000). Such interference is presumably less likely to interfere with the more passive activity of picture viewing.

An exact inversion of the original visual foreground, acoustic probe paradigm has been conducted using emotionally-toned sound clips (e.g., laughter, screaming) as foreground materials and a visual startle probe. Once again, startle blink magnitude was larger when elicited during negative foregrounds and inhibited during positive foregrounds, with responses during neutral stimuli falling in between the two emotionally valent categories (Bradley & Lang, 2000).

A brief mention will also be made here to several other types of foreground that have been used to test emotional modulation of startle. Video footage, including both entertainment films and more specifically sourced material such as demonstrations of surgical technique, has been used to evoke emotional responses, and for the most part these audiovisual stimuli have been successful in producing startle modulation in accordance with response matching predictions (Jansen & Frijda, 1994; Kaviani, Gray, Checkley, Kumari, & Wilson, 1999; Kumari et al., 1996). Failure to produce startle blink attenuation during positive film clips by Jansen and Frijda (1994) was attributed to the fact that many participants not finding the sexually-explicit positive film clips pleasant. Similarly, a film clip depicting toe surgery failed to augment startle responding in Kaviani et al. (1999) — this will be discussed in the introduction to Study 3.

Pleasant and unpleasant odours have also served as foreground stimuli for startle modification studies (Ehrlichman, Brown, Zhu, & Warrenburg, 1995; Ehrlichman, Brown Kuhl, Zhu,

& Warrenburg, 1997; Miltner, Matjak, Braun, Diekmann, & Brody, 1994). All three of these experiments found heightened startle blink magnitude during unpleasant odours, when compared to startle during a no-odour condition. Inhibition of startle during pleasant odour stimulation has been less consistent, and only the most recent of these studies (Ehrlichman et al., 1997) found a significant level of startle inhibition during positive odours. This study used a between-subjects design to prevent confounding of positive odour perception by negative odour presentation (Miltner et al., 1994, had presented participants with their negative and positive odours in separate sessions a week apart). The positive and negative odours were also limited to one exemplar of each, which were matched in terms of hedonic valence (that is, both pleasant and unpleasant were of the same absolute difference in valence from neutral; Ehrlichman et al., 1997); compare Ehrlichman et al. (1995), where there were six odours in each of the pleasant and unpleasant odour conditions. Using these hedonically matched odours and a between subjects design, both unpleasant and pleasant odours successfully modified startle relative to the no-odour condition (Ehrlichman et al., 1997), in the manner predicted by the response matching model (Lang, 1985).

Arousal and Startle Reflex Modification by Emotion

Looking back to the two-dimensional model of emotion outlined by Lang (1985), we should consider the second dimension of emotional experience, arousal, and how this dimension impacts on two components of the startle reflex, the magnitudes of blink and skin conductance responses to the startle probe.

Varying the arousal characteristics of pictures within each of the three standard emotional categories (positive, neutral, and negative) has a revealing effect on startle responding to those pictures. Cuthbert, Bradley, and Lang (1996) divided each category into three groups on the basis of subjective arousal ratings, providing high, medium, and low arousal examples for each valence condition. As neutral pictures increased in arousal, blink magnitude also increased, showing the effects of “arousal without valence” (Cuthbert et al., 1996, p.109). For the affective picture categories (positive and negative), the results were more unexpected — only the

highly-arousing positive and negative pictures produced significant startle modification from the neutral condition.

Codispoti, Bradley, and Lang (2001) elicited startle during or following a 500-ms picture presentation across positive, neutral, and negative categories. Although startle blinks were greater in magnitude for negative compared to positive pictures, the difference between negative and neutral did not reach significance at any probe time. The difference between negative and neutral still did not reach significance when these pictures were split into high and low arousal subgroups (Codispoti et al., 2001), as might have been predicted on the basis of Cuthbert et al. (1996). The post-hoc nature of this split in the later study (Codispoti et al., 2001) may mean that the high-arousal pictures were not equivalent in intensity to the earlier study's high-arousal category.

Imagery studies looking at arousal and startle show a different pattern of results from picture based studies, perhaps reflecting different attentional demands of the two paradigms. Witvliet and Vrana (1995, 2000 — the first of these studies employed an acoustic startle probe, the second a visual one) found separate effects on startle blink magnitude for script arousal and script valence. Highly arousing imagery was associated with greater startle blink magnitude than the low arousal imagery, while within each arousal level, negative imagery showed greater blink magnitude than positive imagery. Thus the greater startle magnitude seen in the high-arousal condition was not due only to the high-arousal negative condition. These two effects of arousal and valence were independent of one another, producing a summational effect on blink magnitude modification, so that high-arousal positive imagery produced a similar blink magnitude to low-arousal negative imagery (Witvliet & Vrana, 1995, 2000).

The arousal characteristics of foreground stimuli are more simply related to the skin conductance component of the startle reflex. While blink magnitude increases as the unpleasantness of the foreground increases, the magnitude of SCRs increases with arousal, so that positive and negative emotional stimuli, matched on arousal characteristics, will produce equivalent SCR magnitudes in response to the startle probe (e.g., Bradley et al., 1990). Some experiments (e.g.,

Bradley, Lang, & Cuthbert, 1993) report greater startle SCR magnitude during negative compared to positive stimuli, although this often indicates that the selected materials were not in fact matched in terms of arousal characteristics (as was the case in the cited study). This in turn reflects the difficulty in matching positive and negative stimuli for emotional arousal, as can be seen in Cuthbert et al. (1996), where SCR magnitude increased with arousal across all three valence categories, but was at a higher level for negative contents of low and medium arousal relative to the corresponding positive categories. Normative ratings of picture arousal (depicted in Figure 3 of Cuthbert et al., 1996) show that most people viewing these pictures rated these low- and medium-arousal negative contents as more arousing than their positive category equivalents.

Startle Reflex Inhibition During Emotionally Positive Stimuli

A personalised imagery study by Miller et al. (2002) clarifies these findings regarding startle blink magnitude during imagery, but also raises several questions that are central to theory regarding emotional modification of startle. Miller et al. (2002, Experiment 2) used two different types of imagery script for each of their emotional categories: standardised scripts, developed by the experimenters for use with all participants (as had been done with all of the imagery experiments previously detailed); and personalised scripts, developed by the experimenter in conjunction with each participant to produce a more effective and appropriate emotional response. Imagery based on these personalised scripts was rated by participants as more arousing, more interesting, and more vivid than standardised script imagery. Both standard and personal negative script imagery produced greater startle blink magnitude than neutral scripts. As observed by Witvliet and Vrana (1995, 2000), positive emotional imagery also produced potentiated startle. This potentiation was greater still for personal compared to standard imagery scripts. Given the subjectively more arousing nature of these personal positive scripts, which also elicited greater magnitude SCRs to the probe than standard scripts, it seems there is strong evidence that startle modification during positive imagery is dependent on emotional arousal (Miller et al., 2002).

The authors hypothesised that increasing arousal levels has differential effects on startle in pic-

ture viewing and imagery because, in the first instance, perceptual engagement increases with arousal, leading to a reduction in the attention that is directed to the startle probe, and hence inhibition of the reflex. As there is no perceptual engagement in the imagery task, it was proposed that increased non-perceptual mental processing is associated with heightened startle (Miller et al., 2002), a position that is backed up by data from startle elicited during a non-emotional cognitive task which varied in cognitive demand: Startle blink magnitude was enhanced during an eight second rehearsal period between presentation of a digit series and recall of that series, compared to blink magnitude during the digit presentation period (Panayiotou & Vrana, 1998). Although this hypothesis is advanced as tentative, it does open up further considerations:

1. Does the positive emotion experienced during this imagery have an inhibitory effect on startle that interacts with the proposed effects of mental engagement?

2. Is the startle potentiation observed during negative emotional imagery due to emotional content or to mental engagement, or, again, a combination of the two?

3. Is the startle inhibition seen during arousing positive picture stimuli an effect of perceptual engagement, emotional content, or both?

Answering these questions requires discussion of experiments that compare startle responding between different varieties of positive emotional stimuli.

Cuthbert et al. (1996), described above, found that startle inhibition for positive contents was significant during highly-arousing stimuli only. Levenston, Patrick, Bradley, and Lang (2000, for non-psychopathic male prison inmates; see next section for a fuller description of this study) found blink inhibition for positive contents was only associated with erotic picture contents, and ‘thrill’ picture contents (e.g., adventure sports such as rafting and skiing) were associated with blink potentiation in this sample. This result was replicated in a sample of male undergraduate students, although potentiation for thrill relative to neutral contents was not significant (Bernat, Patrick, Benning, Blonigen, & Hicks, 2002). In both of these studies, erotic contents were rated as more arousing than thrill contents, and so the difference in blink inhibition cannot be

ascribed to content type rather than emotional intensity in these instances. The undergraduate sample also showed an effect for intensity within the erotic content category, as only medium- and high-arousal erotic contents produced significant inhibition, a finding in line with Cuthbert et al. (1996).

In female undergraduates, blink inhibition for positive picture contents was again limited to erotic picture contents, and did not occur during nurturant or action (similar to thrill content type described above) contents (Bernat, Patrick, Steffen, & Sass, 2002) — action content blinks were potentiated relative to neutral, an effect that only approached significance, although these data were from a preliminary report (n = 21). Erotic and action contents were matched here on normative arousal ratings, so the observed differences in blink modification can be ascribed to differences in the emotional content rather than to effects of stimulus intensity.

Two papers discussing the same experimental data set will be discussed separately here (Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley, Codispoti, Sabatinelli, & Lang, 2001). The experiment involved elicitation of the startle reflex during multiple positive, neutral, and negative photographic contents. The eight specific positive categories were, in order of normative arousal ratings, nature, families, food, adventure, sports, opposite-sex erotica, and erotic couples. The number of participants (n = 85, 45 female) and pictures per condition (n = 4) were very high, although startle probes were only presented on half of the pictures presented in each category. The first study (Bradley, Codispoti, Cuthbert, & Lang, 2001) considers the data set as a whole, and found that across the eight positive picture contents blink magnitude decreased as content arousal increased. The erotic contents appeared to be the only categories for which blink inhibition (relative to neutral) was significant. Same-sex erotic photographs produced startle inhibition to the same degree as opposite-sex erotica, despite other aspects of emotional responding (facial muscle activity, self report) being more indicative of a negative emotional state during these picture contents.

The second study (Bradley, Codispoti, Sabatinelli, & Lang, 2001) examined these same data while considering differences in responding between male and female participants, with blink

magnitude for both genders decreasing for positive contents as arousal increased. The previously noted blink inhibition for same-sex erotica was evident for both males and females. Blink inhibition for the positive category (as a whole) relative to neutral was only significant for male participants. Although pairwise comparisons between each specific positive content and the neutral category were not reported, it seems likely (from visual inspection of figures) that blinks for the most highly arousing positive contents, opposite sex erotica and erotic couples, would have been inhibited relative to neutral for both males and females.

One final study should be discussed here regarding positive stimuli. Individuals who have been deprived of food (for either six or twenty-four hours) show potentiated startle blinks during presentation of food photographs, while non-deprived individuals show blink inhibition for these same stimuli (Drobes et al., 2001, Study1). The authors suggest that this potentiation could be caused by frustrative non-reward leading to activation of aversive motivational systems, because appetitive cues (the food stimuli) are presented but cannot lead to reward (the participants could not eat the photographic stimulus).

The current status of theory regarding startle responding during positive stimuli is not entirely clear. It is evident from the studies described above that not all pleasant stimuli lead to startle inhibition, although whether this is due to the arousal qualities of the foreground or to more specific emotional processes (e.g., limited to sexual material) requires further investigation. This question is related to an even more interesting question that impacts on a basic assumption of the startle modification paradigm, that startle blink inhibition during positive emotional stimuli is due to engagement of appetitive motivational systems. If blink inhibition is limited to highly-arousing positive stimuli, then this could indicate support for the attentional engagement hypothesis proposed by Simons and Zelson (1985) and Anthony and Graham (1985), whereby more highly interesting/arousing visual stimuli divert attention from the acoustic startle stimulus. The results from studies of startle during positive imagery of varying intensities (Witvliet & Vrana, 1995, 2000; Miller et al., 2002) are more in line with this hypothesis than with the motivational priming hypothesis.

The answer to this question is very important for understanding emotional responding, but the outcome would not negate the conclusions regarding startle potentiation during negative foregrounds. Revisions of theory regarding startle modification are currently in progress, with resolution of the effects of attentional and emotional processes being of particular interest (Bradley and Lang, 2001, cited in Codispoti et al., 2001, not yet published at time of writing).

Applied Use of the Emotional Modification of Startle Paradigm

The final section of this chapter will examine three areas of clinical interest where responses in the startle probe paradigm further the validity of the startle modification paradigm: depression, eating disorders, and psychopathy.

Depression is thought to influence the processing of both negative and positive emotional stimuli, overemphasising the importance of the first type while reducing perception of the second type. These two aspects of emotional processing in depression may be present to different degrees, and the startle reflex paradigm offers an ideal method to test the relative influence of these two processes. When startle responding in a standard three-content picture viewing paradigm was assessed for a group of clinically depressed (but medicated) individuals, these individuals showed no significant differences between the emotional categories (Allen, Trinder, & Brennan, 1999). When the depressed participants' data were analysed separately for groups on the basis of severity of depression as measured by the Beck Depression Inventory (BDI; Beck, 1967), there was an interaction between picture content and severity of depression. Startle reflex modification in the moderate BDI score group showed the expected pattern of results, as did the results from a non-depressed control group. Participants in the severe BDI score range showed an abnormal pattern of startle modification: blink magnitude for negative and neutral contents were undifferentiated from one another, while blink responses during positive picture contents were of significantly greater magnitude than either negative or neutral contents (Allen et al., 1999).

These differences in blink modification were observed even though the depressed individuals did not differ from the non-depressed controls in their ratings of pleasantness or arousal for the different picture content categories. Dividing participants into groups on the basis of score on measures of anxiety or anhedonia did not reveal differential startle modification patterns. The authors suggest that for the severely depressed individuals, stimuli that are positive for non-depressed individuals actually engage negative emotional systems in the brain, although it is also possible that the results indicate a deficit in the allocation of attention to positive emotional stimuli in severely depressed individuals (Allen et al., 1999).

A comparison can be made between the startle responding of depressive patients and food-deprived individuals (Drobes et al., 2001, Study 1); both groups of individuals show abnormal startle responses to what are positive stimuli for the general population, possibly as a function of frustrative non-reward (Allen et al., 1999). A final caveat regarding this study is that all of the depressed participants were taking antidepressants at the time of testing (Allen et al., 1999), which intuitively suggests that any effects of depression on startle modification should be diminished. Testing depressed individuals when they present for clinical treatment (i.e., before receiving medication) would confirm the nature of startle responding in this group, as well as ruling out possible interference between the medication and responding. It is possible that non-medicated, moderately depressed individuals would show a similar pattern of results as that seen with the severely depressed group in Allen et al. (1999).

Food deprivation has been shown to change startle modification for food photographs from blink inhibition (for non-deprived participants) to blink potentiation (Drobes et al., 2001, Study 1). Female participants who reported eating patterns similar to those for bulimics (i.e., binge eating) showed startle modification that was similar to food-deprived individuals, with blinks during food photographs potentiated relative to neutral content blinks (Drobes et al., 2001, Study 2). Startle blink responding for participants who reported eating patterns more analogous to anorexia (i.e., restrained eating) showed startle inhibition for food photographs, just like non-deprived participants. All participants in this study rated the food stimuli as pleasant and arousing, which adds some support to the interpretation that the abnormal patterns of respond-

ing shown by the food deprived and bulimia-like participants was due to frustrative non-reward rather than these participants finding the food stimuli aversive (Drobes et al., 2001). However, startle responding does not always conform to subjective pleasantness ratings, as described in the cases of depressed patients (above) and psychopathic criminals (below).

Psychopathic individuals are another group who process emotional information abnormally. Psychopathy as a disorder consists of two distinct tendencies, the first of 'emotional detachment' from others, and the second being a disposition toward 'antisocial behaviour' (Patrick, Bradley, & Lang, 1993). The startle blink magnitudes of psychopaths during negative emotional stimuli were inhibited, rather than potentiated, relative to neutral slide blinks, a trend that was apparent only for those psychopathic individuals with high levels of emotional detachment (Patrick et al., 1993). These negative contents were rated as emotionally unpleasant in the self-reports of these psychopathic participants, probably indicative of "a superficial grasp of emotional language" (Patrick, 1994, p. 324) in these participants, even in the absence of normal emotional processing for unpleasant materials. Subsequent work has shown that these abnormally inhibited responses are only apparent for negative pictures portraying bodily mutilation or other-directed assault: Images that represented a threat to the viewer did not produce inhibited startle in psychopathic participants (Levenston et al., 2000). This observation is discussed again in the introduction to Study 3. The startle modification data thus support the theoretical position that psychopaths are deficient at processing emotionally negative information (Levenston et al., 2000; Patrick et al., 1993; Patrick, 1994). Furthermore, data from the most recent of these studies suggest that negative emotional information involving an external referent (i.e., a threat directed toward another individual) is processed more abnormally in these individuals than emotional information that is self-referent (i.e., threats directed toward the viewer).

The results of these studies on startle modification for individuals with depression or psychopathy show that the paradigm is valid for testing assumptions about the processing of emotional information.

Blink Latency to Peak

Experiments on emotional modification of startle that have measured the latency to onset of blink responses have found effects that mirror those for blink magnitude — blink onset is facilitated (occurs earlier) during negative emotional states, and is delayed during positive emotional states, relative to neutral state responses (Bradley et al., 1990; Bradley, Cuthbert, & Lang, 1993; Cook, Davis, Hawk, Spence, & Gautier, 1992; Kaviani et al., 1999; Patrick et al., 1993; Simons & Zelson, 1985; Vrana & Lang, 1990; Vrana, 1994; Witvliet & Vrana, 1995). Note that some of these experiments employed only negative and neutral emotional states, others only negative and positive states.

In experiments where blink magnitude did not follow the expected pattern across valence categories (potentiation for negative, inhibition for positive contents), blink latency followed the same pattern as blink magnitude. For instance, in Cook et al. (1992), low-fear participants (preselected on the basis of FSS-III scores) showed no difference in blink magnitude between neutral and aversive contents, and blink latency to onset also did not differ across content types for these participants; in Vrana (1995), positive script imagery blink magnitude was not inhibited, and blink latency for this category was also no different from neutral; Kaviani et al. (1999) did not find blink magnitude potentiation for a disgusting film clip (see Study 3), and blink onset was not different from neutral for this film clip; and the participants with psychopathy in Patrick et al. (1993), who showed no blink potentiation for negative picture contents, also did not show onset facilitation for this category.

It is also possible that the arousal characteristics of an emotional state play an important part in modifying latency to blink onset. Cook et al. (1991) found blink onset facilitation for highly arousing compared to less arousing imagery, averaged over positive and negative valence scripts; this effect is consistent with their blink magnitude findings in that valence effects on blink magnitude (differences between positive and negative imagery) were only significant for the low-arousal contents, and not high-arousal contents. High-arousal positive and negative imagery blink magnitudes did not differ, and blink latency to onset for these scripts was shorter

than for the smaller, low-arousal script blinks. Witvliet and Vrana (1995) also suggested an arousal component to blink onset facilitation, in that blinks during high-arousal imagery were facilitated relative to blinks during low-arousal imagery. In this experiment, arousal and valence were confounded to a certain extent, so that the pattern of blink magnitude and latency varied almost exactly along the dimension of arousal (i.e., lowest arousal imagery script had smallest/slowest blinks, and highest arousal imagery script had largest/fastest blinks). This issue is covered in more depth in the introduction to Study 4.

Using an experimental design similar to Miller et al. (2002, Experiment 2), where positive imagery produced blink magnitude potentiation, it might be possible to assess the effects of arousal on blink latency more effectively. It may also be possible to discern whether blink onset latency covaries with blink magnitude, so that blink latency is always facilitated in situations where blink magnitude is potentiated, or is altered differently for positive and negative emotional processing.

The pattern observed across all the studies described above is that blink magnitude and onset latency are closely related. Three studies should be noted where blink onset results were different from the pattern of blink magnitude. Cuthbert et al. (1996) varied arousal and valence qualities of their picture sets and found blink magnitude modification by valence that depended on the arousal dimension of the stimuli. Blink latency did not differ as a function of valence, arousal, or their interaction. Balaban and Taussig (1994) found no difference in blink latency between emotional categories (disgust, fear, neutral, and positive) despite significant blink magnitude modification for the fear and positive conditions. This experiment is discussed in more depth in the introduction to Study 3. Finally, in a film clip study, Kumari et al. (1996) found blink onset facilitation for both positive and negative conditions relative to neutral, despite finding blink magnitude inhibition for the positive condition. This finding suggests an arousal mediated effect of emotional content on blink onset latency, rather than a valence mediated effect.

The majority of studies on blink latency show that response onset is facilitated under those conditions where blink magnitude is potentiated, and delayed when blink magnitude is inhibited.

This could be due to parallel effects of emotional processing on these components of the blink response (e.g., negative emotional states prepare both for larger and faster blinks) or could be a simple effect of the response properties (e.g., larger magnitude blinks always have a faster onset). The effects of arousal on blink latency to onset are not clear at present.

Summary.

To summarise this chapter, it has been demonstrated repeatedly that the startle reflex is modified by the valence of emotional information being processed by an individual. The validity of this position has been reinforced (a) by the use of multiple methods of emotional induction to ensure that the noted effects are not specific to or caused by a particular task (e.g., picture viewing); and (b) by elicitation of startle through various sensory modalities (e.g., visual, auditory, or tactile) so that it is again clear that responses observed for different emotional foregrounds are related to the emotional state of the individual, rather than other characteristics of the stimulus that elicits this state or of the stimulus used to trigger startle. Finally, two situations (depression and psychopathy) were detailed in which clinically-described abnormalities in emotional processing manifested themselves as deviations from the expected pattern of startle responses to emotional stimuli. Blink latency to onset was facilitated in a similar pattern to blink magnitude.

On the basis of these results, it seems that the startle reflex provides a valid indication of the individual's underlying emotional state, at the level of whether the state is aversive or appetitive. Some qualifications to this statement have already been noted (e.g., with regard to the foreground's arousal characteristics), and more will be raised in the introductions to the following sections.

Study 1

This first study was conducted simply to obtain ratings of valence and arousal for a substantial subset of IAPS photographs (Lang et al., 1999a). The set comes with standardised ratings for all pictures (Lang et al., 1999b), including separate reports of ratings for male and female participants. The main purpose of this study was to ensure that picture ratings used to select pictures for experiments on New Zealand participants were valid.

Part of the rationale behind the acquisition of ratings was based on two potentially major differences between New Zealand and the United States (where the standardised ratings were collated) regarding snakes and firearms. Firstly, New Zealand has no wild snake population, and so the actual threat of encountering a snake in New Zealand is negligible. Secondly, pistol ownership is rigidly restricted so that pistol owners may only store and use their pistols at registered and monitored pistol clubs. The majority of New Zealanders therefore would only have vicarious exposure to these two threatening situations, through media and popular cultural references. It should be acknowledged that while this may also be the case in other countries, the purpose of this study was to ensure that these stimuli were perceived as unpleasant by New Zealand participants. Photographs of snakes and firearms are frequently used to evoke fear experimentally, representing of two different classes of threatening stimuli: Those such as snakes that may have been of importance to survival during the course of human evolution (phylogenetic fear-relevant stimuli) and those that have only emerged as threats to survival recently in terms of the human species (ontogenetic fear-relevant stimuli). Study 2 contrasts startle potentiation between these two types of negative stimuli.

Participants rated pictures with a computerised (Jones, 2000a) version of the Self-Assessment Manikin (SAM; Hodes, Cook, & Lang, 1985). The SAM is a graphical rating scale comprised of three separate measures tapping three dimensions of emotion: valence, arousal, and dominance. Each scale has five anchor points, represented by cartoon-like pictures of a person in

different emotional states (presented in Appendix A). The computerised SAM used in this study produced values from 1 to 9 for each dimension, with each anchor point on a scale producing a discrete score for that dimension (i.e., the characters in Appendix A produced scores of 1, 3, 5, 7, & 9). The valence dimension ranges from very unpleasant (a score of 1), through neutral, to very pleasant (score of 9). The arousal dimension ranges from no arousal (score of 1) to highly arousing (score of 9). The dominance dimension covers how in control of their emotional experience the participant felt while viewing the picture, and ranges from highly dominated (score of 1) to highly dominant (score of 9). Dominance ratings were taken but not analysed in this study, for reasons given in Chapter 1.

Participants also filled in several questionnaires to assess their fear levels in several situations. The questionnaires given were of two types. Three questionnaires (Klorman, Weerts, Hastings, Melamed, & Lang, 1974) were designed to measure specific fears: toward snakes (the SNAQ), spiders (SPQ), and blood or bodily mutilation (MQ). The questionnaires require participants to read each of a series of statements (e.g., “I feel sick when I see a spider”) and indicate whether they believe the statement is true or false for them. Several items on the SNAQ and SPQ were changed to be more applicable to New Zealand participants (e.g., references to locations on the American continents where snakes and large spiders are highly prevalent were changed to Australia). The revised questionnaires are included in Appendix B, and the changes are duly noted there.

A fourth questionnaire was designed to measure fear toward a variety of situations, hence producing a non-specific total fearfulness score, and was produced by selecting items from the second Fear Survey Schedule (FSS-II; Geer, 1965). For the sake of brevity this questionnaire is referred to as the FSS in the following results sections of this thesis; references to other experiments that used one of the FSS measures will specify which FSS version was used. The items included on this revised schedule are presented in Appendix C.

There were no experimental hypotheses, as such, for this study: It was predicted that ratings of pleasantness and arousal would differ depending on the participants’ self-reported fear levels to-

ward certain stimuli, as assessed by the four fear questionnaires. Participants scoring highly on a given questionnaire were hypothesised to give lower pleasantness ratings and higher arousal ratings, relative to low-scoring participants, for negative content stimuli relevant to that questionnaire (e.g., pictures of spiders in the case of the SPQ measure of spider-fear). Ratings for neutral and positive content pictures were predicted to be similar across high and low fear-questionnaire score groups. Consequently, the data analysis will concentrate on describing differences in ratings of emotional valence and arousal between different categories of picture stimuli, as well as evaluating whether these picture ratings differ on the basis of gender or pre-existing fear levels toward that type of stimulus as indexed by the participants' fear questionnaire scores. Means and standard errors of valence and arousal ratings for each picture are presented in Appendix D.

Method

Participants

The participants were 64 female and 24 male first-year psychology students at the University of Otago, aged between 17 and 48 years (median = 19). Participation was voluntary, and participants received credit toward their course grade.

Prior to contributing to the study, all participants confirmed that they either had no eyesight problems or were wearing corrective lenses, in addition to not having received treatment for anxiety or depression in the twelve-month period preceding the experiment.

Picture Stimuli

The 160 photographic stimuli used in this experiment were selected from the IAPS (Lang et al., 1999a). From this set, all instances of pictures relevant to the hypothesis of Study 2 were selected, including snakes (n = 16), spiders (n = 5), other threatening/unpleasant animals (n = 12), aimed guns and knives (n = 10), and other dangerous modern items (n = 5). These pictures were combined with a set of disgust and mutilation specific photographic stimuli (n = 17) to make up an a priori unpleasant set of photographs (total n = 65). Pleasant (n = 48) and neutral (n = 47) pictures were also included. Disgusting, neutral and pleasant photographs were selected mainly on the basis of having been used in previous startle investigations of emotion, as noted in Table 5 of the IAPS instruction manual (Lang et al., 1999b), with additional pictures being selected for these categories by the experimenter so as to roughly balance the number of positive, neutral and negative pictures in the study. Appendix D lists the pictures included in the negative, neutral, and positive categories, as well indicating the pictures included in the specific negative categories.

Experimental Design

The pictures were divided into eight blocks of 20 pictures using a Latin square design, so that each block consisted of the same proportion of negative (n = 8), neutral (n = 6), and positive (n = 6) pictures, with the exception of block eight, which had 5 neutral and 9 negative pictures. Within each block, the order of picture presentation was determined by assigning each picture a number and then using a random number generator to assign picture order, with the sole criterion being that no more than two adjacent pictures were from the same a priori affective category.

Following these arrangements, the blocks were split into two subsets of four blocks each (i.e., 80 pictures), with each participant rating only one subset to reduce the likelihood of fatigue. The first subset consisted of blocks one to four, while the second subset included the remaining four blocks. Finally, each subset was viewed in either the originally designated order or in the reverse of this order. Picture subset viewed and presentation order were counterbalanced across participants.

Apparatus

Participants viewed and rated the pictures on an IBM-compatible Pentium-III computer, with a 30 by 22 cm viewing screen. The computer controlled both presentation of the pictures and the recording of SAM ratings via an interface developed specifically for this experiment (Jones, 2000a).

Procedure

On entering the experimental room, the participant was briefed on the experimental procedure before providing written informed consent. A battery of questionnaires was then completed to assess prior levels of fear of snakes, spiders and blood/bodily mutilation (SNAQ, SPQ, and

MQ, respectively: Klorman et al., 1974, included in Appendix B), as well as a 39 item general fear questionnaire adapted from the Fear Survey Schedule II (Geer, 1965, see Appendix C). On completion of these questionnaires, the participant was seated in front of the computer display of the SAM rating system (Hodes et al., 1985). The SAM used in this study consists of three 5-point pictorial scales, representing the dimensions of valence, arousal, and dominance, on which the participant was instructed to rate how the picture made them feel.

At this stage the participant viewed and rated a sample picture set of six pictures (not included in the results) in order to familiarise themselves with the rating system and allow them to ask for clarification of the instructions. The room was then darkened to improve screen contrast, and the experimenter left the participant to complete the ratings for the 80 experimental stimuli. Each picture was viewed for a total of six seconds, with the computer automatically displaying the SAM ratings screen at the end of this period and recording the ratings upon completion of all three scales. Once the participant had finished the ratings for a picture, the next one was presented after a five second pause.

Data Analysis

Means and standard errors of ratings for each individual picture are presented in Appendix D. Ratings for individual pictures are not considered in the results section. The analyses performed on the data fall into three categories. Firstly, valence and arousal ratings were calculated for all pictures, and these data were divided into the a priori positive, neutral, and negative categories. Repeated-measures ANOVAs were performed on these data, with Gender as a between subjects variable and Emotional Category as a repeated measures variable. Greenhouse-Geisser corrections to the degrees of freedom were applied to all ANOVA results involving the repeated measures variable to protect against possible violations of the sphericity assumption (Jennings, Cohen, Ruchkin, & Fridlund, 1987). This correction reduces the degrees of freedom used to determine the probability values for an *F* test involving the repeated measures variable, by multiplying the actual degrees of freedom for that ratio by a correction epsilon value (ε). Epsilon values for each correction are given at the first stage in each ANOVA when a result involving the

repeated measures variable is reported. Degrees of freedom reported in the text of the results are the uncorrected levels, while the probability values stated were calculated from the corrected levels. As the epsilon value of this correction remains the same for interactions involving the same repeated measures variables, the epsilon value for each ANOVA is only stated once in each analysis, as there was only the one repeated measures variable in this study.

Separate analyses were performed for the valence and arousal dimensions, along with planned simple contrasts of ratings between the three categories. Additionally, a quadratic contrast was tested across the three categories for the arousal dimension to test the hypothesis that emotionally valent images (i.e., either positive or negative content) would produce higher arousal ratings than neutral images.

Secondly, data from within the negative category were split into five distinct content categories: snakes, spiders, other negative animals, disgust/mutilation pictures, and non-animal threats. The negative-content picture ratings were then analysed in repeated measures ANOVAs, again separate for valence and arousal, with Gender as a between-subjects variable and Specific Content as the repeated measures variable. As there were no hypotheses regarding differences in ratings between these negative categories, significant ANOVA effects were assessed using post-hoc Tukey's Honest Significance Difference (HSD) tests.

Finally, median splits of scores on the four fear questionnaires were used as between subject variables to test how prior levels of fear influenced the participants' ratings of picture contents. Analyses were again performed for both the three Emotional Categories, and the five specific negative categories. To avoid repetition of data trends already described, only the highest order interaction involving questionnaire score group in each ANOVA was followed up with post hoc testing. Comparisons were made between the high- and low-score groups at the same levels of the other variables in each significant interaction.

Results

Comparisons Between a priori Positive, Neutral, and Negative Pictures

Ratings of the pleasantness of the three picture groups varied significantly by Emotional Category, F (2, 170) = 601.12, $p < .001$, $\varepsilon = .85$. As can be seen in Table 1, pleasantness ratings increased from the negative to the neutral category, and from the neutral to the positive category, Fs (1, 85) > 325.23, ps $< .001$, for simple comparisons between the three conditions. Averaged across all picture contents, females rated pictures as less pleasant (M = 5.24) than males did (M = 5.53), although this difference was just short of significance, F (1, 85) = 3.94, p = .05.The interaction between Emotional Category and Gender also approached significance, F (2, 170) = 2.49, p = .095.

Arousal ratings also differed significantly on the basis of Emotional Category, F (2, 170) = 210.5, $p < .001$, $\varepsilon = .92$. As seen in Table 1, negative picture contents were rated as more arousing than both neutral and positive picture contents, Fs (1, 85) = 393.06 and 95.6, both ps $< .001$. Positive pictures were also rated as more arousing than neutral content pictures, F (1, 85) = 132.62, $p < .001$, and the trend indicating higher arousal ratings for the emotionally valent compared to neutral contents was confirmed by a significant quadratic trend, F (1, 85) = 389.01, $p < .001$. Participant Gender did not have a significant main effect on arousal ratings, F (1, 85) = .45, p = .505, nor did it interact with Emotional Category,

Table 1: Means and Standard Errors of Valence and Arousal Ratings for Positive, Neutral, and Negative Categories

Dimension	Positive	Neutral	Negative
Valence	6.92	5.57	3.48
(S.E.)	(.07)	(.08)	(.10)
Arousal	3.21	2.00	4.69
(S.E.)	(.14)	(.10)	(.15)

Table 2: Means and Standard Errors of Valence and Arousal Ratings for Specific Negative Contents

Dimension	Snakes	Spiders	Animals	Disgust	Threat
Valence	3.94	4.38	4.01	2.61	3.50
(S.E.)	(.15)	(.19)	(.14)	(.09)	(.12)
Arousal	4.55	4.03	4.55	5.15	4.57
(S.E.)	(.18)	(.21)	(.16)	(.17)	(.17)

Note. Animals = Non-snake/spider unpleasant animals. Disgust = Disgust and mutilation pictures. Threat = Non-animal threatening images.

F (2, 170) = 1.5, p = .226.

Comparisons Between Specific Types of Negative Pictures

The ANOVA for valence ratings of the five negative subcategories found a main effect for Specific Content, F (4, 340) = 33.78, $p < .001$, ε = .72. There was also a main effect for Gender, F (1, 85) = 6.33, p = .014, with female participants (M = 3.53) rating the negative pictures as less pleasant than male participants did (M = 4.1) across all five negative subcategories. No interaction occurred between Gender and Specific Content, F (4, 340) = .11, p = .948.

Means and standard errors of valence and arousal ratings for the five specific negative content types can be seen in Table 2. Post-hoc testing of valence ratings showed that disgust/mutilation pictures were rated as less pleasant than all other contents, ps $< .001$. Non-animal threat content pictures were likewise rated as less pleasant than any of the three animal negative contents, ps $< .05$. For the three animal content negative pictures, snakes were rated as less pleasant than spiders, ps = .013. The 'other animal' category was also rated as less pleasant than spiders, although this difference only approached significance, p = .056. Valence ratings were not significantly different for snake and 'other animal' content pictures, p = .988.

The ANOVA addressing arousal ratings in the negative categories showed a significant main effect for Specific Content, F (4, 340) = 7.23, $p < .001$, ε = .79. The disgust/mutilation category

Table 3: Descriptive Statistics for the SNAQ, SPQ, MQ, & FSS Questionnaires.

Questionnaire	Mean	S.E.	Median
SNAQ	7.39	(.54)	6
SPQ	6.29	(.63)	4
MQ	9.17	(.63)	8
FSS	116.87	(3.23)	116

pictures were rated as more arousing than any other negative picture contents, *p*s $< .026$. Both snakes and non-animal threat contents produced greater arousal ratings than spider pictures, *p*s = .048 and .026, respectively. Gender was not a significant influence on arousal ratings, either as a main effect, F (1, 85) = 1.21, $p = .274$, or as an interaction with Specific Content, F (4, 340) = .66, $p = .586$.

Questionnaire Scores

Table 3 reports median scores, mean scores and standard errors for each questionnaire. Gender and Picture Set were between-subjects variables for each analysis. In the SNAQ and MQ questionnaire score ANOVAs, Gender approached significance, *F*s (1, 83) = 3.09 and 3.39, *p*s = .083 and .069. On the SPQ and FSS questionnaires, Gender did not approach significance, *F*s (1, 83) = 2.38 and 1.89, *p*s = .126 and .173. Questionnaire scores did not vary on the basis of Picture Set viewed, *F*s (1, 83) $< .94$, *p*s $> .333$, nor did Gender interact with Picture Set for scores on any of the questionnaires, *F*s (1, 83) $< .25$, *p*s $> .622$.

Correlations were also calculated between all four of the questionnaires, and the coefficients are reported in Table 4. All of the possible correlations between the questionnaire scores were significant, *p*s $< .001$.

Table 4: Correlations Between Scores on the SNAQ, SPQ, MQ, & FSS Questionnaires (n = 88). All correlations were significant at $p < .001$.

Questionnaire	SNAQ	SPQ	MQ	FSS
SNAQ	--	.647	.5	.548
SPQ		--	.407	.59
MQ			--	.627
FSS				--

Picture Ratings by Questionnaire Score — the Three Pleasantness Categories

Due to the vast number of data that would require presentation in the following table to show means for both high- and low-fear groups for each emotional category, only the difference in valence and arousal ratings between these groups is reported in Table 5. Approximate means for the high- or low-fear groups can be calculated by adding or subtracting (respectively) half of the appropriate reported difference in Table 5 from the category means reported in Table 1.

With a median split on the SNAQ questionnaire used to divide participants into two groups for analysis of pleasantness ratings, there was a significant interaction between SNAQ group and Emotional Category, F (2, 166) = 4.76, $p = .013$, ε = .89. Negative pictures were rated as less pleasant in the high-SNAQ group than in the low-SNAQ group, $p < .001$. Ratings of valence for the neutral and positive picture contents were not significantly different between high- and low-SNAQ groups, ps = .771 and .713. Similar interactions between questionnaire score group and Emotional Category were found for the MQ, F (2, 166) = 3.29, $p = .047$, ε = .86, and for the FSS, F (2, 166) = 9.09, $p < .001$, ε = .89. Again, participants in the high-fear groups rated the negative pictures as less pleasant than the low-fear group did, ps $< .001$, and there were no differences in valence ratings of the neutral and positive categories between the high- and low-fear groups on either questionnaire, all ps $> .835$. Differences in valence ratings for each category between the high- and low-score groups for each questionnaire can be seen in Table 5.

Table 5: Difference in Mean Valence and Arousal Scores Between High and Low Fear-score Groups, for Positive, Neutral, and Negative Categories

Questionnaire	Dimension	Positive	Neutral	Negative
SNAQ	Valence	-.17	-.18	-.88*
	Arousal	.33*	.13	-.7
SPQ	Valence	-.17	-.19	-.69
	Arousal	.17	.18	-.56
MQ	Valence	-.18	-.15	-.73*
	Arousal	-.16	-.27	-1.01*
FSS	Valence	-.01	-.1	-.79*
	Arousal	.09	.07	-.88*

Note. The difference score represents the difference in picture ratings between high and low fear groups, for each questionnaire. Negative scores indicate that pictures in each category were rated as more unpleasant/arousing in the high-fear condition. Picture ratings could range from 1 to 9 on each measure. Significant differences between the high- and low-score groups are indicated, * $p < .001$.

A median split on the SPQ questionnaire found an interaction between Gender, SPQ group, and Emotional Category, F (2, 166) = 4.33, $p = .019$, $\varepsilon = .88$. For male participants, there were no differences in valence ratings between high- and low-SPQ groups at any of the three Emotional Categories, ps $> .93$. Female participants who scored above the median on the SPQ showed lower pleasantness ratings of the negative picture set (M = 2.86) compared to females who scored below median on the SPQ (M = 3.87), $p < .001$.

Several patterns were apparent in the ANOVAs performed on arousal ratings by questionnaire scores. Significant interactions between questionnaire group and Emotional Category were apparent for the MQ, F (2, 166) = 5.69, $p = .005$, $\varepsilon = .94$, and FSS questionnaires, F (2, 166) = 10, $p < .001$, $\varepsilon = .96$. In the post hoc tests for these analyses, arousal ratings for negative content pictures were higher in the groups scoring above the median compared to those scoring below the median on the respective questionnaires, ps $< .001$. Arousal ratings for neutral and positive picture contents were not significantly different between the high- and low-score groups on either questionnaire, ps $> .437$. Table 5 reports the differences in mean ratings of arousal for high- and low-score groups for each questionnaire.

For the analysis of arousal ratings by SNAQ score, the interaction between SNAQ group and Emotional Category was again significant, F (2, 166) = 7.12, $p < .001$, ε = .96. As shown in Table 5, below median SNAQ-score participants rated pleasant pictures as more arousing than did participants scoring above the median on this measure, p = .001. No significant differences were observed between high and low SNAQ-score participants for negative or neutral picture contents, ps = .293 and .547, respectively.

The ANOVA for arousal ratings by SPQ score returned a significant interaction between SPQ group and Emotional Category, F (2, 166) = 3.46, $p = .037$, ε = .93. Post hoc tests showed no significant differences between high- and low-SPQ score groups for arousal ratings in any of the Emotional Categories, all ps $> .125$.

Picture Ratings by Questionnaire Score — Specific Negative Contents

Once again, the following table only reports differences between the high- and low-fear groups on their ratings of pleasantness and arousal for the five specific negative picture contents. Approximation of actual group means can be performed as per Table 5, this time comparing Table 6 to Table 2.

For valence ratings by SNAQ score group, a significant interaction appeared between SNAQ group and Specific Content, F (4, 332) = 7.56, $p < .001$, ε = .742. All three categories of animal pictures (snakes, spiders, and other) were rated as less pleasant by participants who scored above the median on the SNAQ questionnaire compared to the below-median group, ps $< .012$. Valence ratings of disgust/mutilation and non-animal threat pictures were not different in the high and low SNAQ-score groups, ps $> .947$.

The SPQ score ANOVA showed an interaction between SPQ-score group and Specific Content, F (4, 332) = 8.54, $p < .001$, ε = .79. Participants who scored above the median on the SPQ rated snake and spider pictures lower on pleasantness than participants who scored below the median, ps $< .038$. Valence ratings for the other negative content categories were not significantly

Table 6: Difference in Mean Valence and Arousal Scores Between High and Low Fear-score Groups, for Specific Negative Contents

Questionnaire	Dimension	Snakes	Spiders	Animals	Disgust	Threat
SNAQ	Valence	-1.63***	-1.67	-.98	-.23	-.51
	Arousal	-1.09	-1.10**	-.66	-.42	-.41
SPQ	Valence	-1.04*	-1.94***	-.65	-.38	-.27
	Arousal	-.73	-1.83**	-.68	-.30	-.16
MQ	Valence	-.88	-1.12	-.66	-.65	-.58
	Arousal	-1.10	-1.77	-.89	-1.03	-.76
FSS	Valence	-1.33***	-1.92***	-.8†	-.43	-.36
	Arousal	-1.23***	-1.76***	-.84*	-.79	-.39

Note. Animals = Non-snake/spider unpleasant animals. Disgust = Disgust/mutilation type pictures. Threat = Non-animal threatening images. Each score represents the difference in ratings between the above-median score group and the below-median score group for that variable. Negative scores indicate that pictures in that category were rated as more unpleasant/arousing in the high-fear condition. Picture ratings could range from 1 to 9 on each measure. Significant differences between the high- and low-score fear groups are indicated as follows, *** $p < .001$; ** $p < .01$; * $p < .05$; † $p < .1$.

different in the high and low SPQ-score groups, *p*s $> .656$.

An interaction between FSS score group and Specific Content was also evident, F (4, 332) = 6.69, $p < .001$, $\varepsilon = .79$. The snake and spider categories were again rated as less pleasant by the high-FSS group compared to the low-FSS group, *p*s $< .001$ for the snake and spider categories. For the other animal category, this difference only approached significance, $p = .069$. The disgust/mutilation and non-animal threat category ratings were not significantly different between the two median-split FSS groups, *p*s $> .94$.

The ANOVA for valence ratings and MQ score showed a three-way interaction between Gender, MQ group, and Specific Content, F (4, 332) = 5.84, $p < .001$, $\varepsilon = .79$. Female participants showed lower pleasantness ratings for snake and spider picture contents if they had scored above the median on the MQ compared to those females scoring below median on this measure, *p*s $< .003$. No other negative category showed differences in valence ratings between high- and low-MQ score females, *p*s $> .214$, and male participants showed no difference in ratings on the

basis of MQ score group for any of the specific negative contents, *p*s $>$ .633.

Arousal ratings also differed according to fear group, with an interaction between SNAQ group and Specific Content, F (4, 332) = 2.64, $p = .047$, ε = .79. Spiders were rated as more arousing in the high-SNAQ than in the low-SNAQ group, $p = .001$, but arousal ratings for snake pictures did not differ by SNAQ group membership, $p = .153$. A similar interaction was found in the SPQ group analysis, F (4, 332) = 7.89, $p < .001$, ε = .85. As with the SNAQ analysis, only spider arousal ratings were modulated by SPQ group score, with higher arousal ratings in the high SPQ-score group compared to the low score group, $p < .001$. No other categories differed in ratings by SPQ group membership, *p*s $>$ .556.

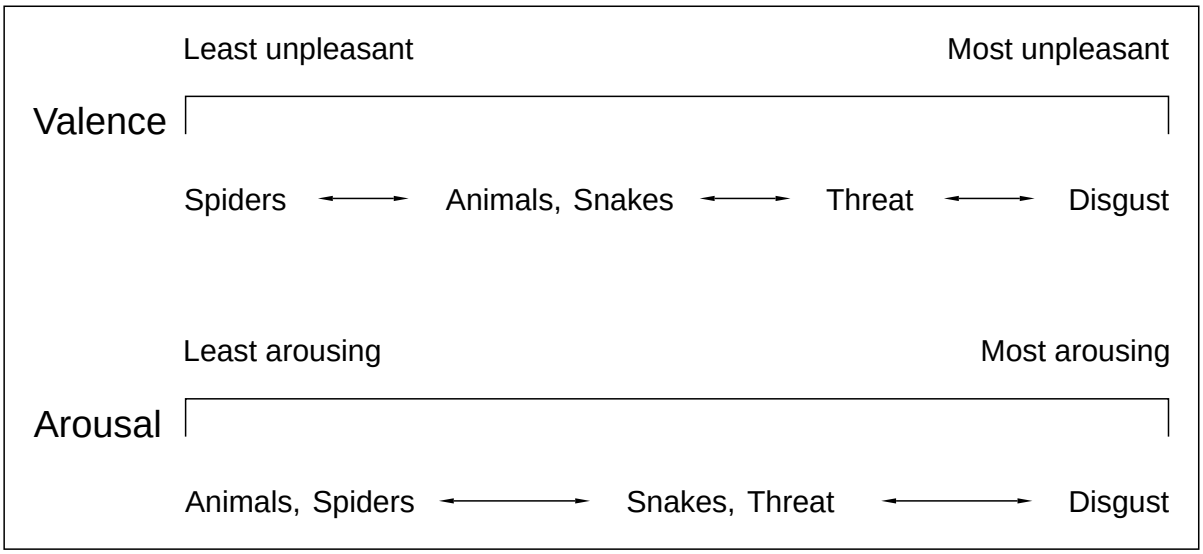
On the MQ score ANOVA, there was no significant interaction between MQ score and Specific Content, F (4, 332) = 2.28, $p = .075$, ε = .81. There was a significant main effect for Specific Content, F (4, 332) = 5.93, $p < .001$, and also a main effect for MQ score group, F (1, 83) = 9.9, p = .002. This difference has already been addressed in the analysis of ratings for the three category model by MQ score; negative pictures were rated as more arousing in the high MQ-score group than in the low MQ-score group.

The FSS by Specific Content interaction was also significant, F (4, 332) = 4.62, $p = .003$, ε = .81. All three negative animal content categories were rated as more arousing in the high FSS-score group than in the low FSS-score group, *p*s $<$ .023.

Discussion

Analysis of valence and arousal ratings across the standard positive, neutral, and negative picture categories showed results that were largely in line with expectations. These three categories differed in valence so that pleasantness ratings were highest for the positive category and lowest for the negative category, with values for neutral content pictures falling between the two. Arousal ratings were in turn higher for the two emotionally valent categories (i.e., positive and negative) compared to the neutral category. Additionally, negative content pictures were rated as more arousing than positive content pictures, a difference which was not hypothesised but was also not without precedent (e.g., Jansen & Frijda, 1994, found that participants were ambivalent in their ratings of sexually arousing materials as pleasant). This finding is probably indicative of the fact that the negative pictures chosen for this study were mostly related to more intense emotions (e.g., fear and disgust) while the positive pictures were not selected as exemplars of specifically intense emotional situations (e.g., sexually explicit images), but were of varied positive contents.

Participants who had scored above the median on the SNAQ, MQ, and FSS questionnaires gave lower pleasantness ratings to the negative content pictures than participants who had scored below the median on these questionnaires. This was also apparent for the SPQ questionnaire for female, but not male, participants. Participants who scored above the median for the MQ and FSS also showed higher arousal ratings for the negative category compared to the low-score groups. Unexpectedly, high-SNAQ score participants showed lower arousal ratings for the positive picture category when compared to the low-SNAQ score group. There is no obvious explanation for this effect; perhaps because high-fear participants find the negative pictures more arousing, the positive pictures are experienced as relatively less arousing, leading to a restriction of arousal ratings for these contents compared to that for low-fear participants. As all other differences between the high- and low-score groups were on ratings of the negative picture category, specific issues will be taken up in the discussion of the specific negative content analyses.



Note. Animals = Non-snake/spider unpleasant animals. Disgust = Disgust and mutilation type pictures. Threat = Non-animal threatening images. Arrows indicate significant differences between groups at $p < .05$.

Figure 2. Hierarchy of valence and arousal ratings for specific negative contents

Looking more specifically at differences within the negative category, mutilation and disgust type pictures were rated as both less pleasant and more arousing than any other negative category, with ratings for non-animal threatening images coming between disgust/mutilation pictures and negative animal pictures. The specific hierarchy of valence and arousal ratings within the negative category is portrayed in Figure 2.

Figure 2 illustrates that negative picture contents that were most extreme on the valence scale tended to have higher arousal ratings. It is worth noting that non-animal negative categories were rated more extremely on both valence and arousal than any animal-content negative pictures, and that ratings of pictures from these categories (disgusting/mutilation pictures and non-animal threat pictures) were never dependent on self-reported fear levels.

Comparing specific negative content picture valence ratings between high- and low-score participants on each of the fear questionnaires showed that pleasantness ratings for all three animal content categories were lower for participants scoring above the median on the SNAQ and FSS. The same was true for valence ratings on snake and spider pictures for participants scoring above median on the SPQ and MQ, but this was only the case for females with the MQ measure

analysis. Ratings of pleasantness for the non-animal threat and disgust/mutilation pictures did not differ on the basis of questionnaire scores in these analyses.

The increased arousal ratings in the negative category for high-MQ score participants, described above, was not specific to any particular negative content type. Higher arousal ratings in the high-FSS score group were specific to the three animal content negative picture types, while high SNAQ and SPQ group participants showed higher arousal ratings than their low-score equivalents for spider pictures only.

In summary, participants who scored above the median on the three specific fear questionnaires (SNAQ, SPQ, and MQ) generally showed lower pleasantness ratings for both snake and spider pictures, in spite of the fact that the MQ was developed to test mutilation fear. This can be explained in light of the fact that scores for all three of these questionnaires were correlated, so that participants who scored highly on the MQ, for example, were likely to have also scored highly on the SNAQ or SPQ.

Scores on the MQ also did not seem to relate to valence or arousal ratings of mutilation and disgust images. As these pictures were rated as the most unpleasant and most arousing of all the negative content pictures, this lack of result may have been due to a constraining effect of the rating scales, so that ratings were around ceiling for all participants, rather than a lack of specificity for the MQ. An alternative interpretation of this finding is that for high blood/injury or mutilation fearful individuals, differences will not appear in the intensity of subjective ratings of pleasantness or arousal, but rather in the behavioural and physiological responses to these unpleasant stimuli. In a study using females preselected for very high or very low blood-injury fear (above the 90th percentile and below the 15th percentile on the MQ measure, respectively), Hamm, Cuthbert, Globisch, and Vaitl (1997) found that the two fear groups did not differ on ratings of pleasantness or arousal for mutilation content pictures. Measures of viewing time, startle potentiation, and heart rate changes were in line with the high-fear participants finding these materials aversive. Discordance between subjective ratings and physiological responding is not uncommon: In Chapter 3, it was noted that individuals with depression or psychopathy

rate fear-relevant pictures at similar levels for pleasantness and arousal as control participants, but show abnormal patterns of physiological responding to these pictures (Lethbridge, Simmons, & Allen, 2002; Levenston et al., 2000).

A second point of difference between mutilation/disgust type pictures and pictures of specific feared animals relies on the ratings from this study. Both the high and low MQ-score participants rated the mutilation/disgust pictures as unpleasant — mean valences were 2.28 and 2.93, arousal ratings 5.66 and 4.64, for high and low MQ-score groups respectively (derived from Tables 2 and 6). With mean valence and arousal for the neutral category standing at 5.57 and 2 respectively, it is clear that both the high and low mutilation-fear participants found these pictures both unpleasant and highly arousing. Taking spider pictures as a second example, the ratings for valence and arousal were as follows — valence 3.41 and 5.35, arousal 4.95 and 3.12, for high and low-SPQ score groups, respectively. Here, the high spider-fear participants find the spider pictures both highly unpleasant and arousing, while the low-fear participants gave similar pleasantness ratings for the spiders as for neutral pictures. The difference between the two types of fear and their relationship to subjective ratings of picture stimuli hence seem qualitative rather than quantitative — for mutilation and disgust type pictures, the difference between high- and low-fear participants is the degree to which they find the picture unpleasant, while for spider pictures the difference between the two fear groups can be conceptualised as whether the stimulus is experienced as unpleasant or neutral.

As compared to the specific fear questionnaires, comparing high and low scoring participants from the FSS-II-R scale showed valence and arousal rating differences, in the anticipated direction, for all three animal-content categories, but not the disgust/mutilation or non-animal threat category. The FSS-II-R seemed to have greater validity for predicting differences in arousal ratings between high- and low-fear individuals than any of the other questionnaires completed by participants.

The main purpose of this study was to obtain valence and arousal ratings for a large subset of the IAPS picture set, and mean ratings and standard errors are reported in Appendix D for each

picture in the study. The ratings collected in this study were comparable to the standardised ratings from other studies (Lang et al., 1999b, comparisons were not systematically conducted). Picture selection criteria in subsequent studies will be described in detail, as well as including mean valence and arousal ratings from this study for each of the picture categories used.

Ratings of valence and arousal were not collected in the following studies on emotional modification of startle. The *F* ratios obtained for comparisons between Emotional Categories in this study suggest that it is unlikely that subsequent tests would show null rating differences between negative, neutral, and positive categories, when considered across the entire sample. Following on from this, the only situation in which picture ratings for each participant may be useful is in analysis where physiological responses to the picture contents are organised according to that person's rating for each picture (e.g., so that only responses for pictures rated as both unpleasant and arousing are included in the negative category for the data analysis). While this could provide some useful information, such a manipulation would represent a major shift away from the data analysis procedures commonly used in the startle modification literature.

Study 2

The Fear System

LeDoux (1998) describes fear as a system for detecting and responding to danger so as to "maximize the probability of surviving a dangerous situation in the most beneficial way" (LeDoux, 1998, p. 128). The threshold for activation in this system should be relatively low, given that the evolutionary disadvantage of falsely identifying a non-threatening situation as dangerous is much smaller than the disadvantage associated with falsely identifying a threatening situation as safe (Öhman, 1993). Both Öhman (1993) and LeDoux (1998) posit that this system should be capable of being activated very rapidly and on the basis of minimal stimulus information.

LeDoux (see reviews in LeDoux, 1995, 1998, 2000) has identified the amygdala and associated subcortical structures as vital components of the fear system, especially regarding the fast detection of threat. The central nucleus of the amygdala provides output to various areas responsible for the physiological and behavioural response components of fear (Lang, Davis, & Öhman, 2000). The lateral nucleus of the amygdala receives input from various sensory areas, including the auditory thalamus and auditory cortex (LeDoux, 2000) as well as from visual areas of the thalamus (the lateral posterior and lateral geniculate nuclei), via the perirhinal cortex (Davis, Walker, & Lee, 1999), and from the superior colliculus, another subcortical stage of visual processing (Morris, Öhman, & Dolan, 1999). It should be noted that the auditory projections to the amygdala have been researched more thoroughly than the visual projections.

The lateral nucleus of the amygdala is connected to the central nucleus of the same structure (LeDoux, 2000), and sensory inputs received by the lateral nucleus are thus capable of modifying outputs to the various response system components associated with fear. The subcortical pathway from the auditory thalamus to the amygdala is sufficient for auditory fear condition-

ing in the rat: Lesions of auditory cortex do not interfere with either learning or expression of conditioned fear (LeDoux, 1995). This subcortical pathway to the amygdala is shorter than the pathway that passes through sensory cortex, but is not capable of fine discrimination between similar stimuli — this is a “quick-and-dirty” pathway (LeDoux, 1995, p. 223), a candidate for the fast, low-threshold threat detection mechanism hypothesised by Öhman (1993).

Evidence is mounting that this subcortical path is sufficient for activation of the amygdala by visually threatening stimuli in humans. Amygdala activation during viewing of fear face photographs, but not happy face photographs, has been observed for stimuli presented in the blind field of a patient with major lesions to their primary visual cortex (Morris, DeGelder, Weiskrantz, & Dolan, 2001). This activation occurred without conscious awareness of the stimuli.

Amygdala activation in the absence of conscious awareness of threatening stimuli has also been observed. Masked fear stimuli (previously conditioned fear face photographs presented for 30 ms, followed by a photograph of a neutral face for 45 ms) were associated with significant coactivation of the pulvinar, superior colliculus, and right amygdala, in the absence of conscious recognition of the fear photograph (Morris et al., 1999).

Another study has shown that unattended fear stimuli can activate the amygdala to the same extent as attended fear stimuli (Vuilleumier, Armony, Driver, & Dolan, 2001). Participants were asked to fixate a central point of a display, with each display consisting of a pair of photographs of houses and a pair of photographs of faces, with either fearful or neutral expressions. The display was organised so that the photographs for each picture type were presented on the same axis (e.g., houses both above and below the central point; faces to the left and right of it). Attention was manipulated by asking participants to judge whether pictures on one axis (signalled before each trial) were identical or different. When fearful faces were presented in the unattended position, amygdala activation was equivalent to that for fearful faces in the attended position. No such activation was observed for neutral faces, either attended or unattended. A separate group of participants (not included in the imaging study) performed at chance when

asked to guess the gender or valence (fearful or neutral) of unattended facial stimuli (Vuilleumier et al., 2001). These experiments provide evidence for emotional processing of fear-stimuli by subcortical structures in the absence of conscious awareness, and even without visual cortical processing in Morris et al. (2001).

Once sensory information has reached the amygdala, outputs from the central nucleus project to various targets on the brainstem, including the nucleus reticularis pontis caudalis, an area that is essential for the expression of the startle reflex (Davis et al., 1999). Fear potentiation of startle can be prevented by lesions to areas that provide sensory input to the amygdala (e.g., the auditory thalamus), the lateral or central nuclei of the amygdala itself, or the projections from the central nucleus to the nucleus reticularis pontis caudalis (Davis et al., 1999). These lesions eliminate the modulation of startle in the rat by a conditioned stimulus, but do not prevent expression of the startle reflex itself. A patient with a localised lesion confined to right hemisphere amygdalar nuclei (including the lateral and central nuclei) has been reported to show no startle potentiation during aversive picture stimuli, compared to neutral, while the startle reflex itself was still present (although the overall level of startle blink magnitude in this patient was reduced relative to control participants; Angrilli et al., 1996).

To summarise:

1. The amygdala is involved with processing of fear relevant stimuli.

2. Activation of the amygdala by fear-relevant stimuli can occur in the absence of conscious recognition (Morris et al., 1999; Vuilleumier et al., 2001) or even cortical processing of these stimuli (Morris et al., 2001).

3. The subcortical pathway(s) that transmit sensory information to the amygdala are much shorter than pathways that arrive at the amygdala via sensory cortex.

4. The amygdala is then responsible for outputs to areas controlling various components of fear responding, including the startle reflex.

The evidence presented above suggests that subcortical pathways can allow fast or unconscious processing of threatening stimuli that will potentiate the startle reflex, in situations where cortical inputs have not provided input to the amygdala.

A number of experiments have looked at startle modification for startle reflexes elicited very shortly after picture onset (i.e., less than 500 ms), in contrast to the more typical paradigm where the latency between picture onset and probe onset is longer than two seconds. These studies are considered in the following section.

Experimental Precedents for Early Startle Modification

This study arises from an apparent contradiction within the experimental literature regarding the relationship between phobia and the startle reflex, when startle is elicited very shortly after picture onset. The original report of emotional modulation of the startle reflex (Vrana et al., 1988) found that when startle responses were divided into groups on the basis of delay between picture onset and startle probe presentation (at either 500, 2500 or 4500 ms), only responses at the two longer latencies showed significant emotional modulation of blink magnitude. Startle reflexes elicited 500 ms after picture onset did not differ between the three emotional valence picture groups. A more extensive study by Bradley, Cuthbert, and Lang (1993) included startle probe presentations at 300, 800, 1300, and 3800 ms after picture onset: Only the two later probe times produced the predicted pattern of startle modulation (i.e., augmentation for negative and inhibition for positive, relative to neutral, pictures). When startle was elicited at a latency of 300 ms, both positive and negative pictures showed inhibited blink magnitude relative to startle during neutral pictures at this time. This result was interpreted as being indicative of a period of “processing protection” (Bradley, Cuthbert, & Lang, 1993), with the initial processing of interesting foreground stimuli being protected from external interference (Graham, 1992) — in this case the startle probe stimulus. Subsequent research with non-psychopathic prison inmates has also shown inhibited startle for both positive and negative pictures, relative to neutral, at a 300 ms probe time (Levenston et al., 2000).

Codispoti et al. (2001) partially replicated this result, with blink magnitude for probes at 300 ms inhibited for positive compared to neutral and negative foreground stimuli. Blink responses during negative and neutral stimuli at this latency were not differentiated from each other. The theoretical implications of this result are discussed in a later section.

Several other experiments are relevant to the processing protection hypothesis of early-stage startle modulation. It has been reported that by manipulating the amount of attention directed to emotional pictures, differential startle modification for positive and negative images can become apparent as early as 250 ms after picture onset (Vanman, Boehmelt, Dawson, & Schell, 1996, Experiment 2). To achieve this result, participants were instructed to attend to the presentation duration of either positive or negative slides during the experiment (counterbalanced across participants), and decide on each of the attended slides whether it had been presented for longer than usual (7 seconds as opposed to 5). This manipulation was intended to make participants pay close attention to each picture's emotional content. Blink responses to an acoustic probe at 250 ms after picture onset were significantly larger for negative compared to positive slides, regardless of the valence to which the participant was instructed to attend.

This finding is tempered by methodological considerations. Firstly, another experiment reported in the same paper (Vanman et al., 1996, Experiment 1) failed to show differential modification of startle at a 250 ms delay. The attentional manipulation instructions for participants in that study were to attend to or ignore a slide's duration based on the pitch of a tone preceding picture onset by several seconds, with equal numbers of positive and negative slides assigned to the attend and ignore categories. The authors suggested that the different patterns of results obtained in the two experiments came about because "instructing participants to make a decision about whether to attend or ignore a stimulus by noting it's [emotional] valence . . . may speed up the emotional processing of the stimulus" (Vanman et al., 1996, p. 695). However, in the second experiment (described above) participants had also previewed each picture for five seconds in a session prior to the presentations on which startle was elicited — a factor which the authors concede could allow faster identification of the pictures' emotional content on the second viewing, thus engaging startle modulation circuits at an early stage (Vanman et al.,

1996). This confound could be avoided by using the attentional instructions of Experiment 2 in the absence of picture previewing, perhaps with sample pictures to explain the difference between positive and negative stimuli. This situation remains to be tested.

A second caveat to the conclusions drawn is that both the Vanman et al. (1996) experiments utilised only positive and negative picture contents. The absence of emotionally neutral slides means it is not possible to decide whether the observed difference in blink magnitude between the two picture categories is due to startle inhibition during positive slides, augmentation during negative slides, or a combination of both processes, measured relative to neutral picture responses. It is of further interest whether startle during both positive and negative slides at 250 ms would be inhibited relative to startle during neutral pictures, as would be suggested by Bradley, Cuthbert, and Lang (1993), or whether the inclusion of neutral slides would lead to a linear effect of valence at this short delay when attentional levels are manipulated. The inclusion of neutral pictures should act to test the effect of emotional-content free picture processing on the startle reflex, so that differences in responding between picture contents can be ascribed to the emotional information represented therein.

The effects of manipulating attention on emotional modulation of startle at early stages of picture viewing have been replicated and extended (Vanman, Dawson, & Brennan, 1998) using the same methodology as Experiment 2 of Vanman et al. (1996), and also dividing participants into several groups for analysis on the basis of questionnaire results. An earlier probe condition was added at 120 ms following picture onset, and participants who scored above the sample's median on the BDI (Beck, 1967) showed a trend toward differential startle modification between positive and negative slide contents at this delay. Of course, the same caveats regarding picture preview and absence of a neutral category, discussed above, apply to this experiment as well.

Bradley, Cuthbert, and Lang (1993) interpreted their results as evidence of prepulse inhibition (PPI). Briefly, PPI is a phenomenon that occurs when the elicitation of startle follows presentation of another (non-startling) stimulus, whereby blink magnitude is inhibited relative to trials where no prepulse precedes the eliciting stimulus (Blumenthal, 1999). The degree of

PPI depends upon a variety of factors, including the delay between the prepulse and the probe. The onset of an emotional picture stimulus has been suggested to be a type of prepulse that will inhibit the startle reflex, as indicated by reduced blink response magnitudes at early (e.g., 300 ms) relative to late probe times (on average over emotional categories; Bradley, Cuthbert, & Lang, 1993; Codispoti et al., 2001; Levenston et al., 2000). The experiment described below (Globisch, Hamm, Esteves, & Öhman, 1999) suggests that the startle inhibition observed for negative contents at 300 ms may be more complicated than the PPI interpretation suggests. Furthermore, at probe times late in the picture viewing period, acoustic prepulse presentation does not change affective modification of startle, so that even though the difference between prepulse/no-prepulse conditions is significant (inhibition of blink magnitude for the prepulse condition) the differences between emotional categories within these two conditions is still apparent (Hawk & Cook, 2000). Thus it appears that the early pattern of modification observed may be dependent on attentional processes other than PPI.

The results of the studies using a three picture-content paradigm (Bradley, Cuthbert, & Lang, 1993, Codispoti et al., 2001; Levenston et al., 2000) are incongruent with those of an independent study (Globisch et al., 1999) looking at the time course of startle responding in individuals showing a high degree of small animal fear. The experimental group consisted of individuals who had scored above the 85th percentile on either the SNAQ or SPQ questionnaire (Klorman et al., 1974), with a control condition made up of individuals who scored below the 50th percentile for at least one of these measures. A startle paradigm similar to that of Bradley, Cuthbert, and Lang (1993) was used, with the negative picture category consisting of animal stimuli specific to the individual's fear group (i.e., either snakes or spiders; control group participants were allocated to viewing one of these animal categories). Startle was elicited at several picture onset to probe onset latencies (120, 300, 800, 1300, and 3800 ms) for all three picture conditions; responses to the earliest probe condition (120 ms) were not analysed due to participant blinking in response to picture onset (this is discussed in the introduction and discussion of Study 5). Predictably, the low-fear control participants did not show potentiation of startle blink magnitude for the non-feared snake or spider stimuli, at any of the probe times. The animal fearful participants showed reliable blink potentiation for their feared stimuli relative to neutral across

all probe times, including the 300 ms condition for which Bradley, Cuthbert, and Lang (1993) and Levenston et al. (2000) found startle inhibition during negative foreground material. These results were obtained using a standard 6 second picture presentation. This pattern of augmentation at the 300 ms probe time still held for the animal fearful participants even when the picture viewing period was limited to 150 ms (picture presentation period was a between-subjects manipulation; Globisch et al., 1999). The authors concluded on the basis of these data that "fear responses can be activated very rapidly and with minimal stimulus input" (Globisch et al., 1999, p. 73; Öhman, 1993).

Competing Theories Explaining Early Emotional Modulation of Startle

The results of these three studies support two theories, not necessarily mutually exclusive, regarding emotional modulation of startle at short picture to probe onset latencies. Globisch et al. (1999) interpreted their findings in purely affective terms: Threatening stimuli in the environment can be at least partially processed and made available to some response systems (parsimoniously, defensive reflexes) at very short latencies.

The attentional explanation of Bradley, Cuthbert, and Lang (1993), regarding the observed inhibition of startle for negative material at an early probe time, was revised following the findings of both Globisch et al. (1999) and their own further investigations (Codispoti et al., 2001) to include both attentional and emotional factors. This revision posits that augmented startle blink responses to negative material "reflect a net effect of a facilitatory process (due to aversiveness) and an inhibitory process (due to attention)" (Bradley and Lang, 2001, cited in Codispoti et al., 2001, p. 477). According to this logic, at the early stages of picture processing, when attentional demands are presumably high, only highly aversive pictures should produce startle potentiation, explaining the results obtained from highly fearful participants in Globisch et al. (1999). Furthermore, highly aversive pictures should be capable of eliciting potentiated startle in non-phobic individuals at an early probe time. High participant fearfulness is not vital, but the foreground intensity threshold for early startle potentiation is lower in these participants (i.e., aversive pictures for control participants are highly aversive for phobic or high-fear

participants).

The results of the studies explicitly manipulating attentional demands to picture viewing (Vanman et al., 1996, 1998) have been taken as evidence of faster picture content processing when a participant is instructed to specifically attend to the emotional valence of the picture. This evidence could be interpreted as consistent with the findings and predictions of Globisch et al. (1999), although as noted it is unknown whether responses to negative pictures would be augmented relative to neutral pictures in the attentionally manipulated paradigm. Although inconsistent with other findings (Bradley, Cuthbert, & Lang, 1993; Levenston et al., 2000), this would be in line with the results of Codispoti et al. (2001), who found that startle blinks elicited at 300 ms were greater during negative than positive pictures, although this difference was not significant. Taking into account the concerns raised by the authors (Vanman et al., 1996) and those raised in the previous section, the evidence is inconclusive as to whether attending to the emotional valence of a picture influences the pattern of early modification of startle, or if the observed difference is due to reduced processing times when pictures are previewed.

The hypotheses suggested by Bradley and Lang (2001, cited in Codispoti et al., 2001) and Globisch et al. (1999) are not necessarily incompatible. However, the Bradley group has yet to explain why negative valence pictures, which had produced consistently inhibited startle responses relative to neutral pictures (e.g., Bradley, Cuthbert, & Lang, 1993; Bradley & Lang, 2001, cited in Codispoti et al., 2001; Levenston et al., 2000), failed to produce inhibition relative to neutral pictures in the most recent experiment (Codispoti et al., 2001). A look at the methodologies of these studies is informative.

Both the Bradley, Cuthbert, and Lang (1993) and Codispoti et al. (2001) studies used exactly the same picture sets; the same negative picture sets were also used (with the addition of six pictures) in the two attention based studies (Vanman et al., 1996, 1998). This rules out the possibility that different emotional stimuli could have accounted for the observed startle modulation patterns. As Levenston et al. (2000) obtained startle inhibition for negative pictures at their early probe time with a distinct set of pictures, it seems that the selected pictures (within

the general negative category) are not responsible for this difference. The only major difference between the two studies under consideration is that in the earlier study (Bradley, Cuthbert, & Lang, 1993), pictures were displayed for 6 seconds, while the latter study (Codispoti et al., 2001) used shorter, 500 ms presentations. As reflexive blink responses should reach their peak magnitude within 150 ms of acoustic startle probe presentation (Balaban, Losito, Simons, & Graham, 1986, cited in Berg & Balaban, 1999), blink responses elicited at 300 ms will have occurred within a 500 ms picture presentation period, and so picture offset in itself could not influence startle blink modulation at 300 ms. It is suggested by Codispoti et al. (2001), however, that shorter picture presentation times may lead to faster processing of their emotional content. Briefly, a shorter stimulus presentation period may cause the viewer to "speed up" their processing of the emotional information, a possibility that should not be ruled out at the moment. Presently, there are no solid empirical grounds for explaining the differences in results between Bradley, Cuthbert, and Lang (1993; also, Levenston et al., 2000) and Codispoti et al. (2001).

Summary and Description of Experimental Design

So far there are four major studies showing some degree of early (i.e., before 500 ms) augmentation of startle during picture viewing (Globisch et al., 1999; Codispoti et al., 2001; Vanman et al., 1996, 1998). The two directed-attention studies will not be considered further here on the basis that picture previewing before commencement of the startle probe experiment confounds their results. The reason for differences between the results of Codispoti et al. (2001) and the results from nearly identical experiments that did not find early startle modulation for negative pictures (Bradley, Cuthbert, & Lang, 1993; Bradley & Lang, 2001, cited in Codispoti et al., 2001; Levenston et al., 2000) is not yet apparent. Methodological differences between the remaining study showing early potentiation of startle during negative pictures (Globisch et al., 1999) and the other studies may explain the discrepant results.

Firstly, members of the experimental group in the Globisch et al. (1999) study all had pre-existing high levels of fear toward small animals. Secondly, the negative picture set in this experiment consisted solely of images of the participant's feared animal; the other experiments

cited in this section utilised negative picture sets that typically consisted of an equal mixture of threatening and mutilation content pictures. An extension of this second difference, of particular interest to an evolutionary model of fear, is that the threatening pictures used by Globisch et al. (1999) were all feared animals, whereas threatening pictures included in other studies (e.g., Bradley, Cuthbert, & Lang, 1993) are usually a combination of threatening animals and guns aimed at the viewer.

On the basis of these observed methodological differences, the following potential explanations for the different results should be considered, with the understanding that in this discussion 'process' implies picture processing to the point where the emotional valence of a stimulus is made available to startle modulatory circuits.

1. The highly-feared nature of the stimuli used in Globisch et al. (1999) activated the aversive system to the point where activity surpassed the level of attentional inhibition in startle modulating brain circuits, leading to an overall potentiation of the startle reflex.

2. The high-fear group of participants in that study were able to process negative or fearful stimuli (whether specific to their animal-feared stimuli or not) more quickly than low-fear participants. This suggests that these participants are hyper-vigilant for threatening stimuli.

3. A highly-feared stimulus can be processed more quickly than other negative stimuli — an effect not limited to high-fear or phobic individuals, but potentially limited to certain types of stimuli (e.g., dangerous animals).

The predictions from the first explanation (Bradley & Lang, 2001, cited in Codispoti et al., 2001) can be tested by looking at the results of several experiments. A corollary of the two-process (emotion and attentional) theory of startle modulation is that, if negative stimulus augmentation of startle is due to highly-aversive stimuli activating the aversive modulation system to a degree that is greater than attentional inhibition, then at later stages in picture viewing, when attentional demands have presumably been reduced, highly aversive stimuli should produce a greater degree of startle modulation compared to less aversive stimuli, which should produce

less activation of the aversive startle modulation circuit. Assuming that the difference in early (300 ms) modulation of startle between Bradley, Cuthbert, and Lang (1993) and Codispoti et al. (2001) was due to the pictures being more aversive in the latter study, we would predict that startle at later probe times (i.e. at least 2 seconds following picture onset) would be potentiated to a greater degree in the latter study than the former. On the basis of relative differences between startle blinks elicited during negative and positive pictures at late stages of processing in these two studies (3.8 and 2.8 seconds, respectively), this was not the case — the difference between the two valence categories is roughly the same (taking into account gross differences in startle blink magnitude) in both experiments (these observations were based on estimations performed on Figures 1 of each experiment, using a ruler.) It is possible that early picture offset in Codispoti et al. (2001) ameliorated the attentional demands on picture viewing, nullifying the process suggested above.

Alternatively, startle potentiation during negative foregrounds could be attaining a ceiling level of responding after several seconds of viewing so that reducing attentional demands does not influence the level of startle. Given that neutral pictures should engender no emotional processing, startle responses elicited after offset of these pictures should be of greater magnitude than those during the presentation period, as there will be no modification by either emotion (in either direction) or attention (which would inhibit the response). This would explain the lack of potentiation for negative pictures at probe times following picture offset: responses following neutral picture presentation are hypothetically context-free, and not inhibited by attentional factors as they are when elicited during viewing of same pictures. The best test of this would be to compare startle responses elicited 2 seconds after picture onset between a condition where the picture is still present and another condition where picture offset occurred before probe presentation. This explanation still does not cover startle modification at the 300 ms probe time, this being prior to picture offset.

The validity of the second and third hypotheses can not be determined on the basis of data from previously conducted studies, and so the following experiment was designed to test the hypotheses in the following manner. Participants viewed a series of pictures divided into four emotional

categories — positive, neutral, and two negative categories, composed exclusively of fear-type stimuli: an animal threat category, which included pictures of attacking or threatening animals; and a human threat category, which consisted solely of pictures of more modern threatening situations, such as guns pointed at the screen. Startle probes were presented on six of the twenty picture presentations per category. The participants were an unselected sample of university students, thus allowing testing of whether early startle modulation during threatening images is specific to individuals with phobia, or occurs through the entire population. The two separate negative picture categories will test whether early startle modulation is specific to threatening images that have been present during the course of human evolution (represented by the animals category) or is common to all threatening images. To test whether the startle reflex is modified differently at early and late stages of picture viewing, one group of participants received startle probes primarily at 300 ms and a second group primarily received startle probes between 3 and 5 seconds after picture onset. These groups are referred to as the “Early” and “Late” probe time groups throughout this and subsequent sections. The Probe Time factor was tested as a between-subjects variable in order to maximise the number of pictures for each category from which startle data were collected, while keeping the total number of startle instances for each participant relatively low.

Method

Participants

The experiment was completed by 83 participants (41 male, 42 female), ranging in age from 17 to 44 years old (median age = 19 years). Of these individuals, 31 were recruited from a student job placement centre, and paid NZ$10 for taking part, while the remaining participants were first-year psychology students who received course credit after participating in the experiment.

A further five participants did not complete the experiment, because of either failure of the stimulus presentation or response recording computer (n = 4), or declining to continue participation in the experiment (n = 1). Due to experimenter error in the programming of picture presentation orders, data from some female participants were excluded (n = 4) because they had viewed a mixed combination of picture blocks from two experimental conditions. Data from these nine participants were excluded from all analyses.

Startle Probe Presentation

The startle probe consisted of a 95 dB (A), 50-ms burst of broad band white noise, with a near instantaneous rise-fall time. The probe stimulus was produced by a Pentium-III IBM-compatible computer and amplified by Jazz speakers (model JS-300), before being presented binaurally to the participant through Gamma stereo headphones (model LH 075). Background noise in the headphones, due to the amplification procedure, was constant during picture presentation at 48 dB (A). Calibration of the probe stimulus intensity was performed with a Digital Sound Level Meter (model 8928) placed at the approximate position of a participant's ear in relation to the headphone. The volume of the probe stimulus was periodically rechecked during the course of running the experiments.

Table 7: Mean Valence and Arousal Ratings for Pictures Used in Study 2.

Dimension	Positive	Neutral	Animal Threat	Human Threat
Valence	7.53	5.34	3.46	3.17
Arousal	3.69	1.87	5.19	5.08

Picture Stimuli

Selection of the picture stimuli used in this study was on the basis of valence and arousal ratings, the collection of which was described in Study 1; see Table 7 for the mean emotional valence and arousal scores for each picture category. A complete list of the pictures used in the current study is presented in Appendix E. The following is a recapitulation of the composition of the picture categories in the current study. The 60 pictures used fit into three main categories, negative, neutral and positive, each comprising 20 pictures. The negative category was further split into two subcategories, animal threat and human threat pictures.

The pictures for the two threat categories were chosen by the author on the basis of typicality as (a) threatening animals (n = 8) and (b) threatening situations of modern origin (n = 8), to make up the animal and human threat categories respectively. The remaining pictures included in the negative category (n = 4) were more typical of disgust-eliciting situations; these were included to expand the negative set to the same size as the other Emotional Categories, and so startle probes were never presented on these pictures.

Neutral and positive stimuli were chosen largely on the basis of having been included in past studies of emotional startle modification, as listed in Table 5 of the IAPS instruction manual (Lang et al., 1999b). Some pictures of nudes in the positive category differed for male and female participants (as noted in Appendix E).

The Pentium-III computer controlled presentation of both picture and startle probe stimuli

through a custom designed programme (Jones, 2000b). The pictures were displayed on a 40 cm monitor, with 60 Hz refresh rate, situated 1.2 m away from the participant's seat. Pictures were presented for 6 seconds each, with a random intertrial interval of between 15 to 21 seconds.

Experimental Design

Probe Time was a between-subjects factor in this experiment, with one group of participants contributing data to the early Probe Time condition, and a second group contributing to the late Probe Time condition. Early startle probes were presented 300 ms after picture onset, while late probes occurred at random between 3 and 5 seconds after picture onset. There were 6 startle probes presented for each Emotional Category at the selected Probe Time; participants also received 6 startle probes during both neutral and pleasant pictures at the time for the other experimental condition (i.e., at the late stage for early Probe Time condition participants, and at the early stage for late Probe Time condition participants). These probes were included to reduce the predictability of startle probe presentation, and were not used for data analysis or the standardisation procedures employed for the blink magnitude and SCR magnitude dependent variables (these procedures are described below).

Startle probes were also presented during two intertrial intervals (ITI) within each block of pictures, making a total of ten ITI startle responses for each participant. Responses to probes during the ITI are referred to as ITI startle instances.

There were also two separate Picture Combinations, so that participants received startle probes during different combinations of pictures within each Emotional Category. Furthermore, the five blocks of pictures in each Picture Combination were presented either in normal or reverse order. The Picture Combination manipulation was included to test whether results would be similar across many pictures typical to an Emotional Category, while the order of presentation was varied between participants to counteract the course of startle habituation over time. Participants were assigned to these Picture Combination and order conditions in a counterbalanced manner. Picture Combination was included in the general ANOVA for each dependent variable;

block presentation order was not.

Physiological Recordings

EMG recordings of blink activity were taken from the participant's orbicularis oculi muscle below their left eye. The participants' skin was cleaned using a 70% w/w ethanol disposable pad, followed by application of OmniPrep skin preparation paste (D. O. Weaver) to the electrode sites. The placement for the negative lead electrode was below the outer canthus of the left eye, with the positive lead electrode placed slightly medial and inferior to the negative lead electrode. The ground electrode was placed on the participants forehead, near the hairline. Blue Sensor BRS-50-K disposable electrodes (Medicotest, Denmark) were used for differential EMG recording. These electrodes have a 1.5 by 1.5 cm surface area (the entirety of which is conductive), preventing placement with an interelectrode distance of 1 cm, as recommended by Fridlund and Cacioppo (1986), and so a slightly wider interelectrode distance of approximately 2 cm (centre to centre) was consistently used in this study and all subsequent studies in this thesis.

The raw EMG signal was passed through a MacLab Bio Amp (model ML132) connected to a MacLab 8/S signal processor, both controlled by a Power Macintosh 8600 computer running Chart, a specialised physiological recording programme (all recording software and MacLab hardware designed by ADInstruments). The raw EMG signal was filtered prior to recording with a bandpass of 0.3 - 500 Hz, as well as a 50 Hz notch filter to remove noise from external power sources. This filtered signal was then recorded at a rate of 1000 samples per second.

Skin conductance was recorded by attaching bright-plated, dry-operation (i.e. no conductive paste required) electrodes (ADInstruments) to the medial phalanges of the participant's index and ring fingers on their left hand. The signal was passed through a front-end skin conductance amplifier (GSR Amp, ADInstruments) before connecting to the MacLab and Power Macintosh in the same manner as the EMG signal. The skin conductance level (SCL) was calibrated to zero for each participant prior to beginning the experiment; if necessary, the amplifier was reset

to a zero SCL between blocks to prevent responses to the startle probe drifting off the recordable scale during testing. The skin conductance signal was recorded at 400 samples per second.

In addition to the two physiological signals, the stimulus presentation computer also produced signals marking onset and offset of the picture stimulus, and onset of the startle probe stimulus. These were recorded by the Chart software at a rate of 400 samples per second. All signals were recorded for a 12 second period for each picture, from 2 seconds prior to picture onset until 4 seconds after picture offset.

Off-line Data Reduction

Data were edited for each picture on which the startle probe had been presented, so that each picture's data began 150 ms prior to presentation of the startle probe. The raw EMG signal was passed through a digital high-pass filter (designed by the author using Chart's Smoothing and Arithmetic functions), nominally set at 28 Hz, as recommended for optimal recording of the acoustically elicited startle blink reflex (van Boxtel et al., 1998). On completion of all the studies in this thesis, an error was discovered in the calculation for this high-pass filter, so that the raw EMG signal was filtered with a high-pass of 15 Hz rather than 28 Hz. This setting still removed movement artefacts from the EMG record, and so the data were not recalculated using the 28 Hz setting.

The filtered signal was then digitally rectified and smoothed at a 10 ms time constant, using Chart's RMS (root-mean-square) off-line calculation function. Figure 3 presents five examples of the EMG trace for reflexive blinks, for startle probes elicited at a time of zero on the X-axis. The left-hand column represents the unprocessed signal (i.e., with the minimal filters set during the recording procedure mentioned in the previous section), the middle column the high-pass filtered signal at approximately 15 Hz, and the right-hand column showing the rectified and smoothed signal.

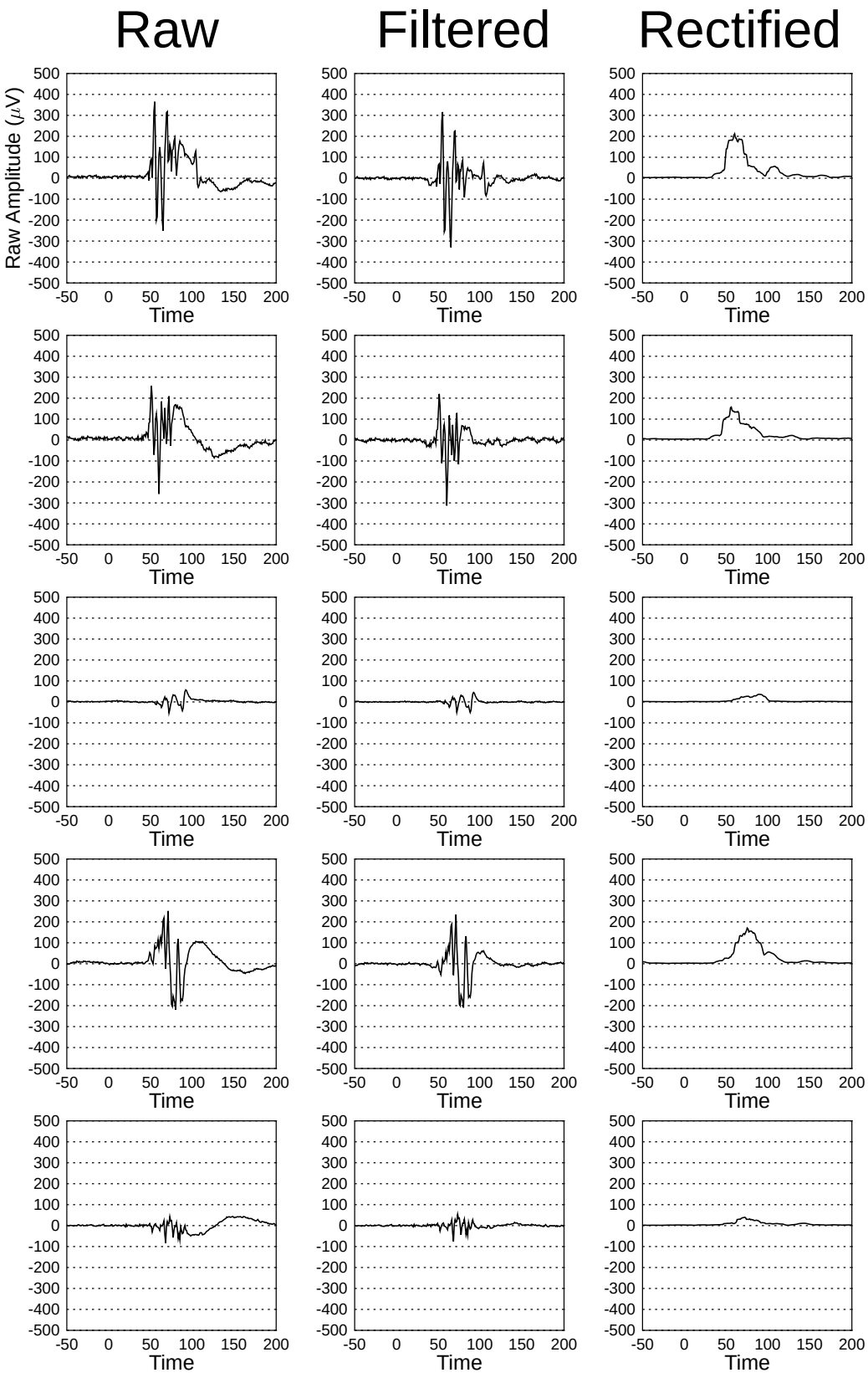


Figure 3. Example blink EMG signals for raw, filtered, and rectified traces. Startle eliciting stimulus presented at zero seconds. Each row consists of a single blink response, and each blink was randomly selected from a single participant.

Scoring Blink Magnitude and Latency to Peak

Startle blink magnitude was calculated by taking the peak point of the smoothed orbicularis oculi EMG response, occurring in a 20 to 150 ms time window following startle probe onset, and subtracting the mean EMG level for the 20 ms period prior to probe onset. If the calculated blink magnitude was less than or equal to twice the standard deviation of the smoothed EMG signal for the 20 ms prior to probe presentation, then blink magnitude for that picture was coded as zero, and blink latency for that picture noted as missing. For non-zero magnitude blinks, latency was recorded as the time from startle probe onset to the peak of the EMG response, as designated in the blink magnitude calculation. Both non-zero and zero responses were included in the analysis of blink magnitude, as this is the approach commonly taken in papers on emotional modification of startle. Furthermore this methodology has been recommended as suitable when startle is elicited with relatively intense probe stimuli, such as those used in this study (Berg & Balaban, 1999).

Blink magnitude was standardised prior to analysis by transforming all blink magnitude data for each participant into points on a z-distribution (Globisch et al., 1999). This included responses during emotional pictures at the participant's Probe Time, as well as responses for ITI probe instances. This z-distribution was then converted into a T-distribution with a mean of 50 and standard deviation of 10. The two distributions are identical, but use of the T-distribution arguably facilitates comprehension of figures because all values will be positive, rather than some being positive and some negative.

Scoring SCR Magnitude and Latency to Peak

The magnitude of SCRs to the startle probe were calculated in a similar fashion to blink magnitude, by taking the peak height of the skin conductance record in a 1 to 5 second period following probe onset, and subtracting the mean skin conductance level for the 20 ms period preceding onset of the startle probe. Again, if the SCR magnitude for a trial was less than or equal to twice the standard deviation of this 20 ms pretrial period, then SCR magnitude for that

trial was coded as zero and latency was noted as missing. Latency was again calculated for non-zero responses by measuring the time between probe onset and the peak in skin conductance as identified in the SCR magnitude calculation.

To reduce the effects of responsiveness differences in skin conductance, raw SCR magnitude scores were converted to proportions of the range of SCR magnitudes exhibited by an individual across startle probed pictures at the participant's Probe Time and all ITI probe instances. Each raw SCR magnitude datum was thus divided by the individual's SCR range (equal to the maximal SCR shown minus the minimal SCR shown), yielding a proportion for each data point (Lykken & Venables, 1971).

For both blink responses and SCRs, peak height (in the appropriate time window), mean level and standard deviation of activity in the 20 ms period before probe onset, and latency to observed peak were calculated automatically by the Chart software. Calculations of the magnitude of responses, and whether this magnitude fell within 2 standard deviations of pre-startle-probe activity, were performed in Microsoft Excel using set formulae.

Procedure

On arrival at the laboratory, the experimenter described the physiological recording techniques, picture presentation procedure, and startle probe protocol to the participant. After consenting to the study, the participant was asked to wash and dry their hands to ensure skin conductance could be recorded accurately. Following attachment of the EMG and skin conductance electrodes, the experimenter switched off the lights and the participant received a series of three startle probes, separated by approximately 12 seconds and in the absence of any picture stimuli, to allow habituation of the initially large responses to the probe stimulus. Recording scales were adjusted during this phase to ensure that no responses would exceed the recordable range. The experimental picture sets then began, with a short break between sets. Once the participant had completed all five sets, the electrodes were detached and the participant filled in the SNAQ and FSS-II-R questionnaires. Finally, the participant was debriefed on the experimental hypotheses

and thanked for their assistance.

Data Analysis

Firstly, data were excluded from participants who showed insufficient responding to the startle probe. For the blink response variables, participants with more than eight instances of raw response magnitude below 10 μV were excluded from data analysis; visual inspection confirmed that these eight instances had no blink response for all participants to whom this applied. Likewise, data were excluded on the SCR analyses if a participant had more than 8 untransformed SCRs with zero magnitude (i.e., more than a quarter of startle probes failing to elicit any SCR).

Initial analyses of the four physiological dependent variables were performed using ANOVAs that included Gender, Picture Combination, and Probe Time as between-subject variables, and Emotional Category as a repeated-measures variable. As in Study 1, Greenhouse-Geisser corrections were applied to *F*-statistics involving Emotional Category to protect against violations of the sphericity assumption (Jennings et al., 1987). The epsilon (ε) value by which degrees of freedom are multiplied in this correction is reported at the first point in each analysis when statistics including Emotional Category are reported; the value remains the same for interactions involving Emotional Category and between-subject variables. Degrees of freedom reported in the text are uncorrected, while probability levels reported in these ANOVAs have been calculated from the corrected degrees of freedom. The epsilon value for an interaction involving Emotional Category and a between-subjects variable remains the same as for the Emotional Category main effect, and is hence not reported if the main effect epsilon value has already been stated in the analysis for that variable.

Planned contrasts were performed between the levels of Emotional Category, at both early and late Probe Times, in line with the hypotheses of the experiment. Linear and quadratic trends were performed in the following manner, for both early and late Probe Time data. A linear contrast was performed across human threat, neutral, and positive contents, comparing the threat and positive categories. A similar linear effect was also assessed for animal threat, neutral, and

positive content responses. As these contrasts do not test actual linearity across the three content types (because neutral responses are simply ignored in the model), a second contrast is needed to ascertain the position of neutral responses relative to positive and threat responses. A quadratic trend across threat, neutral, and positive content responses compares the average of threat and positive responses to neutral responses. A significant quadratic effect indicates that positive and threat responses, on average, differ from neutral responses. In a contrast with only three levels, as is the case for all contrasts in these analyses, a significant quadratic effect indicates that the level of neutral responses does not fall between the levels for threat and positive. Thus, to truly assess linearity for blink magnitude across positive, neutral, and negative contents — which should be increasing with foreground unpleasantness — both linear and quadratic effects need to be performed, and the results can be interpreted as described in the following paragraph.

A significant linear trend indicates that one end level (positive or negative) is greater than the other, while a non-significant quadratic trend indicates that the response for neutral falls between those for the two end levels. These two observed effects would describe a linear trend across the three categories. In the absence of a significant linear effect, a significant quadratic effect indicates that threat and positive responses, when combined, are different from neutral responses. Significant linear quadratic effects indicate a non-linear pattern where positive and threat responses still differ from each other. This can mean one of two things: Firstly, a quadratic effect (i.e., both threat and positive responses are different from neutral) where the threat and positive responses are also significantly different from one another: For example, threat responses could be greater than both neutral and positive responses, while positive responses are also higher than for neutral. A second possibility is that responses for one of the two affective conditions in the significant linear effect (either threat or positive) are at a different level from both the other affective condition (giving the significant linear effect) and neutral responses, while the other affective condition does not differ from neutral. For example, threat content responses can be potentiated relative to neutral and positive (significant linear effect), yet positive content responses are not different from neutral: If the composite positive and threat response level still differs from neutral here, a significant quadratic effect is observed.

The above discussion should make clear that linear and quadratic effects do not individually test for linearity and quadraticity in a contrast with three levels. The “quadratic” contrast does, however, test for deviation from linearity, thus making the combination of linear and quadratic comparisons both valid and reasonable for assessing linearity across three levels of an independent variable.

When any other interactions involving Emotional Category were significant, the analysis decomposed the ANOVAs to test these interactions, and applied planned contrasts across the levels of Emotional Category where these were appropriate.

When other effects reached significance in the overall ANOVAs, post-hoc testing was performed using Tukey’s HSD test used to test differences between levels of the independent variables concerned.

Analysis of Blink and SCR Magnitude by Questionnaire Score.

To assess whether fear levels influenced startle modification, further repeated measure ANOVAs were conducted in which participants were split into low and high fear groups on the basis of median splits on the SNAQ and FSS questionnaires. As group sizes were highly uneven, it was decided that responses would be tested separately for each Probe Time/Fear Group condition, for both questionnaires. Planned contrasts (as per the previous analyses) were performed on Emotional Category within these single-factor ANOVAs. This decision avoids issues with error term calculation for planned contrasts which are described in the following paragraphs.

Firstly, the error term for planned contrasts within such a model only includes error sums of squares (SS) components from the emotional category conditions that are being compared. If planned comparisons are performed using a model including between-subject factors, such as Probe Time and Fear Group, then the error term SS for comparisons between levels of Emotional Category in a specific group (e.g., Early Probe Time, low SNAQ score) is calculated with data for the tested Emotional Categories from all of the between-subjects groups (i.e., both

Probe Times, both SNAQ score groups).

The degrees of freedom associated with the error term also differ between the two models. In the model including between-subjects variables, the degrees of freedom for the error term would be higher than for a comparison with a model including only one group from those between-subject divisions.

These two concerns should not influence the results of planned comparisons if standard error is the same across the levels of the between-subjects factor. It is felt that the planned comparisons within the single factor ANOVAs (as in this results section) are both more conservative and also more representative tests of the effects of interest than planned comparisons within the omnibus ANOVA containing all between-subject variables.

Results

Physiological Variables

Table 8 presents descriptive statistics for the four physiological variables recorded in this study, with data presented for each Emotional Category averaged across the two Probe Times. For the blink magnitude and SCR magnitude variables, both raw and transformed data are reported; only the transformed data were used in the following analyses.

Table 8: Physiological Dependent Variable Means and Standard Errors, by Emotional Category of Picture, Averaged Across Probe Time.

Physiological measure	Positive	Neutral	Animal Threat	Human Threat
Blink magnitude *n* = 73				
Raw (μV)	56.06	55.95	59.45	63.30
(S.E.)	(5.30)	(5.37)	(5.50)	(5.87)
Standardised (T-score)	49.26	49.12	50.66	52.41
(S.E.)	(.44)	(.46)	(.47)	(.45)
Blink latency to peak (ms)	74.36	74.88	75.80	74.26
(S.E.)	(.92)	(.86)	(.89)	(.86)
SCR magnitude *n* = 56				
Raw (μS)	2.40	2.18	2.32	2.59
(S.E.)	(.24)	(.21)	(.24)	(.24)
Standardised (p of range)	.41	.38	.39	.46
(S.E.)	(.02)	(.02)	(.02)	(.02)
SCR latency to peak (ms)	4220.24	4154.87	4136.94	4143.90
(S.E.)	(108.24)	(112.84)	(106.66)	(108.46)

Questionnaire Results

Mean scores and standard errors for the SNAQ and FSS questionnaires are presented in Table 9.

In separate ANOVAs incorporating Gender, Probe Time group, and Picture Combination as

Table 9: Descriptive Statistics for SNAQ and FSS Questionnaires, Between Gender.

Questionnaire	Females	Males	All	Median
n	40	40	80	80
SNAQ	9.15	6.05	7.6	7
(S.E.)	(.7)	(.51)	(.46)	
FSS	122.25	102	112.13	110
(S.E.)	(4.24)	(3.67)	(3.01)	

between-subject variables, main effects were found for Gender on both the SNAQ and FSS questionnaires, *F*s (1, 72) = 11.98 and 14.01, both *p*s $< .001$, respectively. Female participants had higher scores than males on both questionnaires, as can be seen in Table 9. Questionnaire scores did not differ on the basis of Picture Combination or Probe Time groups, *F*s (1, 72) < 1.8, *p*s $> .184$. The median scores reported in Table 9 were used to split participants into high and low score groups for analyses of blink and SCR magnitude by questionnaire score.

Blink Magnitude

The repeated measures ANOVA including all independent variables showed no effect or interactions involving Gender, highest F (1, 65) = 1.73, $p = .193$. The following model therefore excluded this variable.

There was a significant main effect for Probe Time, F (1, 69) = 14.59, $p < .001$. This factor also interacted significantly with Picture Combination, F (1, 69) = 5.29, $p = .025$. Blink responses were generally larger at the late Probe Time (M = 51.08) than at the early Probe Time, (M = 49.65). Post hoc testing of the interaction with Picture Combination revealed that this effect was significant for the first Picture Combination, $p < .001$, but not for the second Picture Combination, $p = .719$.

There was a main effect for Emotional Category on blink magnitude, F (3, 207) = 10.52,

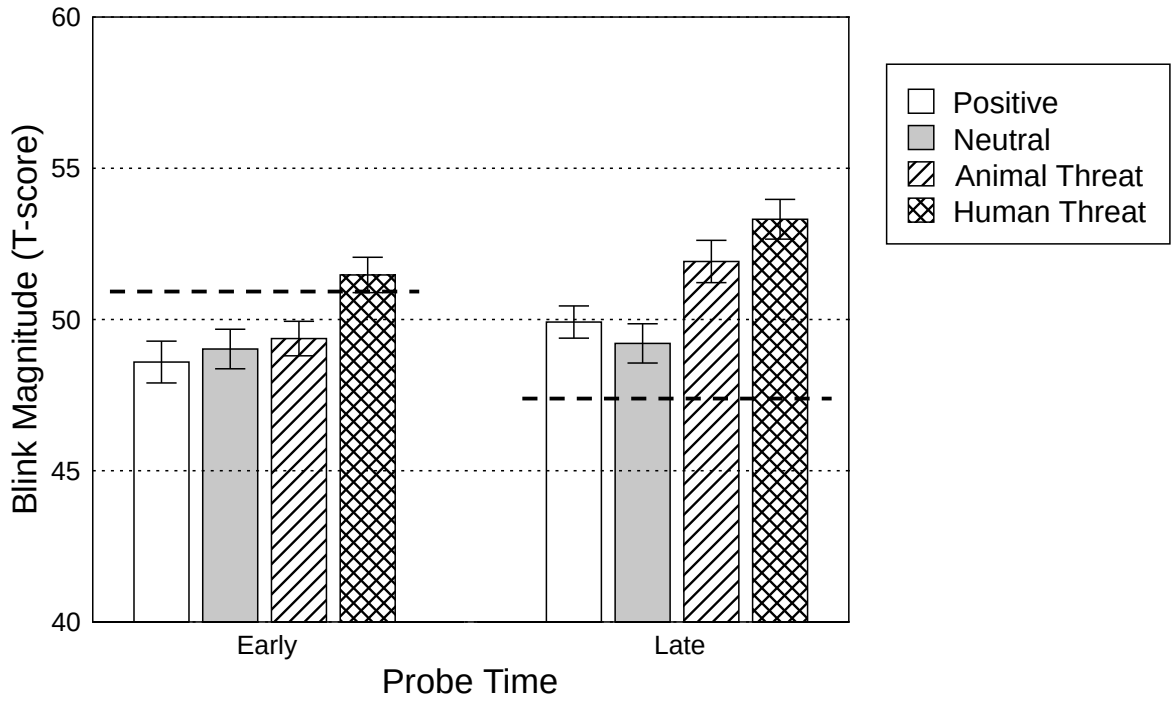


Figure 4. Mean standardised blink magnitude by Emotional Category, at the early and late Probe Times. Error bars indicate one standard error. Dotted lines represent appropriate mean level of ITI responses for each Probe Time condition.

$p < .001$, $\varepsilon = .96$. Emotional Category did not interact with any other factors, Fs (3, 207) < 1.65, ps $> .18$.

Figure 4 displays the data to which the following contrasts refer. Contrast analysis at the early Probe Time (left side of Figure 4) showed significantly greater blink magnitude for human threat contents compared to positive contents, linear F (1, 69) = 9.92, p = .002. There was no quadratic effect for human threat, F (1, 69) = 1.06, p = .306. Neither the linear nor quadratic effect for animal threat contents were significant, Fs (1, 69) = .85 and .03, ps = .359 and .872.

At the late Probe Time (right side of Figure 4), human threat blinks were again of greater magnitude than positive blinks, linear F (1, 69) = 14.19, $p < .001$. Animal threat content blinks were also potentiated relative to positive contents, linear F (1, 69) = 5.39, p = .023. Significant quadratic effects were also obtained for both human and animal threat contrasts, Fs (1, 69) = 7.99 and 4.44, ps = .006 and .039, respectively. This indicated that blink response magnitudes for neutral contents did not fall between the values for threat and positive conditions. Figure 4 clearly shows that blink responses during neutral and positive contents were not

significantly different at the late Probe Time.

Blink Magnitude and SNAQ Score

Due to the very uneven group sizes mentioned in the method section, ANOVAs are performed separately on each Probe Time by Score Group condition, for both questionnaires.

For early Probe Time participants scoring below the median on the SNAQ measure (n = 23), the main effect of Emotional Category on blink magnitude approached significance, F (3, 66) = 2.81, $p = .061$, ε = .783. Data for these participants are on the left of Figure 5. Planned contrasts showed significantly greater blink magnitude for human threat contents compared to positive, linear F (1, 22) = 9.87, p = .005. There was no quadratic effect for human threat, F (1, 22) = .81, p = .379. For the animal threat condition, neither the linear nor quadratic contrasts approached significance, Fs (1, 22) $< .76$, ps $> .393$.

For high SNAQ scoring participants at this early Probe Time (n = 13), whose data are on the right hand side of Figure 5, there was no effect of Emotional Category, F (3, 36) = .96, $p = .409$, ε = .78. No planned contrasts were significant, Fs (1, 12) < 1.71, ps $> .216$.

Blink magnitude data by Emotional Category for the late Probe Time participants are presented in Figure 6, divided by SNAQ score group. For the low score participants (n = 15), there was a significant effect for Emotional Category on blink magnitude, F (3, 42) = 4.06, $p = .021$, ε = .79. Linear contrasts were not significant for either of the threat conditions, Fs (1, 14) = 1.45 and 1.14, ps = .249 and .303, for human and animal threat respectively. The quadratic contrasts for both human and animal threat were significant, Fs (1, 14) = 6.46 and 6.78, ps = .023 and .021. These results indicate that blink response magnitudes were greater during the three affective content types than during neutral contents for these participants, as can be seen on the left of Figure 6.

Finally, in the blink magnitude ANOVA for high SNAQ score participants at the late Probe

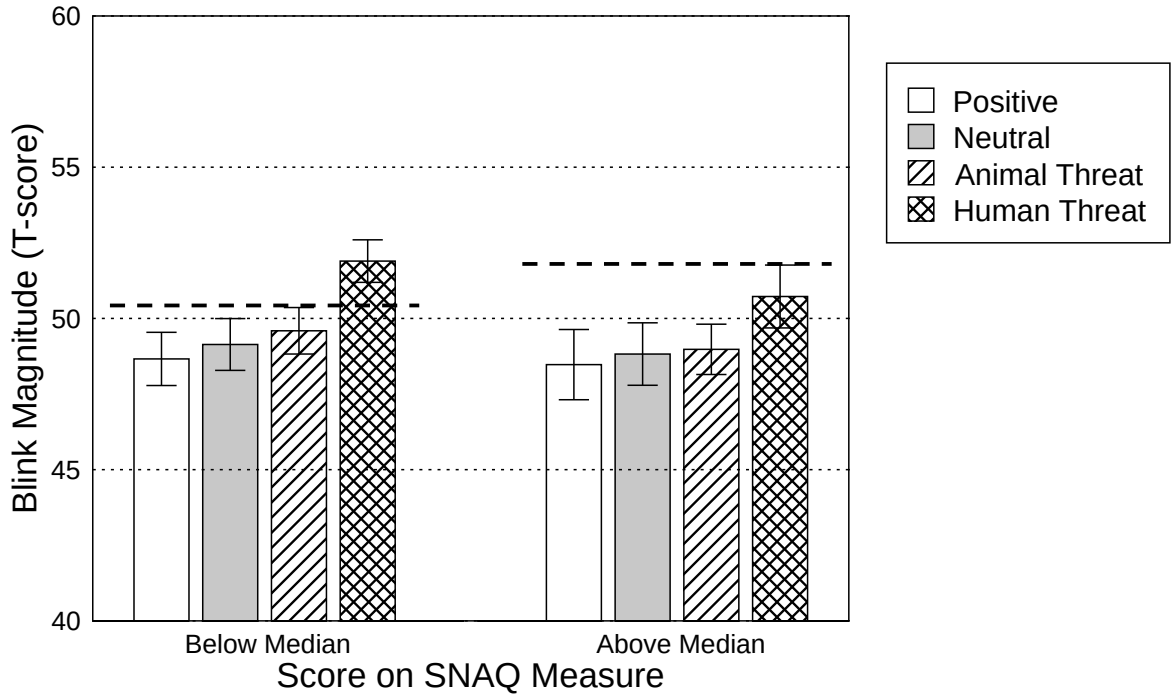


Figure 5. Mean standardised blink magnitude by Emotional Category at the early Probe Time, by participant score on the SNAQ. Error bars indicate one standard error. Dotted lines represent appropriate mean level of ITI responses for each score group.

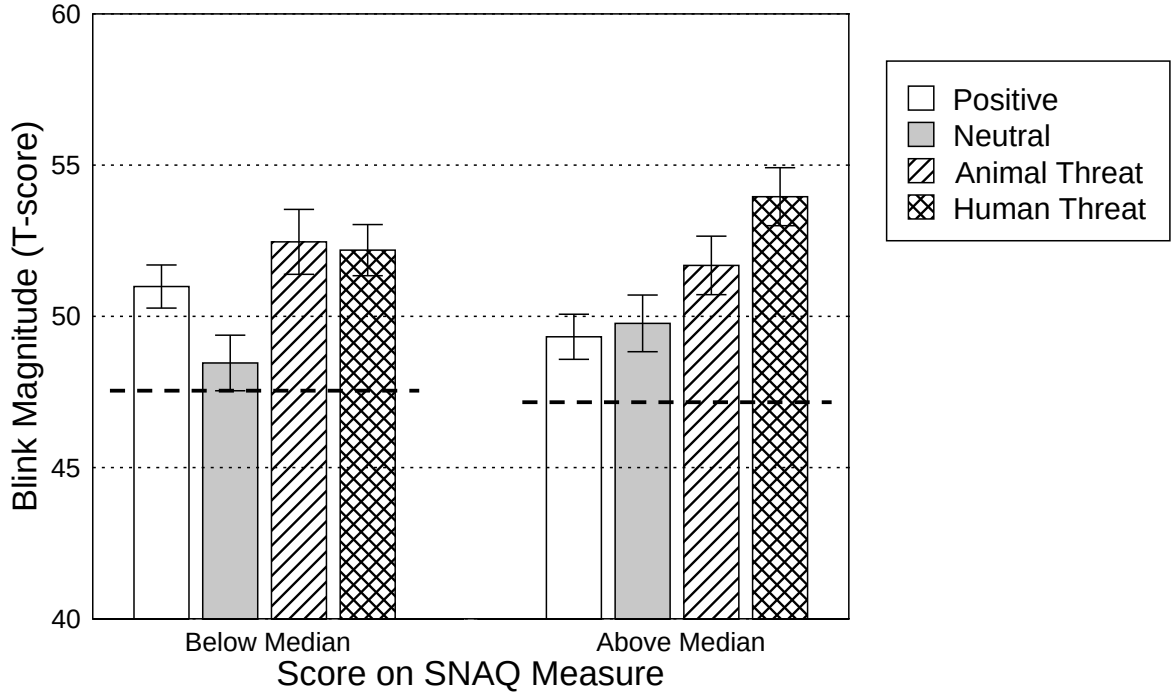


Figure 6. Mean standardised blink magnitude by Emotional Category at the late Probe Time, by participant score on the SNAQ. Error bars indicate one standard error. Dotted lines represent appropriate mean level of ITI responses for each score group.

Time (n = 21) the main effect for Emotional Category was significant, F (3, 60) = 4.91, $p = .006$, ε = .86. The data for these participants are presented on the right of Figure 6. Human threat content blinks were significantly greater in magnitude than positive blinks, linear F (1, 20) = 12.68, p = .002. The linear contrast for animal threat contents approached significance, F (1, 20) = 3.24, p = .087. Neither quadratic comparison was significant, Fs (1, 20) = 2.45 and .6, ps = .133 and .448

Blink Magnitude and FSS Score

For early Probe Time participants scoring below the median on the FSS (n = 16), there was an effect for Emotional Category, F (3, 45) = 3.54, $p = .028$, ε = .87. Contrast analysis showed greater blink magnitude for human threat contents than for positive, as can be seen in Figure 7 (left hand side), linear F (1, 15) = 11.64, p = .004. There was no quadratic effect for human threat, nor was there a linear or quadratic effect for animal threat contents in this group, Fs (1, 15) $< .47$, ps $> .503$. These results indicated increasing blink magnitude with increasing foreground unpleasantness for human threat contents only.

For high FSS-score participants at the early Probe Time (n = 20), there was no main effect for Emotional Category, F (3, 57) = 1.03, $p = .373$, ε = .76. Data for this group are shown on the right of Figure 7, where it is clearly shown that blink magnitude did not differ between the four Emotional Categories, contrast Fs (1, 19) < 1.96, ps $> .177$.

At the late Probe Time (Figure 8), participants scoring below the median on the FSS (n = 20) showed a significant effect of Emotional Category on blink magnitude, F (3, 57) = 3.57, $p = .024$, ε = .9. For human threat contrasts, the quadratic effect was significant while the linear effect approached significance, Fs (1, 19) = 4.45 and 3.76, ps = .048 and .067. For animal threat, the quadratic effect approached significance but the linear comparison did not, Fs (1, 19) = 4.19 and 2.11, ps = .055 and .162. Both quadratic effects indicate higher blink magnitude for the threat and positive conditions than for neutral.

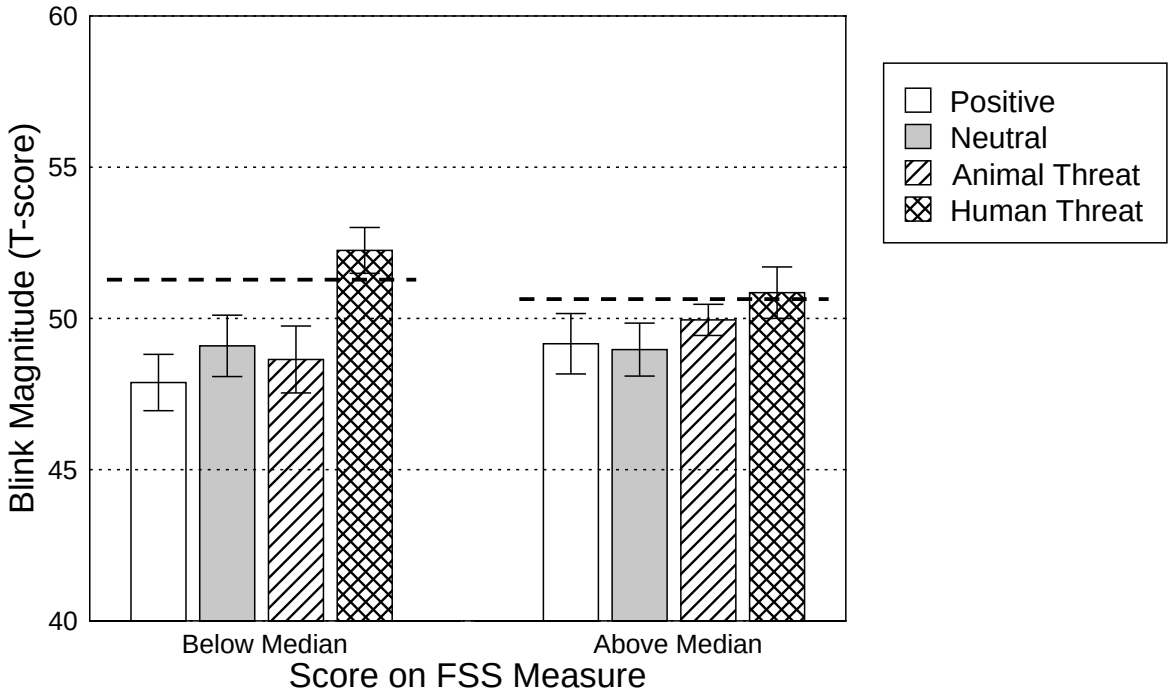


Figure 7. Mean standardised blink magnitude by Emotional Category at the early Probe Time, by participant score on the FSS. Error bars indicate one standard error. Dotted lines represent appropriate mean level of ITI responses for each score group.

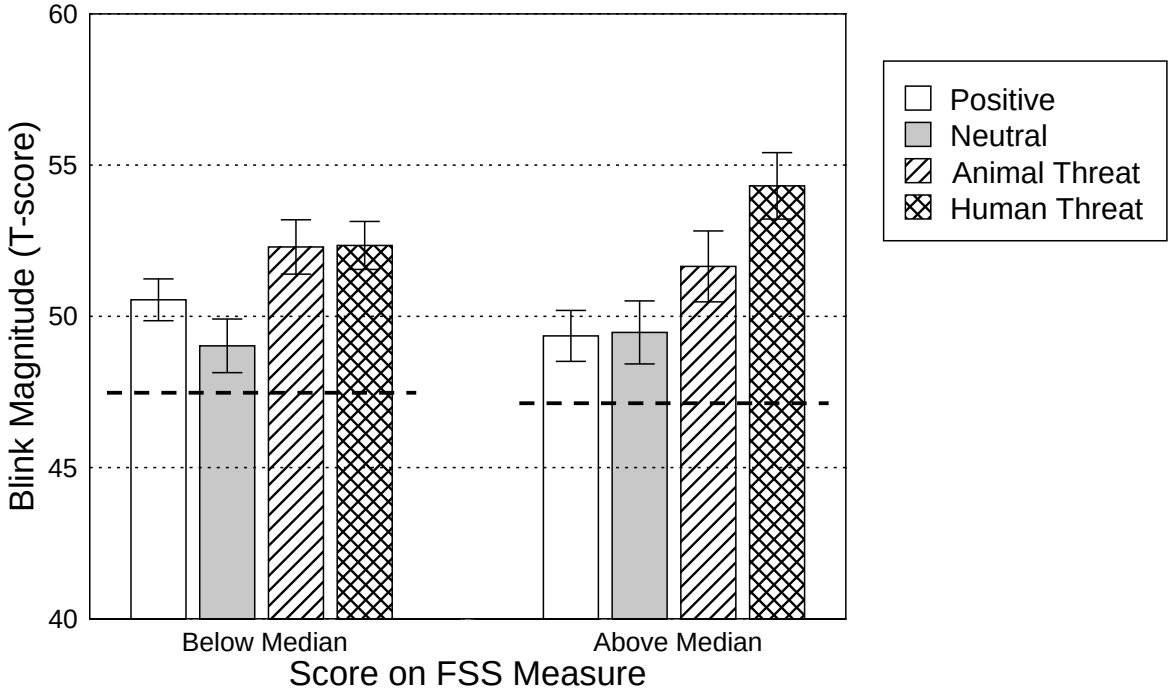


Figure 8. Mean standardised blink magnitude by Emotional Category at the late Probe Time, by participant score on the FSS. Error bars indicate one standard error. Dotted lines represent appropriate mean level of ITI responses for each score group.

For the above-median FSS score participants (n = 16), there was again a main effect for Emotional Category, F (3, 45) = 4.46, $p = .014$, ε = .81. Data for these participants are on the right hand side of Figure 8. Blink responses were of greater magnitude for human threat than for positive contents, linear F (1, 15) = 9.71, p = .007. The quadratic effect for human threat approached significance, F (1, 15) = 3.11, p = .098. As can be seen in Figure 8, neutral and positive content blinks did not differ from one another. Neither linear nor quadratic effects for animal threat were significant, Fs (1, 15) < 2.19, ps $> .159$.

Blink Latency to Peak

For the ANOVA on blink latency to peak, there were no significant effects involving Gender or Picture Combination, highest F (1, 65) = 2.06, p = .156. These were removed from the model. The main effect for Probe Time approached significance, F (1, 71) = 2.98, p = .088. There were no significant effects for Emotional Category or the interaction between Emotional Category and Probe Time, Fs (3, 213) = 1.53 and .09, ps = .21 and .961, both ε = .97 and . The absence of significant differences between Emotional Categories in each Probe Time group can be seen in Figure 9, contrast Fs (1, 71) < 2.29, ps $> .135$.

SCR Magnitude

For the SCR magnitude ANOVA, Gender was not significant as a main effect or interaction, highest F (3, 144) = 1.82, $p = .149$, ε = .95. This factor was removed from the model. In the new model, Emotional Category was a significant main effect, F (3, 156) = 6.4, $p < .001$, ε = .96. The interaction between Emotional Category and Picture Combination approached significance, F (3, 156) = 2.17, p = .097. Probe Time was not significant as a main effect, F (1, 52) = .493, p = .486, nor did it interact with Emotional Category, F (3, 156) = 1.06, p = .364.

SCR magnitudes are presented by Emotional Category at the two Probe Times in Fig-

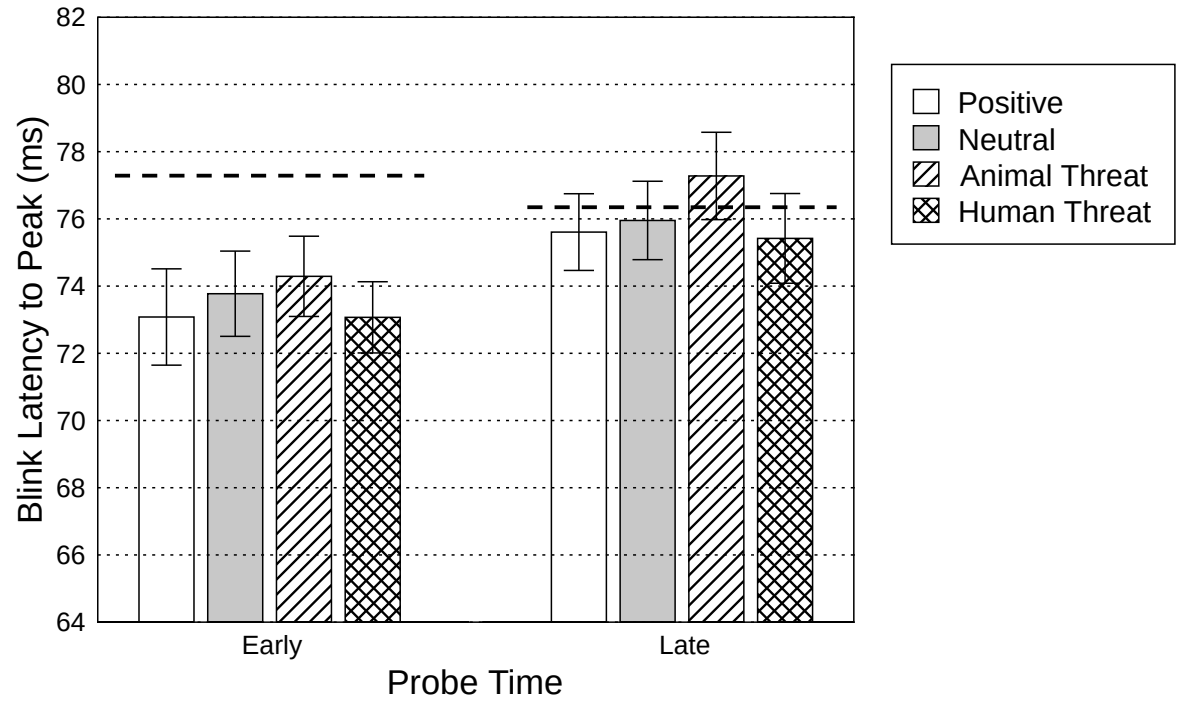


Figure 9. Mean blink latency to peak by Emotional Category, at the early and late Probe Times. Error bars indicate one standard error. Dotted lines represent the appropriate mean level of ITI responses for each Probe Time condition.

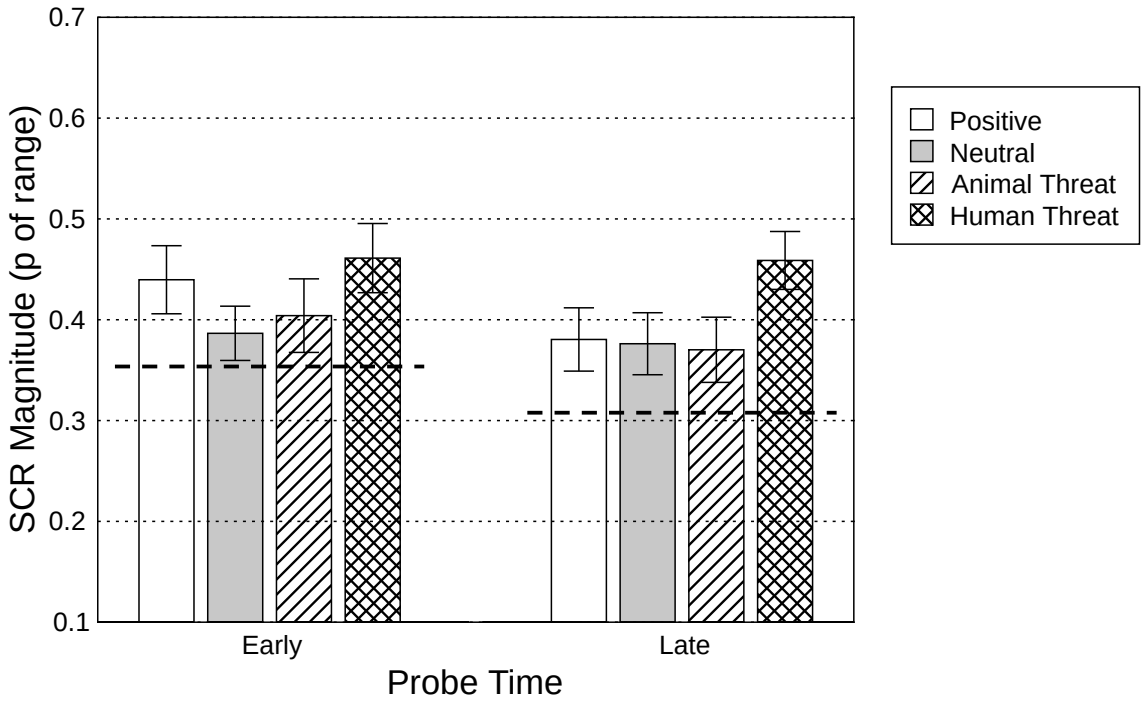


Figure 10. Mean standardised SCR magnitude by Emotional Category, at the early and late Probe Times. Error bars indicate one standard error. Dotted lines represent the appropriate mean level of ITI responses for each Probe Time condition.

ure 10. At the early Probe Time, there was a significant quadratic effect for human threat, F (1, 52) = 5.93, p = .018. This indicated greater SCR magnitude in the positive and human threat conditions compared to neutral. The linear effect for human threat, which would indicate a difference in SCR magnitude between human threat and positive, was not significant, F (1, 52) = .24, p = .624. Neither linear nor quadratic effects were apparent for animal threat, Fs (1, 52) = 2.17 and 1.66, ps = .147 and .217.

At the late Probe Time, the linear effect for human threat was significant, F (1, 52) = 9.2, p = .004. A quadratic effect also approached significance for human threat, F (1, 52) = 3.56, p = .065. Figure 10 shows that neutral and positive picture SCR magnitudes were not significantly different from one another; human threat was associated with enhanced SCR magnitude compared to those pictures. Animal threat again showed no significant linear or quadratic effect at this late Probe Time, Fs (1, 52) $<$ .14, ps $>$ .708.

SCR Magnitude and SNAQ Score

As with the blink magnitude analysis by questionnaire score, ANOVAs were performed on each Probe Time/Score Group combination due to uneven group sizes. Planned contrasts are only reported for groups showing a significant effect for Emotional Category, or an effect that approached significance — this was decided because of the small group sizes.

For the early, low SNAQ score participants (n = 17), there was no main effect for Emotional Category, F (3, 48) = .54, p = .642, ε = .92. SCR magnitude data for these participants are presented on the left of Figure 11.

For above-median SNAQ score participants at this Probe Time (n = 10), there was a significant effect of Emotional Category on SCR magnitude, F (3, 27) = 4.93, p = .014, ε = .78. There were significant quadratic effects for both human and animal threat contents, Fs (1, 9) = 15.53 and 12.39, ps = .003 and .007. The animal threat linear effect approached significance, F (1, 9) = 4.62, p = .06. This linear effect is caused by the larger magnitude SCRs

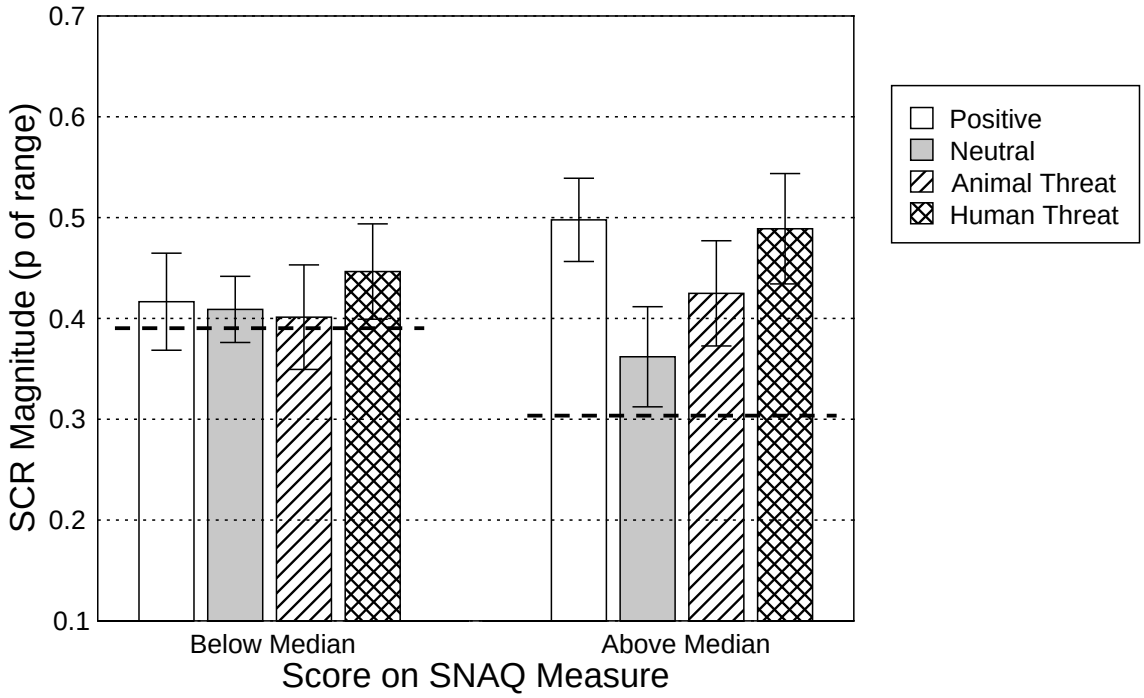


Figure 11. Mean standardised SCR magnitudes by Emotional Category at the early Probe Time, by participant score on the SNAQ. Error bars indicate one standard error. Dotted lines represent the appropriate mean level of ITI responses for each score group.

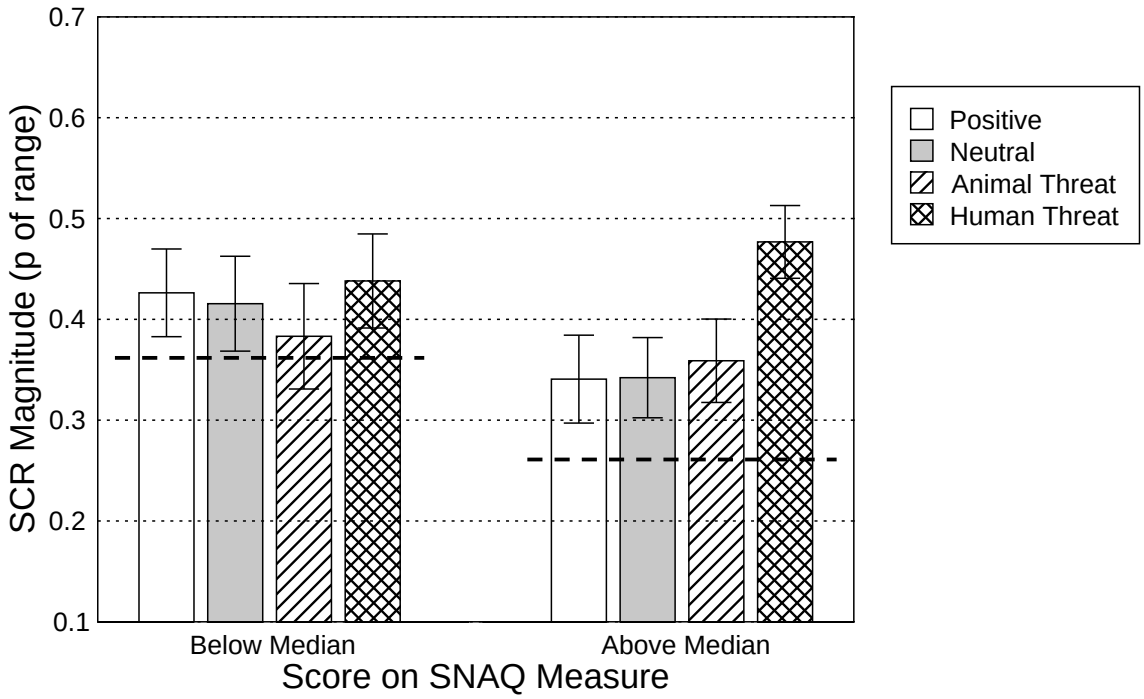


Figure 12. Mean standardised SCR magnitudes by Emotional Category at the late Probe Time, by participant score on the SNAQ. Error bars indicate one standard error. Dotted lines represent the appropriate mean level of ITI responses for each score group.

for positive compared to animal threat contents, as can be seen on the right of Figure 11. There was no linear effect for human threat, F (1, 9) = .03, p = .86.

At the late Probe Time, participants who scored below the median on the SNAQ measure showed no effect for Emotional Category (n = 13), F (3, 36) = .73, $p = .499$, ε = .69. The data for this group are presented on the left of Figure 12.

For those scoring above the median on the SNAQ at this Probe Time (n = 15), there was a significant effect of Emotional Category, F (3, 42) = 7.44, $p = .001$, ε = .8. Animal threat contents showed no significant contrasts, Fs (1, 14) = .29 and .06, ps = .597 and .803, for linear and quadratic contrasts respectively. Human threat showed a significant linear effect, F (1, 14) = 14.32, p = .002, indicating greater magnitude SCRs during human threat relative to positive contents. A significant quadratic effect was also apparent for human threat, F (1, 14) = 5.87, p = .03. It can be discerned in Figure 12 that SCR magnitudes during positive and neutral contents for this group were not significantly different, accounting for the significant quadratic effect.

SCR Magnitude and FSS Score

For early Probe Time, below-median FSS score participants (n = 12) there was no effect for Emotional Category, F (3, 33) = .93, $p = .425$, ε = .82. These data are on the left of Figure 13.

For participants scoring above the median on the FSS in the early Probe Time condition (n = 15), the effect for Emotional Category approached significance, F (3, 42) = 2.72, $p = .062$, ε = .92. There were significant quadratic effects for both human and animal threat, Fs (1, 14) = 8.38 and 5.34, ps = .012 and .037. Neither threat category showed a linear effect, Fs (1, 14) = .23 and 2.81, ps = .641 and .116, for human and animal threat respectively. These quadratic effects confirm that SCR magnitudes for these high-fear participants were greater at this Probe Time for the three affective conditions than for the neutral condition, as can be seen on the right of Figure 13.

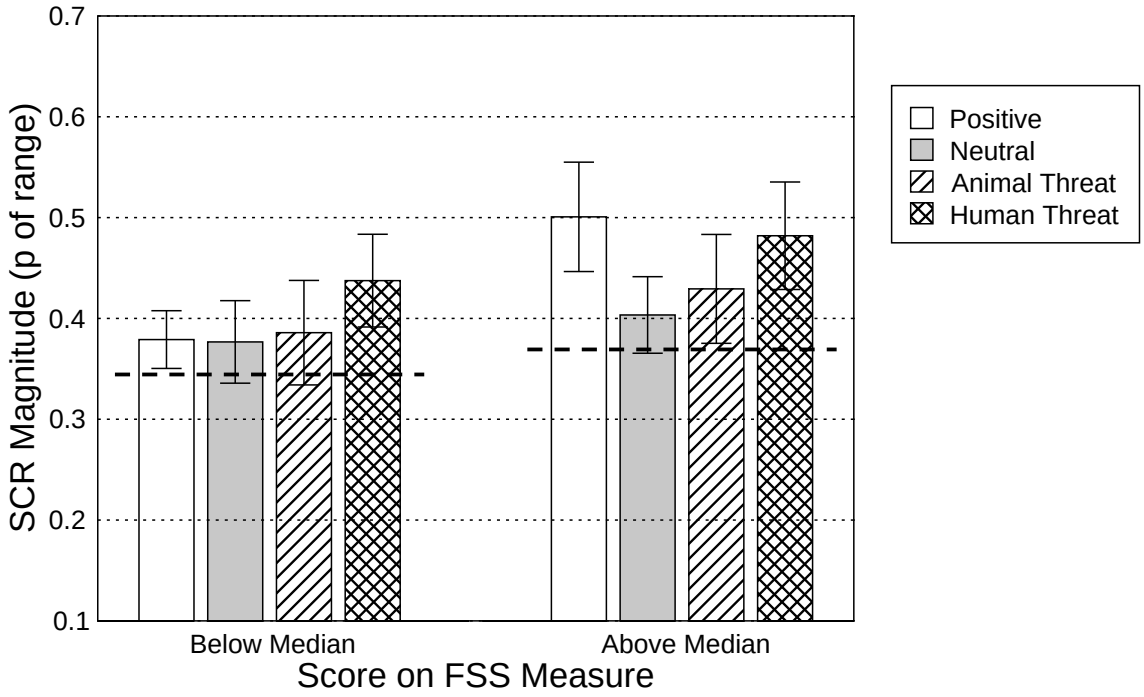


Figure 13. Mean standardised SCR magnitudes by Emotional Category at the early Probe Time, by participant score on the FSS. Error bars indicate one standard error. Dotted lines represent the appropriate mean level of ITI responses for each score group.

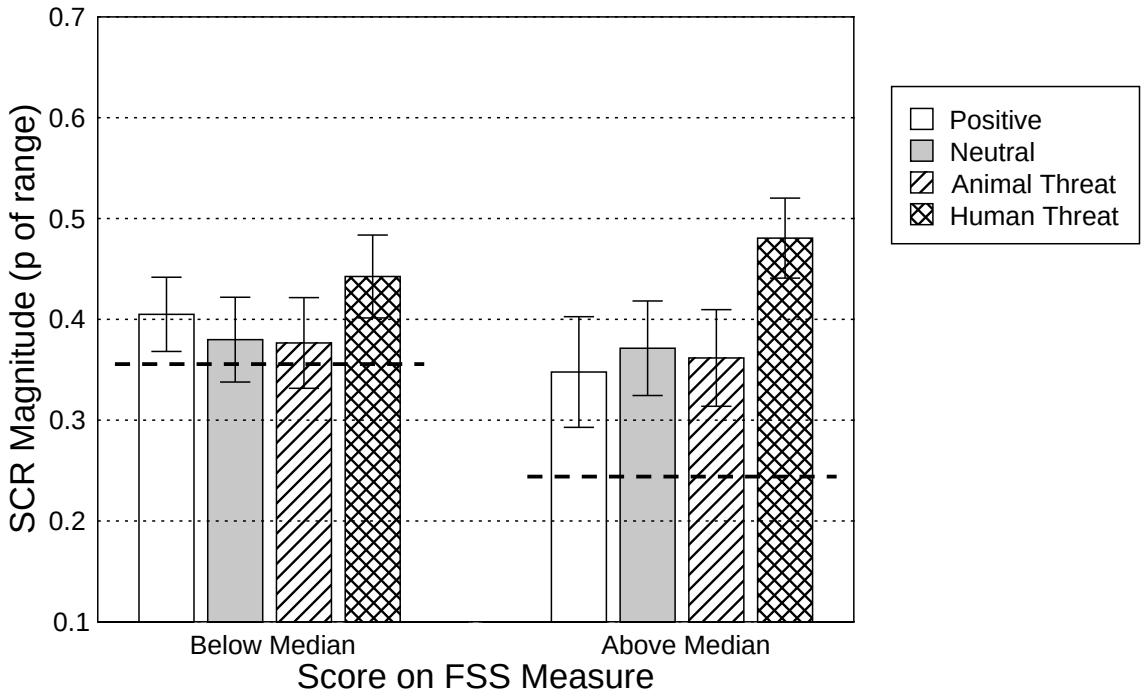


Figure 14. Mean standardised SCR magnitudes by Emotional Category at the late Probe Time, by participant score on the FSS. Error bars indicate one standard error. Dotted lines represent the appropriate mean level of ITI responses for each score group.

At the late Probe Time, participants who scored below the median on the FSS measure (n = 16) showed no effect of Emotional Category on SCR magnitude, F (1, 15) = 1.99, $p = .145$, ε = .79. For participants scoring above the median on the FSS (n = 12), there was a significant effect of Emotional Category, F (1, 11) = 3.5, $p = .042$, ε = .74. SCR magnitudes during human threat contents were greater than those during positive contents, as can be seen in Figure 14, linear F (1, 11) = 8.24, p = .015. No other contrasts were significant here, Fs (1, 11) < 1.08, ps $> .321$.

SCR Latency to Peak

For the analysis of SCR latency to peak, there were no significant main effects for any of the between subject variables, nor interactions between them Fs (1, 48) $< .81$, ps $> .373$. There was also no main effect for Emotional Category, F (3, 144) = 1.55, $p = .211$, ε = .86. The only significant interaction was between Emotional Category, Probe Time, and Picture Combination, F (3, 144) = 3.59, p = .021. Interactions between Emotional Category, Probe Time and Gender, as well as Emotional Category, Picture Combination and Gender, approached significance, Fs (3, 144) = 2.27 and 2.23, ps = .093 and .097.

To test the interaction between Emotional Category, Probe Time, and Picture Combination, the data were analysed separately for each Probe Time group with Emotional Category, Gender, and Picture Combination as factors. For the early Probe Time group, the interaction between Emotional Category and Picture Combination approached significance, F (3, 72) = 2.47, $p = .085$, ε = .79. For the late Probe Time group, there was no main effect for Emotional Category, F (3, 72) = .47, $p = .674$, ε = .85, nor was the interaction between Emotional Category and Picture Combination significant, F (3, 72) = 1.94, p = .141. Further comparisons were not conducted.

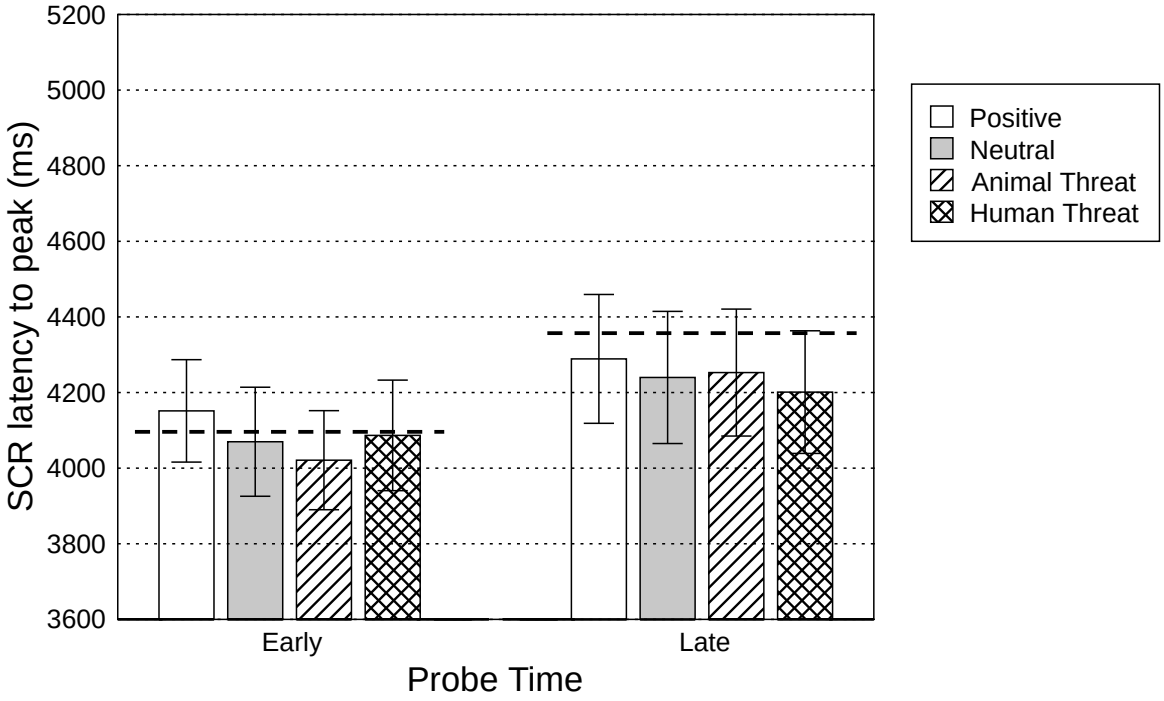


Figure 15. Mean SCR latency to peak by Emotional Category, at the early and late Probe Times. Error bars indicate standard error. Dotted lines represent the appropriate mean level of ITI responses for each Probe Time condition.

Discussion

This experiment compared startle responses during four types of emotional pictures (positive, neutral, animal threat, and human threat) at early (300 ms) and late (between 3 and 5 seconds) stages of picture viewing.

Blink Modification at 300 Milliseconds

When participants had only been viewing pictures for 300 ms prior to elicitation of startle, blink responses were larger for human threat pictures compared to neutral and positive pictures. This potentiation of the startle blink occurred at the same stage of picture viewing as in Globisch et al. (1999), in their highly animal fearful participants. The current study showed that startle modification can occur, for threatening pictures, at this early stage of picture viewing, and by the use of an unselected sample of participants also represents an extension of the earlier results. This result supports the hypothesis that fast processing of the emotional significance of negative emotional stimuli is not specific to phobic or highly fearful participants. In fact, early startle potentiation for human threat stimuli was limited to low-fear participants in this study.

Animal threat stimuli failed to potentiate startle blinks at the 300 ms probe time, even though these pictures reliably enhanced the reflex in participants who received the probe several seconds after picture onset. Although comparisons between the two probe times are compromised by the between-subjects nature of this factor, it is quite clear that the animal threat stimuli (half of which were snakes, the remainder other aggressive animals) failed to potentiate startle at the early Probe Time.

Globisch et al. (1999) found startle potentiation at their 300-ms probe time with high fear participants, for similar pictures of snakes and spiders. In the current experiment, even those participants who scored highly on the SNAQ measure of snake fear did not show potentiation of startle at the early Probe Time for these pictures, although the size of this early Probe Time, high snake-fear group was quite small (n = 11). It is important to note that the definition of

high-fear is different in the two experiments — in the present one, it describes a post hoc median split of an unselected sample of participants, while Globisch et al. (1999) selected their high-fear participants on the basis of scoring above the 85th percentile on either the SNAQ or SPQ measure. Thus the present experiment's high snake-fear participants are not an analogous group to that of Globisch et al. (1999).

A more interesting point is that both high and low snake-fear participants showed potentiation for these animal threat pictures at the late Probe Time. This suggests that these pictures fail to activate early potentiation mechanisms, rather than being incapable of modifying startle at all, although the between-subjects Probe Time factor limits more concrete conclusions.

It seems that the animal threat pictures were not identified as unpleasant as quickly as the human threat pictures. In a task where participants made a forced choice as to the valence of emotional pictures (drawn from the IAPS), Bradley and Lang (1999) found slower reaction times for pictures of animals than for those of people or objects. For unpleasant pictures, this effect seemed only to occur for participants low in general fearfulness (Figure 2 of Bradley & Lang, 1999, p. 8), although no statistical comparisons between the three content types were reported. This might indicate a difference in complexity between animal photographs and other unpleasant photographs. In turn, this can explain why blinks were potentiated for animal threat pictures at the late, but not the early, Probe Time (i.e., the pictures are too complex to be processed in a short space of time). It is also consistent with previous findings of enhanced startle blink magnitude for animal pictures in high animal-fear participants (Globisch et al., 1999) — these participants are capable of processing these stimuli quickly. Thus, feared stimuli are capable of being processed to the point of potentiating startle by 300 ms — but the stimuli that are feared can differ between participants in each study, depending on the experimental design.

Leaving aside stimulus complexity as an explanation of differences in startle modification between the two threat content categories, the lack of early potentiation of startle for animal threat pictures could be due to the criteria for picture selection. The animal threat picture condition consisted of four photographs of snakes and four photographs of other aggressive, non-human

animals (two of dogs, two of sharks). Although the snake photographs were selected on the basis of ratings identifying them as unpleasant (across all participants, not only high snake-fear participants), and depicted snakes preparing to strike or bite, the pleasantness and arousal ratings for these pictures still varied according to self-reported fear levels in Study 1. Comparison of blink magnitude results during the two types of animal stimuli, not reported in the results section, revealed (non-significantly) larger responses for non-snake animal than snake stimuli at both probe times. The inclusion of these snake pictures in an experiment that did not specifically test a high snake-fear sample may be responsible for the lack of blink potentiation for animal threat contents at the early probe time, even though potentiation was still absent in participants who had scored highly on the SNAQ measure of snake fear — see previous reservations regarding small group size and definition of high-fear in the present study.

Blink Modification During Positive Contents

As a final note on the blink modification results, blink reflexes during positive contents were inhibited relative to neutral at the early Probe Time for low-fear participants only (cf. Bradley, Cuthbert, & Lang, 1993; Codispoti et al., 2001; Levenston et al., 2000), but not at the late Probe Time for these participants(cf., Vrana et al., 1988, for example). High SNAQ score participants did show startle inhibition after several seconds of picture viewing, but for both low-fear groups positive contents at the late Probe Time were associated with startle potentiation (indicated by significant quadratic effects across positive, neutral, and negative contents).

As mentioned in Chapter 3, failure to find startle inhibition during positive stimuli is not an uncommon occurrence. In their study of startle potentiation across the picture viewing period, Globisch et al. (1999) found no startle inhibition for positive relative to neutral pictures at any probe time, for either animal fearful or control participants. Picture set selection appeared to be the cause of this. Splitting blink magnitude data for positive stimuli into responses for high and low arousal exemplars revealed that blink responses were smaller during the high arousal positive stimuli, and when only these pictures' blink data were included in the positive picture condition, startle was inhibited at the 300 ms probe time relative to neutral picture responses

(Globisch et al., 1999).

Looking at arousal-related qualities of pictures in the present experiment, SCRs for the positive category were enhanced at the early Probe Time for high-fear participants only, indicating that positive pictures were emotionally arousing. These participants also showed significant startle inhibition for positive contents at the late Probe Time (for the SNAQ analysis, at least).

Startle blink magnitude was inhibited at the 300 ms Probe Time for low-fear participants in the absence of enhanced SCR magnitudes. With regards to the lack of late stage blink inhibition for positive pictures in the low-fear participants, it was noted in the introduction on positive emotion and startle (p. 26-30) that blink inhibition during positive contents may in fact be limited to certain types of pleasant situations, whether highly arousing ones or more specific content types, and some studies (e.g., Levenston et al., 2000) have shown potentiation of startle for specific positive content types. For the low-fear participants in the present study, positive condition SCRs were not significantly potentiated relative to neutral, at either Probe Time, and blink inhibition was absent for these pictures at the late Probe Time — a more congruent pattern of results, although still inconsistent with the literature.

If early inhibition of the startle blink during positive pictures is caused by attentional demand, then a group of pictures that fails to inhibit startle at a probe time several seconds after picture onset (whether indicative of attentional engagement or emotional processing) should also not inhibit startle at a very early stage either. This was not the case in this study, although again the between subjects design for Probe Time qualifies comparisons between early and late Probe Times.

Skin Conductance and Specific Emotional Content

The effects of emotional content on SCR magnitude were limited to high-fear participants only. The results at the early Probe Time showed that SCRs were greater for two emotional categories, human threat and positive, than for the neutral condition. At the late Probe Time, human threat

SCRs were of greater magnitude than all other picture categories. SCRs in the positive picture category were not significantly different from neutral at this Probe Time.

This evidence is a reliable indication that human threat pictures produced more intense emotional activation than the other picture categories; to a lesser extent, the same can be said for the positive category on the basis of early Probe Time data. This in turn raises several questions:

1. If positive pictures activated the positive emotional processing networks or were attentionally engaging, as suggested by SCR enhancement, why were startle blinks not inhibited for these pictures at either probe time?

2. Why were SCRs during positive pictures enhanced compared to neutral for the early Probe Time participants only?

3. Why were SCRs never enhanced during animal threat compared to neutral pictures?

Firstly, although emotional activation (as indicated by heightened SCR magnitude relative to the neutral condition) is necessary for startle blink modification to occur, the presence of an enhanced magnitude SCR does not guarantee that emotional activation (or perhaps attentional engagement, in the case of positive stimuli) is sufficient to cause blink modification. Secondly, SCR enhancement for positive pictures was only observed for high-fear participants, and so low-fear participants showed neither SCR nor blink magnitude potentiation for these contents; in fact, blink modification for positive pictures for these participants was in the direction of potentiation rather than inhibition.

Regarding the first and second question, there may be differences in the SCR components recorded at early and late Probe Times. Viewing an emotional picture, in the absence of startle probe presentation, typically elicits an SCR from the viewer (Lang et al., 1993). Presentation of the startle probe also elicits an SCR. When both events (picture and probe presentation) occur in quick succession, co-activation of sweat glands by the two events may lead to temporal summation of the SCRs to picture and probe. This can explain the absence of significant differ-

ences in SCR magnitude for positive pictures at the late Probe Time, where there would be no summation of the two SCRs. It can also explain the absence of blink inhibition for these picture contents for high-fear participants at the early Probe Time, where the SCR data suggest it should be occurring — the recorded SCR magnitude would be a combined effect of picture content and probe presentation, and thus exaggerated, while the actual level of emotional activation is insufficient for blink modification to occur.

The relationship between SCR magnitude and blink magnitude is not much clearer with regard to the third question raised. Enhancement of SCR magnitude, relative to neutral, can be taken as an indicator of activation of an emotional system or systems (aversive or appetitive), a condition which is of course necessary for emotional modification of startle to occur. As SCR magnitudes for the animal threat category were not enhanced relative to neutral, at either Probe Time, we should not anticipate startle blink modification for these pictures. Startle blink magnitude was in fact potentiated for animal threat pictures at the late Probe Time. The explanation for this blink modification in the absence of SCR enhancement — an inversion of the problem for positive picture contents — may be related to a problem in calculating SCR magnitude data, rather than due to a discrepancy between the two output systems.

As noted in the method, SCR magnitude was calculated by taking a 20-ms baseline of skin conductance in the period immediately prior to startle probe potentiation, and subtracting this baseline from the peak in the SCR occurring 1 to 4 seconds after probe presentation. The problem is related to the summation hypothesis proposed above: Viewing an arousing emotional picture evokes an SCR in the absence of any other stimulation (Lang et al., 1993), and this response should be at or near peak magnitude a few seconds after picture onset — around the time of late probe presentation in this experiment. Thus, the “baseline” level of skin conductance for participants in this condition would be recorded at an erroneously high level, and if the SCR to the startle probe returned toward baseline before the SCR to the probe manifested itself, the calculated magnitude would be quite small. Figure 16 provides an illustrative example of this phenomenon, drawn from a single participant in this study. The 20 ms period prior to point A is the baseline period for the magnitude calculation, and point B marks the peak amplitude of

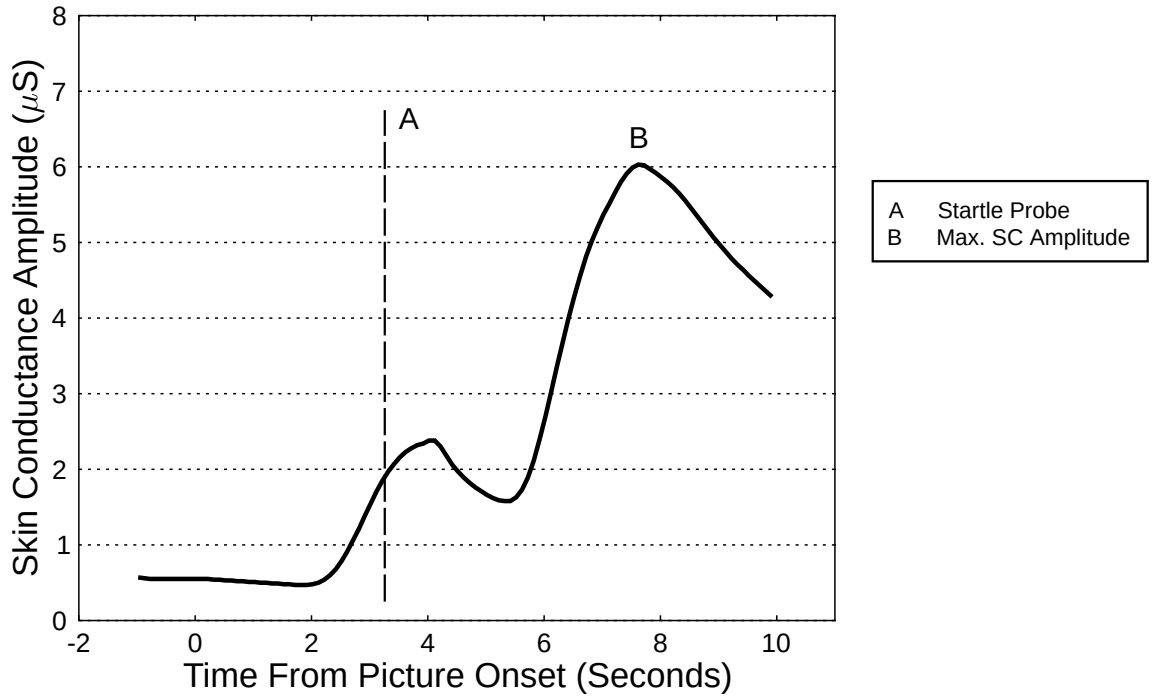


Figure 16. Skin conductance record from a single participant, showing superimposed SCRs to picture content and to the startle probe.

the SC record. The response magnitude is the skin conductance amplitude at point B minus that at point A, and it should be quite clear from Figure 16 that this calculation method is sub-optimal for calculating the size of the second SCR. An alternative calculation could take the baseline from the period immediately prior to picture presentation (at zero seconds on Figure 16). However, if the SCR to the probe appeared before the SCR to the picture alone had returned to baseline, summational effects of the two SCRs could lead to an enhanced amplitude for the probe SCR that was not representative of the probe-evoked response. This would be the case in the instance illustrated in Figure 16, if this calculation method was used.

An interesting corollary of this hypothesis regarding the actual magnitude calculation used is that it should still lead to accurate calculations of SCR magnitude for emotionally neutral contents at this late probe time. These pictures should elicit no SCR on their own, and thus the baseline for calculating the size of the probe SCR would not interfere with the magnitude calculation. The absence of emotional modulation of late probe SCRs could then be ascribed to faulty calculation of late SCRs for affective contents.

Early SCR modification by Emotional Category is probably the best indicator of emotional arousal available in this study.

Blink and Skin Conductance Response Latencies to Peak

Both the analyses for blink response and SCR latency to peak amplitude were uninterpretable. Males showed faster blink latencies to peak than females. Comparing Emotional Categories, the only significant difference for blink latency to peak was at the late Probe Time, between positive and animal threat contents, with shorter response latencies for the positive condition.

For SCR latency to peak, effects of comparisons between Emotional Categories were not significant.

Latency to peak is a less interesting psychophysiological variable than latency to response onset, partially because the period between response onset and peak will depend on both the magnitude of the response and the time constant used for rectifying the data. The reason latency to peak was analysed in this thesis was that latency to onset was not consistently calculated by the computer program used, and the number of manual calculations needed to obtain this data would be inhibitively time consuming; there would be 46 blinks for each of 65 participants, making a total of 2990 blinks latency estimations for blink latency this study alone. This issue is addressed in the General Discussion at greater length, discussing results from all of the studies in the thesis.

Limitations of the Experimental Design

The primary limitation of this study was the use of a between-subjects design. The design was chosen in order to maximise the number of startle data that could reasonably be collected for each of the four picture conditions, but in turn renders comparisons between effects at the early and late probe conditions less valid. It is unclear whether the differences in blink modification for animal threat pictures between the two probe times is due to generalisable qualities of the

pictures themselves or some characteristic of the participants in the two groups.

A further concern of the between-subjects design regards the predictability of the startle probe presentation. For the late probe time participants, 12 out of 36 startle probes were presented at the 300 ms probe time, with the remaining 24 presented between 3 and 5 seconds after picture onset. For these participants, the majority of startle probes were presented at the later, random time period, with reduced predictability. The primary concern lies with participants in the early probe time condition, who received 24 of their 36 startle probes at the fixed 300 ms picture-to-probe onset time. The preponderance of startle probes at the same time may have led to increased anticipation of startle probe presentation immediately following picture presentation. In the general startle modification paradigm, participants tend to estimate probe presentation as more frequently occurring on negative that positive foreground trials (Witvliet & Vrana, 2000), which presumably means that participants experience heightened expectations of probe presentation for negative content pictures during the course of the experiment. Anticipation of the startle probe is likely to increase response magnitude by directing attention toward the modality of the aversive probe (Haerich, 1994), and, in combination with greater expectations of probe presentation immediately following picture onset, these phenomena could explain the early potentiation of startle for the human threat category. The hypothesis envisions a state of affairs for the early probe time participants as follows: participants anticipate greater likelihood of startle probe presentation (a) immediately following picture onset and (b) during negative content pictures, so that anticipation of the probe during these pictures directs attention toward the auditory modality, thus enhancing the startle reflex to the acoustic probe.

For this attention-directed potentiation to only occur for negative pictures, participants would still need to have identified the emotional content of the picture by the 300 ms probe time, in which case the mechanisms causing blink potentiation by emotional valence could already be active. A more likely possibility arising from anticipation of early probe presentation is that blink magnitude would be enhanced across all picture contents at the early stage of viewing, independent of their content. Intuitively, directing attention toward the acoustic probe at picture onset might delay processing of the visual stimulus, thus reducing the probability of emotional

modification of startle. The presence of differential startle across the four Emotional Categories at the early Probe Time is evidence against this hypothesis.

The net impact of the considerations in this section is that, for the factors of emotional content and probe time, a within-subjects design is preferable to a between-subjects design in this type of experiment, even though this requires either reducing the number of data points constituting each probe time/emotional content condition, or increasing the total number of startle probes presented to each participant. All subsequent studies in this thesis employ a within subjects design for the variables of experimental interest, and compromise between reducing the number of pictures contributing data to each condition and the total number of probes presented.

Summary

The observed potentiation of startle blink magnitude by human threat contents after 300 ms of picture viewing is contrary to the findings of several experiments cited in the preamble to this study (Bradley, Cuthbert, & Lang, 1993; Codispoti et al., 2001; Levenston et al., 2000). These picture contents, depicting human aggression directed toward the viewer, produce the greatest degree of startle potentiation of all negative picture contents (Bradley, Codispoti, Cuthbert, & Lang, 2001). It is also apparent that portrayals of human aggression prompt greater startle potentiation when the threat is directed toward the viewer (e.g., a gun pointed at the screen) rather than other-directed threat, occurring between actors in the photograph (e.g., Levenston et al., 2000). Some experimental data suggest that females show greater blink potentiation for mutilation than threat contents, while males do not (Bernat, Patrick, Benning, Blonigen, & Hicks, 2002; Bernat, Patrick, Steffen, & Sass, 2002; Yartz & Hawk, 2002). The introduction to Study 3 discusses more experiments bearing on this point. This experiment found no difference in blink modification between the two categories of threat stimuli (animal and human/non-animal) when participants had viewed the picture for several seconds, although again differences between these two types of pictures have previously only been observed in female participants (Bradley, Codispoti, Sabatinelli, & Lang, 2001). Participant gender did not interact with Emo-

tional Category in analyses of blink modification in the present study.

The section on SCR magnitude showed that participant fearfulness had a more consistent effect on this variable than on blink magnitude, and suggested that only the more highly-fearful participants show SCR modification during the startle probe paradigm. Problems in calculating SCR magnitude for the late Probe Time participants meant that analysis of SCR modulation was unreliable for this group.

Although the between-subjects design was less than ideal, this experiment clearly showed startle blink potentiation at 300 milliseconds, with an unselected participant sample and different picture stimuli from the previous report of early startle potentiation (Globisch et al., 1999). It is still not clear why studies using mixed-content negative picture sets have failed to find early startle potentiation, and so the introduction to Study 3 explores several aspects of negative emotion that may explain these phenomena.

Study 3

The results of Study 2 showed early potentiation of the startle reflex for threatening stimuli, in an unselected sample. Contrary to the hypothesis, this occurred for modern threat stimuli rather than for animal threat stimuli. This next study attempts to ascertain reasons for the still unresolved discrepancies in early startle modification by contrasting responses for two distinct categories of negative pictures, threat and mutilation content photographs, which should be more evocative of fear and disgust, respectively.

In Chapter 1, it was noted that emotion can be described at many different levels — by motivational disposition, emotional valence, or action disposition. The startle reflex is hypothesized to be modified by neural mechanisms that are responsive to the emotional valence of a situation (unpleasant or pleasant) or motivational disposition (approach or avoid), not the action disposition associated with a specific emotional state. The following section describes and critiques experimental work on emotional specificity and startle. As specific positive emotional stimuli have already been discussed briefly in Chapter 3, and given that this thesis is primarily concerned with early startle potentiation during negative emotional stimuli, the following discussion is limited to startle modification during different varieties of negative foreground.

Emotional Specificity and Startle

One of the premises of the emotional startle probe paradigm is that the systems responsible for the emotional modification process are organised by the simple distinction of appetitive and aversive drive systems (Lang et al., 1998). The basic organisation of emotional processing at the level of startle modification circuitry implies that discrete emotions within each system (e.g., fear, anger, and disgust as negative emotions) should produce similar effects on the startle reflex, provided foregrounds are of similar valence and intensity levels.

Breaking the negative emotional category into more discrete emotional subcategories can reveal

a more complex pattern of startle modification than that proposed by the motivational priming hypothesis. This subdivision of negative emotional stimuli can be performed in two conceptually distinct ways: By dividing data from different foregrounds on the basis of the emotion elicited by the stimulus (e.g., fear, disgust), or by dividing data on the nature of the foreground picture content (e.g., threatening animals, mutilated bodies). The first method implies an experimental method where participants provide feedback on the specific emotion or emotions they are experiencing during foreground presentation, by self-report and/or other indicators of emotional state such as facial muscle activity. The second method tacitly accepts that certain foreground types can elicit more than one emotion: For instance, viewing photographs of bodily mutilations often leads to reports of both disgust and fear (e.g., Yartz & Hawk, 2002). Studies of startle modification employing these two distinctions will be considered separately in the following section, followed by a description of the next experiment, which contrasted startle responses for threat and mutilation pictures at early and late stages of picture viewing.

Startle During Specified Emotional States

Experiments testing startle responding during emotionally varied foregrounds have again drawn on mental imagery, photographs and film clips as their emotional stimuli. Cook et al. (1991) employed three emotionally negative categories of imagery scripts: sadness, fear, and anger. All three negative categories potentiated startle relative to neutral and positive imagery, and the specific negative scripts engendered the same degree of potentiation. Comparing startle during disgust, anger, and neutral script imagery, Vrana (1994) tested whether startle modification was specific to he general valence of an emotional stimulus or to the action disposition thereof (i.e., withdrawal from the stimulus for disgust, engagement with the stimulus for anger). If startle modification were associated with the action disposition for an emotion, Vrana predicted inhibition of startle responses during disgust imagery, due to attention being directed away from the disgusting foreground, hence allowing more attentional resources for processing of the acoustic startle probe (Vrana, 1994). There are two objections to this hypothesis: Firstly, the consistent augmentation of startle during fear, strongly associated with a withdrawal action

disposition. Secondly, as the mental imagery procedure asks for the participant's continuous attention, it does not seem to allow for disengagement of emotional processing in the same way as a picture viewing procedure does. Both types of imagery showed potentiated startle relative to neutral imagery, in accordance with both the motivational priming model and the criticisms given above.

A third imagery study compared startle between three aversive scripts — fear involving a threat to the participant, fear involving other-directed threat (e.g., witnessing a physical assault), and anger. All produced heightened startle reflexes, although fear imagery appeared to show greater potentiation than anger imagery (this effect only approached significance; Miller et al., 2002, Experiment 1). When personal imagery scripts were developed for each participant to produce more effective imagery (see description in Chapter 3), anger script imagery produced greater potentiation than non-personalised anger imagery (Miller et al., 2002, Experiment 2). This is most likely an indication of the more vivid and arousing nature of these personalised scripts. Vividness ratings for anger imagery were in fact much higher for personalised imagery compared to standardised anger imagery (16.8 versus 9.8, of a possible score of 20), an effect that was not so strongly stated for fear scripts (vividness ratings of 17.3 and 14.3, for personalised and standard imagery respectively). These data suggest that non-personalised anger imagery is not effective at producing the intended emotional state, and so when the more appropriate material is used, the putative difference in startle augmentation for anger and fear imagery (as observed in Experiment 1 of Miller et al., 2002) ceases to be manifest. No experiments have been performed looking at anger with pictorial stimuli, perhaps due to this difficulty in finding appropriate elicitors of anger in a standardised media format. The difference between standardised and personalised imagery could be attributed to either greater intensity or scripts that are more likely to induce a state of anger. Contrasting mildly and highly arousing personalised anger scripts might resolve this question.

Two other imagery studies compared responses during fear and sadness script imagery to responses during joy and relaxation script imagery, so that the negative emotional scripts differed in emotional intensity as well as specific emotional state (Witvliet & Vrana, 1995, 2000). These

experiments have previously been described in Chapter 3. Both studies found greater startle magnitude during imagery for highly-arousing fear scripts than for the less arousing sadness scripts, as well as greater blink magnitude for the two highly arousing scripts (fear and joy) compared to the low arousal scripts (sadness and relaxation). When comparing within each level of arousal (i.e., fear vs. joy, sadness vs. relaxation), both types of negative imagery produced enhanced startle magnitudes compared to their appropriately matched positive imagery. This highlights the importance of matching the arousal characteristics of negative and positive categories that are to be compared. It is also worth noting that Cook et al. (1991) observed no differences in startle magnitude between their sadness, fear, and anger imagery categories, despite the first being rated as less arousing than the latter two scripts. The conflation of arousal with specific negative emotions is dealt with in Study 4).

These experiments (Witvliet & Vrana, 1995, 2000) also support the possibility that imagery-based startle modification could be driven more by cognitive demand than emotional input (Miller et al., 2002). The findings taken as evidence of independent valence and arousal effects on startle responding during imagery can be explained solely by arousal differences between the groups, as the pattern of startle modification follows the arousal ratings (i.e., highest arousal imagery coupled with greatest startle magnitude; lowest arousal imagery associated with lowest startle blink magnitude).

Research on emotional specificity and startle modification using film clips is limited to three studies at this time, with fear and disgust clips as their negative stimuli. The most recent of these studies failed to find startle potentiation during viewing of toe surgery footage, a film clip that was described as primarily disgusting by participants (Kaviani et al., 1999). A movie segment in which a man is about to be shot potentiated startle successfully, and was described as "anxiety/threat evoking" by some forty-seven percent of participants (thirty-five percent rated this clip as primarily disgusting). An earlier experiment by the same group (Kumari et al., 1996) had found startle potentiation for a negative category composed of two disgust evoking clips, with one of these clips depicting shoulder surgery. Additional data from this study, pertaining to two fear-evoking clips, were included in a reanalysis that compared startle responses between

fear and disgust stimuli (Wilson, Kumari, Gray, & Corr, 2000). These two types of clips did not produce statistically different levels of startle responding. Pleasantness ratings for the disgusting clips were less negative in the Kaviani et al. study (1999) than in the earlier study (Kumari et al., 1996, and, by extension, Wilson et al., 2000), suggesting that the disgusting film clip used in the Kaviani et al. study may not have been intense enough to engage startle modification circuitry. This interpretation would be consistent with studies on emotional arousal and startle (Cuthbert et al., 1996). Arousal ratings were not reported for the film clip studies under discussion, although the two surgical procedures shown strengthen this case, as pleasantness ratings were more intensely negative for the disgust clips which succeeded in potentiating startle (Kumari et al., 1996) than for the disgusting clip that failed to do so (Kaviani et al., 1999).

Having covered imagery and film clip studies, the review will now consider studies employing photographic slides to investigate emotional specificity in startle. Lang (1995) reported that participants showed greater startle blink modification during fear-eliciting than disgust-eliciting pictures; both of these produced greater modulation than when startle was triggered during pity-evoking pictures (e.g., malnourished children).

In order to rigorously test the assumption that fear and disgust states are equivocal in modulating startle, Balaban and Taussig (1994) pre-selected negative slides on the basis of being described by a group of independent raters as primarily fear or disgust evoking. These two negative stimulus sets were compared to standard neutral and positive picture sets. Across two experiments, only fear evoking slides augmented startle relative to the neutral condition. In the first experiment, startle blinks during disgusting slides were of similar magnitude to blinks in the neutral condition, and were significantly smaller in magnitude than responses during fear slides. The second experiment included one group of participants who viewed a second set of positive slides in place of the fear slides, to preclude the fear slides or having a disproportionate number of negative slides in the set from influencing responses to the disgusting slides. There was still no potentiation of startle for disgusting pictures in this second experiment.

This is only the second study described (along with Kaviani et al., 1999) in which a specifically

non-fear negative emotion did not potentiate the startle response. In a similar vein, Yartz and Hawk (2002) also tested emotional specificity of startle modification with fear and disgust as the negative emotional states. In addition to positive, neutral, and fear photograph categories, they included two types of disgust stimuli, one of slides depicting blood or injury (disgust-blood) and a second category of other disgusting photographs (disgust-other, including pictures such as an unflushed toilet or a cockroach on a plate of food). The inclusion of these disgust-other stimuli was intended to produce a category where disgust was predominant, as compared to the disgust-blood condition for which it was hypothesised (and found) that fear would also be evoked (Yartz & Hawk, 2002). Contrary to the findings of Balaban and Taussig (1994), startle magnitude was potentiated during the negative category (all three content types) relative to positive contents, and for female participants, startle magnitude was greater during disgust than for fear stimuli (Yartz & Hawk, 2002).

Startle During Specified Picture Contents

The emotional stimuli in the next group of experiments were divided on the basis of their pictorial content, rather than the emotional response produced by the pictures. Emphasis is once again given here to negative emotional stimuli. The first of these studies included several probe times to trace startle potentiation over the course of picture viewing, using two negative categories, physically aversive (i.e., threat or injury) and socially aversive (i.e., negative human social situations), these being matched on ratings of picture complexity (Lethbridge et al., 2002). Startle potentiation was only found for physically aversive photographs, relative to neutral, at probe times later than 2.5 seconds; startle blink magnitude during socially aversive stimuli was not potentiated at any stage of picture viewing. As observed for the negative picture set in Codispoti et al. (2001), startle responses during physically aversive pictures were not inhibited at a 300 ms probe time, appearing at the same level of magnitude as responses to neutral pictures. Blinks were inhibited for both positive and socially-aversive negative stimuli at this stage of picture viewing (Lethbridge et al., 2002).

Two comprehensive studies of emotional responding by specific content types (Bradley, Codis-

poti, Cuthbert, & Lang, 2001; Bradley, Codispoti, Sabatinelli, & Lang, 2001), discussed in the introduction regarding positive emotional contents, will be discussed again here regarding specific negative contents. The negative content types were, in ascending order of subjective arousal ratings: pollution, loss, illness, contamination, accidents, mutilation, animal attack, and human attack.

The first of these two papers (Bradley, Codispoti, Cuthbert, & Lang, 2001) showed a high correlation between arousal ratings and standardised blink magnitude (r = .86), although several of these categories (pollution, loss, illness, accidents) showed mean levels of blink magnitude that were lower than mean response levels during neutral contents, leading to significant inhibition in the cases of pollution and loss. A significant linear trend for blink magnitude across all eight negative contents also indicated increasing blink magnitude with increases in foreground arousal. The analysis of differences between specific negative content categories was somewhat more complex, and so the reader is referred to Figure 6 and Table 2 of the paper in question. Briefly, human attack, animal attack, mutilation and contamination contents had mean blink magnitudes that were greater than the mean level across both types of neutral stimuli (the original paper does not report pairwise comparisons between specific negative contents and neutral). Within these four negative categories, mutilation contents had lower startle blink magnitudes than human attack contents, and no other comparison between them was significant. As noted above, it was not reported whether these four contents had significantly greater blink magnitudes than neutral.

The second paper reporting on these data (Bradley, Codispoti, Sabatinelli, & Lang, 2001) considered differences in responding between male and female participants, and compared responses between specific negative contents and neutral contents. Male participants actually showed startle inhibition, relative to neutral, for the negative picture condition considered as a whole, while female participants showed significant potentiation for negative contents in the same analysis. Linear trends were apparent for both male and female participants for blink magnitude across the specific negative contents, again indicating increasing blink magnitude with increasing foreground arousal. As in the earlier report, female participants showed startle po-

tentiation, relative to neutral, for all four of the negative contents (human attack, animal attack, contamination, and mutilation) that were previously noted as potentially producing greater blink reflex magnitudes than neutral contents. For the males, animal attack, human attack and contamination contents were the only three content types that were not listed as producing startle inhibition relative to neutral.

Several important results have emerged from these two studies. Most importantly, startle blink magnitude during negative contents is highly correlated with subjective arousal ratings, and blink magnitude increases in step with arousal. This is tempered by two additional findings: Firstly, male participants do not show any blink potentiation for negative contents relative to neutral contents, and secondly, female participants only show potentiation for some negative content types, which are generally the most arousing ones.

A similar division of negative contents was conducted by Levenston et al. (2000) in their study on startle responding at different probe times in psychopathic and non-psychopathic male prison inmates. For startle elicited late in the picture viewing stage (after 1.8 seconds), the negative picture contents were divided into threat and victim contents, with the victim category incorporating photographs of mutilation and assault directed between the actors. For the non-psychopathic participants, both content types potentiated startle relative to neutral, with threat appearing to potentiate startle to a greater degree than victim contents (the comparison was significant when both psychopathic and non-psychopathic participants' data were included; statistics not available for non-psychopathic participants alone; C. J. Patrick, personal communication, April 9th, 2003). Unfortunately, there were not sufficient data for each category for this analysis to be performed at the 300 ms probe time (C. J. Patrick, personal communication, October 5th, 2002).

A differential effect of specific negative content on startle blink magnitude was shown in a further study using a non-incarcerated population of male undergraduate students, with each specific content subdivided into high, medium, and low arousal categories, matched between contents (Bernat, Patrick, Benning, Blonigen, & Hicks, 2002). Here, threat stimuli led to enhancement of the startle response, but only for high and medium arousal stimuli; blink magni-

tudes for victim category stimuli were no different from neutral at any level of arousal. This is clarification that the observations in Levenston et al. (2000) were not specific to a criminal population.

A similar preliminary study testing female participants, with slightly different picture content categories and no arousal component, found significant potentiation of startle blink for threat and mutilation contents, with mutilation providing the greatest mean level of modification of these two contents (Bernat, Patrick, Steffen, & Sass, 2002). Two other negative categories, disgust and victim, were not significantly different from neutral, although the victim category looked likely to reach significance with extra data collection (n = 21 at time of poster presentation, where this difference approached significance). Picture conditions for the negative categories included either three (for mutilation and disgust) or six (for threat and victim) exemplars of that content. These negative pictures also differed in terms of subjective arousal in a manner that was paralleled in the startle reflex data, in that those content types that were higher in arousal also produced greater magnitude startle blinks (Bernat, Patrick, Steffen, & Sass, 2002), so that it is not clear whether differences in blink magnitude between contents were driven by the specific picture content or the emotional intensity of the pictures.

Summary of Startle Modification During Varied Negative Emotional Stimuli

The evidence cited above largely supports the hypothesis that startle potentiation during negative foregrounds is not specific to fear or threat stimuli. The majority of experiments looking at this issue have shown augmentation of the reflex in a variety of distinct emotional contexts, and while many have observed differences in the degree of potentiation caused by the specific negative emotional stimuli, the direction of these reported differences has not been consistent across studies.

Startle potentiation is not posited to depend on the action disposition of an emotional state, but rather depends on the valence dimension of that state. Anger has been shown to potentiate startle to a similar level as fear (Cook et al., 1991; Miller et al., 2002) or disgust (Vrana, 1994), even though the motivational disposition (as defined by approach/avoid) for anger is in the opposite direction to that for fear or disgust.

All three of these studies employed mental imagery procedures rather than slide presentations for their emotional induction, and the findings of Miller et al. (2002) regarding personalised and standard anger scripts highlight that this emotion is more difficult to elicit using standardised material (such as would be necessary for a study using photographic stimuli) than an emotion such as fear.

Imagery studies are unfortunately not suitable for experiments testing the early time course of startle modification, as locating the onset of imagery would be imprecise compared to picture presentation (Vanman et al., 1998). Having established both that anger imagery potentiates startle and that startle potentiation during imagery may be influenced more by arousal or imagery intensity than emotional content, the next section turns to comparisons between fear and disgust as a model for testing the emotional specificity of early startle potentiation.

Startle potentiation is apparent during both fear and disgust emotional states. As noted previously, some photographic stimuli (e.g., mutilated bodies) may at times elicit both disgust and fear. The best test of startle modification during "fear-free" disgust may well be achieved through the use of unpleasant odours (e.g., Ehrlichman et al., 1995, 1997; Miltner et al., 1994). All of these studies have shown startle potentiation during unpleasant odours, which may be more representative of what is known as core disgust, defined as disgust related to foods (Rozin, Haidt, & McCauley, 1993).

With the exception of Lethbridge et al. (2002), whose physically aversive category contained

both threat and mutilation content pictures, none of the aforementioned studies have addressed the emotional specificity of startle at early stages of picture viewing. As noted in the discussion to Study 2, early potentiation of startle has so far only been observed for threat type stimuli (Globisch et al., 1999, and also Study 2 of this thesis), and experiments using mixed content negative categories have not shown early startle potentiation (Bradley, Cuthbert, & Lang, 1993; Codispoti et al., 2001; Levenston et al., 2000). As noted above, Levenston et al. (2000) did not have enough data at their early probe time to compare between stimulus contents.

Fast detection of threatening stimuli has been proposed as an enormously useful tool for human survival (LeDoux, 1995), and it seems highly reasonable to assume that systems involved with the early detection of such stimuli would not be involved in detecting other negative stimuli (e.g., contamination or mutilation stimuli). It is proposed here that such an early threat detection system (detailed in the introduction to Study 2) may be responsible for the divergent findings regarding early startle modification — emotional information from non-threat negative stimuli may not yet be available to the startle modification circuit within 300 ms of picture onset. The amygdala appears to be involved both with early detection of threat (LeDoux, 1995, 1998) and, in the rat, with modification of startle during fear-conditioning, but not during the rat equivalent of anxiety (Davis et al., 1999). It is interesting to note that the amygdala is not activated during perception of disgust faces (Phillips et al., 1997), and so if early startle potentiation during negative stimuli is mediated by the amygdala, disgusting stimuli should not potentiate startle at an early stage of picture viewing. It is of course possible that a second pathway mediates startle during disgust emotional states, although as the majority of studies on the neural pathways involved in startle modification are concerned with non-human animals and typically use conditioned fear as their negative emotional stimulus, it is not known whether other pathways may be available during disgust to allow startle modification. Davis et al. (1999) state that, in the rat, the bed nucleus of the stria terminalis (but not the amygdala) is necessary for startle modification to occur in contextual conditioning or light-potentiated startle, which are described as more reflective of anxiety than fear. Startle potentiation does not necessarily require the amygdala in the rat, although it appears that it is vital to startle potentiation in humans (Angrilli et al., 1996). Disgust has been characterised as a uniquely human emotion (Rozin et al., 1993), and so the

pathway responsible for modification of startle during disgust in humans awaits clarification.

The following study compares startle responding during threat, mutilation/contamination pictures, neutral and, positive pictures at two Probe Time conditions, early (300 ms) and late (between 2 and 5 seconds). The composition of the threat and mutilation categories is described in the method. Unlike Study 2, the Probe Time manipulation was a within-subjects factor in this study. The following predictions were made:

1. Threatening stimuli will potentiate the startle blink reflex at 300 ms, as well as in the more standard probe time range of 2 to 5 seconds after picture onset.

2. Mutilation/contamination pictures will potentiate startle in the 2 to 5 second probe time range, but not at the 300 ms probe time.

There are two experiments described in the following section relating to the hypotheses stated above. The differences between the two may be noted in the method sections for Studies 3a and 3b, and the reasoning behind the change in experimental design is covered in the discussion to Study 3a.

Study 3a

Method

Participants

The experiment was completed by a total of 55 student participants (32 females), from the University of Otago. Thirty of these participants were first-year psychology students who received course credit after participating in the experiment. The remaining 25 participants were recruited from a student job placement centre, and paid NZ$10 for taking part, as in Study 2. Participant age ranged from 18 to 44 years, with a median age of 19 years; the mean age was 20.95 years.

Four participants did not complete the experiment, due to near-simultaneous failure of the stimulus presentation and response recording computers (n = 1), poor EMG signal at the outset of the experiment (n = 1), declining to continue participation in the experiment (n = 1), and showing a lack of any discernible blink responding after the first startle probe presentation in the habituation session (n = 1).

From the pool of those who completed the study, 46 participants (28 females) contributed data to the blink magnitude analyses, and 44 participants (22 females) contributed to the SCR analyses. Exclusion criteria were similar to Study 2, and are detailed in the data analysis section. One participant in the SCR analysis group failed to complete the questionnaires, and so their data were excluded from analysis of SCR magnitude by questionnaire score.

Startle Probe Presentation

Startle probe presentation was conducted in the same manner as in Study 2.

Table 10: Mean Valence and Arousal Ratings for Pictures Used in Study 3a.

Dimension	Positive	Neutral	Mutilation	Threat
Valence	7.69	5.45	2.25	3.08
Arousal	3.81	1.95	5.4	5.34

Picture Stimuli

Selection of the picture stimuli was again on the basis of valence and arousal ratings collected in Study 1. Table 10 reports means and standard errors of valence and arousal ratings from Study 1 for the four picture categories. Appendix F lists the actual pictures included for each Emotional Category.

Positive and neutral pictures were largely the same as for Study 2, as can be seen in Appendix F.

As in Study 2, the negative picture set consisted of two distinct types of picture. The first of these were threat content pictures, and these correspond to the picture types used in Study 2; pictures of threatening humans and animals (excluding snakes and spiders). The second negative category consisted of mutilation pictures and pictures chosen to elicit feelings of disgust (e.g., human fæces, dead animals). For the sake of convenience (and due to the preponderance of this type of picture) this category is referred to as the mutilation category for the remainder of this method and results section.

Picture and probe stimulus presentation was the same as in Study 2.

Experimental Design

The experimental design was slightly different from Study 2. Probe Time was included as a within-subjects factor, with early probes again being presented at 300 milliseconds, and late

probes appeared at random between 2 and 5 seconds after picture onset. This late probe period began at a slightly shorter latency than in Study 2. Participants received startle probes on 3 pictures for each Emotional Category at both Probe Times, making a total of 24 probed pictures relevant to the experimental hypotheses. Inter-trial interval probes were presented during one ITI in each block (a reduced quantity from Study 2). There were thus a total of 29 startle probe instances on which data were collected, and all of these instances were included for standardisation purposes.

Once again there were two different Picture Combinations employed, and these were so arranged that the first Picture Combination's early Probe Time pictures were probed in the late time interval for the second Picture Combination, and vice versa. Each Picture Combination was presented in one of four different block orders. Presentation order was counterbalanced across participants but is not included as a factor in data analysis.

Physiological Recordings

Physiological recording, off-line data reduction, and scoring of magnitudes and latencies were performed as in Study 2. The standardisation procedures for blink and SCR response magnitudes were performed on all available data (i.e., data from both Probe Times and ITI probes).

Procedure

The procedure was the same as for Study 2, excepting that the MQ measure of mutilation fear was administered to participants instead of the SNAQ measure used in Study 2. The FSS-II-R measure was retained for the current study.

Data Analysis

Data analysis was largely the same as for Study 2, with the following points to note. Exclusion criteria were the same as for Study 2, so that a participant's data were excluded if they showed blink responses less than 10 μV in magnitude on more than one quarter of all probe instances (picture and ITI probes), or zero magnitude SCRs on more than a quarter of all probe instances. As there were fewer probe instances in this study than in Study 2, this led to a decrease in the absolute cut-off point (from 8 small responses to 7). The assessment of whether a participant met these criteria was again performed on the raw, untransformed data.

An additional note is needed on the reporting of Greenhouse-Geisser epsilon values in this and subsequent studies. Firstly, the correction only applies to repeated measure factors with more than two levels, and so no correction is applied to the main effect of or interactions involving Probe Time (which only had two levels) without Emotional Category. Secondly, the epsilon value is the same for interactions involving the repeated measures variable (i.e., Emotional Category) and a between-subjects variable or variables (e.g., Gender). However, interactions involving additional repeated measures variables (i.e., those between Emotional Category and Probe Time) have a unique epsilon value. Interactions involving two repeated measure variables and a between-subjects variable have the same epsilon value as for the interaction between the two repeated-measures variables. As in Study 2, epsilon values are only reported for the first result involving each of the two possible correction values.

Results

Summary of Physiological Variables and Number of Valid Participants

Table 11 summarises descriptive statistics for the four dependent variables, averaged across the early and late Probe Time conditions. Both raw and transformed data are presented for the blink and SCR magnitude, although only standardised data were used for the following analyses. The number of participants included for the blink and SCR analyses is noted by the blink magnitude and SCR magnitude summaries.

Table 11: Physiological Dependent Variable Means and Standard Errors, by Emotional Category of Picture, Averaged Across Probe Time.

Physiological measure	Positive	Neutral	Mutilation	Threat
Blink magnitude *n* = 46				
Raw (μV)	54.77	56.13	57.72	64.86
(S.E.)	(5.56)	(6.02)	(6.04)	(6.48)
Standardised (T-score)	47.71	48.91	50.15	52.48
(S.E.)	(.52)	(.45)	(.48)	(.48)
Blink latency to peak (ms)	75.14	76.51	76.68	76.85
(S.E.)	(1.04)	(1.02)	(1.28)	(1.14)
SCR magnitude *n* = 44				
Raw (μS)	2.08	2.10	2.09	2.55
(S.E.)	(.28)	(.26)	(.24)	(.30)
Standardised (p of range)	.38	.38	.38	.45
(S.E.)	(.02)	(.02)	(.02)	(.02)
SCR latency to peak (ms)	4421.51	4505.88	4395.68	4466.59
(S.E.)	(105.93)	(113.55)	(110.81)	(109.62)

Table 12: Descriptive Statistics for MQ and FSS Questionnaires, Between Gender.

Questionnaire	Females	Males	All	Median
n	32	22	54	54
MQ	12.47	7.18	10.31	10
(S.E.)	(.97)	(.82)	(.75)	
FSS	128.63	103.36	118.33	116.5
(S.E.)	(4.72)	(5.84)	(4.02)	

Questionnaire Results

Table 12 reports means and standard errors for the two questionnaires for both male and female participants. Female participants scored more highly than males on both the MQ and FSS questionnaires, respective *F*s (1, 50) = 15.09 and 11.53, both *p*s $< .002$. Scores did not vary across Picture Combination, nor as an interaction between Gender and Picture Combination, for either questionnaire, *F*s (1, 50) $< .78$, *p*s $> .38$. Table 12 also reports median scores for the entire sample, which are used for the analyses of blink and SCR magnitude by questionnaire score reported in subsequent sections.

Blink Magnitude

The analysis for blink magnitude was conducted using all of the independent variables in the study. Probe Time had a significant effect on blink magnitude, F (1, 42) = 13, $p < .001$, with startle probes eliciting greater magnitude responses when presented at the late (M = 51.39) than at the early Probe Time (M = 48.23). Neither Gender nor Picture Combination appeared as a main effect, nor were there any significant interactions between any combination of Gender, Picture Combination and Probe Time, *F*s (1, 42) < 2.01, *p*s $> .163$.

Blink magnitude varied significantly with the Emotional Category of the foreground picture, F (3, 126) = 14.12, $p < .001$, $\varepsilon = .93$. The interaction between Emotional Category, Probe

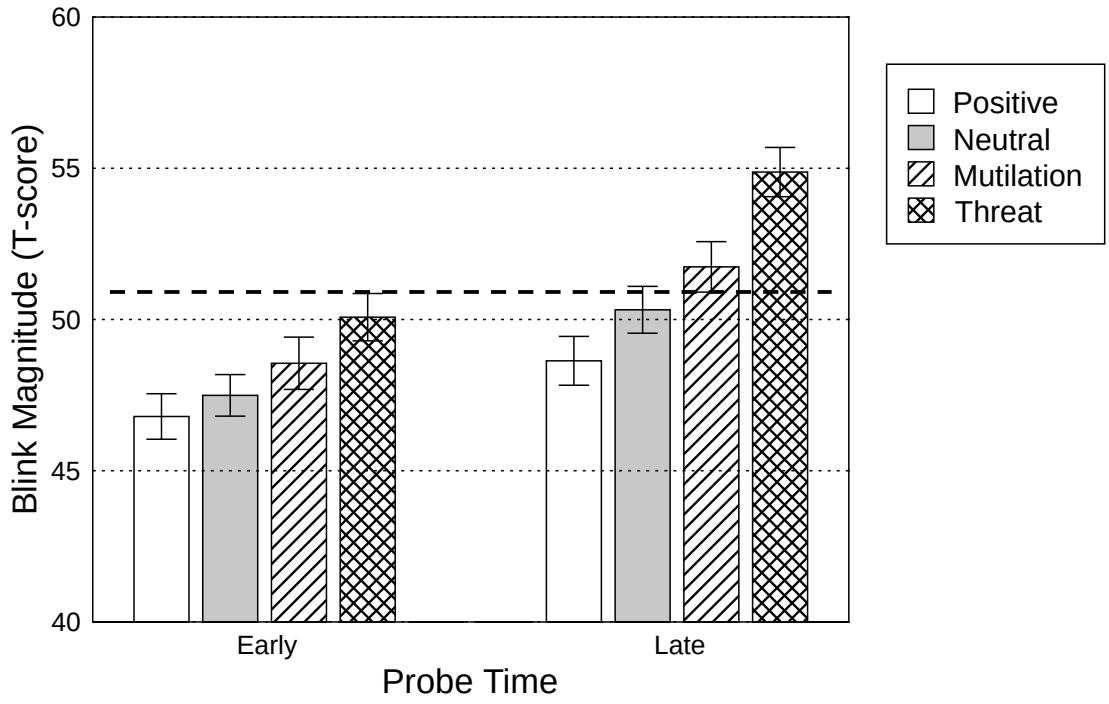


Figure 17. Mean standardised blink magnitude by Emotional Category, at the early and late Probe Times. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

Time, Gender, and Picture Combination approached significance, F (3, 126) = 2.55, $p = .062$, $\varepsilon = .95$. No other interaction including Emotional Category was significant, Fs (3, 126) < 2.04, ps $> .116$.

Differences in blink magnitude between the four Emotional Categories were assessed with separate contrasts at both early and late Probe Times. Mean standardised blink magnitudes for each Emotional Category at the two Probe Times are portrayed in Figure 17. At the early Probe Time, threat content blink magnitude was significantly greater than for positive, linear F (3, 42) = 9.67, $p = .003$. There was no quadratic effect for threat contents, F (3, 42) = 1.51, $p = .226$. Mutilation contents showed neither a linear nor quadratic effect at this early stage of picture viewing, Fs (3, 42) = 1.95 and .001, ps = .17 and .973.

At the late Probe Time, threat picture blinks were again potentiated relative to positive content blinks, linear F (3, 42) = 25.64, $p < .001$. Mutilation content blinks were of significantly greater magnitude than positive blinks, linear F (3, 42) = 7.95, $p = .007$. Neither content type showed a significant quadratic effect, Fs (3, 42) = 2.01 and .03, ps = .164 and .864, for threat

and mutilation respectively. These results indicate linearly increasing blink magnitude across positive, neutral, and negative contents, for both negative categories.

Blink Magnitude by MQ Score

Group size was equal for the median split on MQ score (n = 23 for each group). The overall analysis of blink magnitude by MQ score median split showed main effects for Probe Time, F (1, 44) = 13.12, $p < .001$, as well as Emotional Category, F (3, 132) = 14.5, $p < .001$, ε = .94. MQ score group did not interact significantly with Emotional Category, or Emotional Category and Probe Time, Fs (3, 132) < 1.27, ps $> .29$, $\varepsilon = .96$; the epsilon value is for the three-way interaction.

Blink Magnitude and FSS Score

The size of the groups for the FSS-split analysis was again equal (n = 23 in each). The overall ANOVA for blink magnitude with the FSS median split variable showed a main effect for Emotional Category, F (3, 132) = 15.28, $p < .001$, ε = .96, as well as an interaction between Emotional Category and FSS score-group that approached significance, F (3, 132) = 2.71, p = .05. The interaction between Emotional Category, Probe Time, and FSS score group was not significant, F (3, 132) = .8, $p = .492$, ε = .97.

For those scoring below the median on the FSS measure, whose data are presented in Figure 18, there was a significant effect for Emotional Category, F (3, 66) = 4.07, $p = .012$, ε = .92. The interaction between Emotional Category and Probe Time was not significant, F (3, 66) = 1.62, $p = .197$, ε = .94. However, there were no significant linear or quadratic effects for either negative category at the early Probe Time, Fs (1, 22) < 1.82, ps $> .192$. At the late Probe Time, threat blink magnitudes were of greater magnitude than blinks during positive contents, linear F (1, 22) = 8.81, p = .007. The quadratic effect for threat also approached significance, F (1, 22) = 3.06, p = .094. At this Probe Time, there were no significant effects for the muti-

lation contrasts, *F*s (1, 22) $<$ .79, *p*s $>$ .385. The blink magnitude data for those participants scoring above the median on the FSS measure are presented in Figure 19. This group showed a significant main effect of Emotional Category on blink magnitude, F (3, 66) = 12.89, $p < .001$, ε = .94. At the early Probe Time, threat content blinks were of significantly greater magnitude than positive content blinks, linear F (1, 22) = 20.16, $p < .001$. The linear effect for mutilation contents approached significance, F (1, 22) = 3.18, p = .088. Neither negative content type showed a quadratic effect, *F*s (1, 22) = .31 and 1.2, *p*s = .585 and .285, for threat and mutilation respectively. It can be seen in Figure 19 that mutilation and neutral contents were not significantly different from one another at this Probe Time.

For these high FSS-score participants at the late Probe Time, both threat and mutilation content blinks were potentiated relative to positive contents , respective linear *F*s (1, 22) = 20.7 and 11.87, both *p*s $<$ .003. Again there was no evidence of quadratic effects for these data, *F*s (1, 22) $<$ .33, *p*s $>$ .576.

Blink Latency to Peak

For the analysis of blink latency to peak, Picture Combination did not reach significance as a main effect or as an interaction with Gender or Probe Time, *F*s (1, 42) $<$ 2.35, *p*s $>$ .132, nor in any interaction involving Emotional Category, *F*s (1, 42) $<$ 1.31, *p*s $>$ .275, $\varepsilon < .92$. The following analysis employed a model excluding Picture Combination.

There was a main effect of Probe Time on blink latency to peak, F (1, 44) = 33.39, $p < .001$, as well as an interaction between Probe Time and Gender, F (1, 44) = 4.95, p = .031. This interaction basically indicated that blinks reached their peak more quickly at the early (M = 74.23 ms) than at the late Probe Time (M = 78.55 ms), for both males and females, *p*s = .033 & $<$ .001, respectively. Gender was not involved in any higher order interactions involving Emotional Category, *F*s (3, 132) $<$ .52, *p*s $>$ .66.

Emotional Category was not significant as a main effect, F (3, 132) = 1.01, $p = .387$,

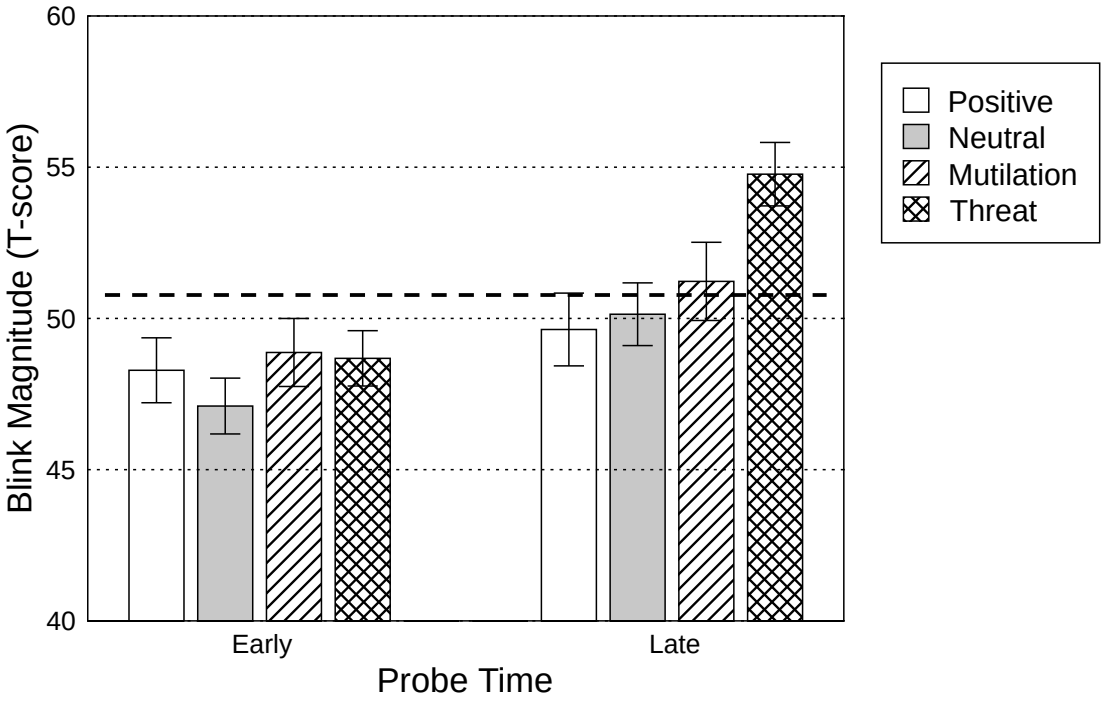


Figure 18. Mean standardised blink magnitude by Emotional Category, at the early and late Probe Times, for participants scoring at or below the median on the FSS. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

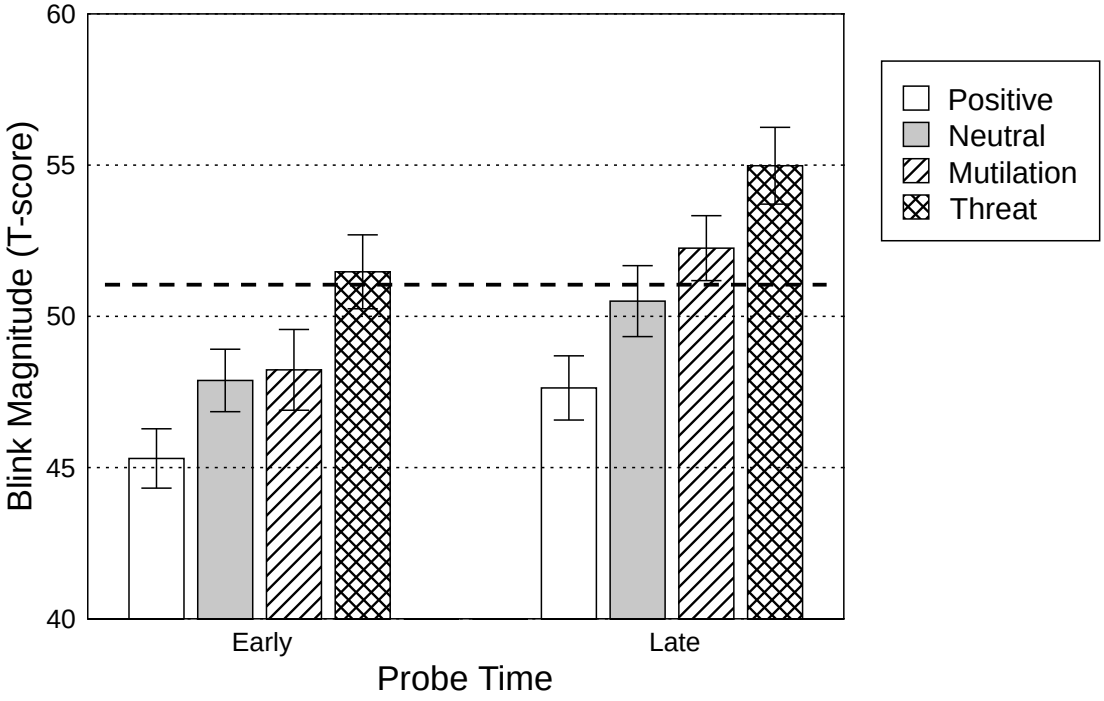


Figure 19. Mean standardised blink magnitude by Emotional Category, at the early and late Probe Times, for participants scoring above the median on the FSS. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

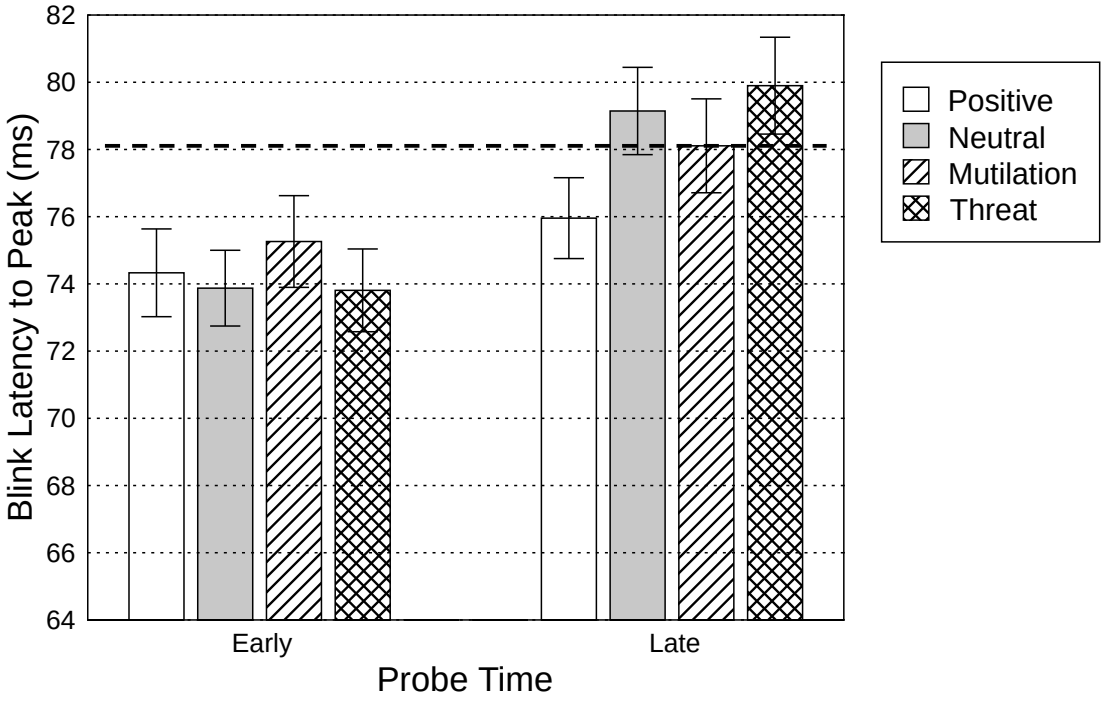


Figure 20. Mean blink latency to peak by Emotional Category, at the early and late Probe Times. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

ε = .92. The interaction between Emotional Category and Probe Time approached significance, F (3, 132) = 2.3, $p = .084$, ε = .95. This interaction is portrayed in Figure 20.

At the early Probe Time, there were no significant contrasts between Emotional Categories, Fs (1, 44) < 1.16, ps $> .287$. At the late Probe Time, blink responses during positive contents reached peak more quickly than those during threat contents, linear F (1, 44) = 4.34, p = .043. No other contrast was significant, Fs (1, 44) < 2.26, ps $> .139$.

SCR Magnitude

The ANOVA for SCR magnitude included all possible independent variables. There were significant effects for the interactions of Probe Time and Gender, as well as Probe Time and Picture Combination, but these effects will not be described as they were subsumed under higher order interactions. The interaction between Probe Time, Gender, and Picture Combination was significant, F (1, 40) = 5.69, p = .022. Post hoc testing revealed that participants generally showed greater magnitude SCRs for early Probe Time pictures than late, with ps ranging from .019 to

.067. The only group who did not show this pattern were female participants who viewed the second Picture Combination, who had greater SCR magnitudes for late than early Probe Time pictures, although this difference did not reach significance, p = .09.

There was a main effect of Emotional Category, F (3, 120) = 10.4, $p < .001$, ε = .92. This variable interacted with Gender, F (3, 120) = 3.13, p = .032. These data are presented in Figure 21. Separate ANOVAs were performed for male and female participants, with Emotional Category as the sole independent variable. For females, there was a main effect for Emotional Category, F (3, 63) = 8.33, $p < .001$, ε = .87. Threat content SCRs were of greater magnitude than neutral and positive content SCRs, as can be seen in Figure 21; this was indicated by significant linear and quadratic effects, Fs (1, 21) = 12.87 and 12.76, both ps $= .002$. Mutilation content SCRs were not significantly different from neutral or positive, Fs (1, 21) = .62 and 1.69, ps = .439 and .208, for linear and quadratic contrasts.

For male participants, there was a significant main effect for Emotional Category, F (3, 63) = 4.71, $p = .008$, ε = .86. Threat content SCRs were of greater magnitude than positive content SCRs, F (1, 21) = 4.71, p = .005. No other contrasts were significant, Fs (1, 21) < 2.52, ps $< .128$.

There were also significant interactions between Emotional Category and Probe Time, F (3, 120) = 3.31, $p = .023$, ε = .99, and between Emotional Category, Probe Time, and Picture Combination, F (3, 120) = 4.28, p = .007. The ANOVA was decomposed into two models, one for the early Probe Time and one for the late, with Emotional Category, Picture Combination, and Gender as factors.

At the early Probe Time, there was a main effect for Emotional Category, F (3, 120) = 6.22, $p < .001$, ε = .97, and the interaction between Emotional Category and Picture Combination was not significant, F (3, 120) = 1.56, p = .204. Planned contrasts were performed between the levels of Emotional Category at the early Probe Time, and can be followed in Figure 22, where data are averaged over both Picture Combinations. For threat contents, the quadratic effect was

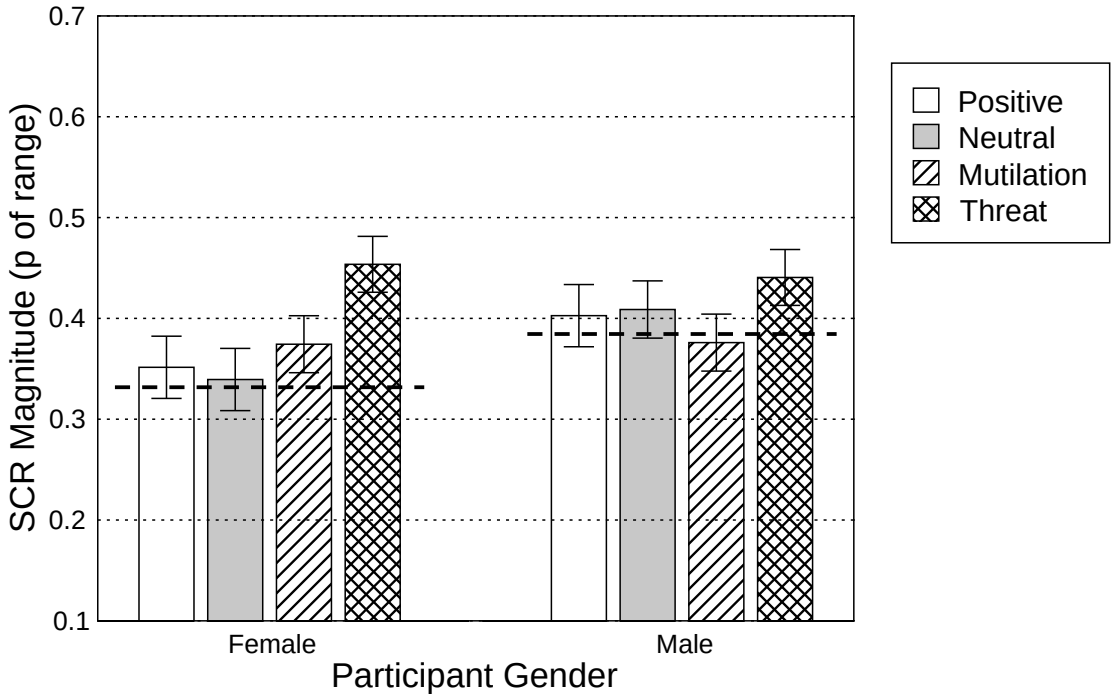


Figure 21. Mean standardised SCR magnitude by Emotional Category, for female and male participants, averaged across Probe Time. Error bars indicate one standard error. Dotted lines represents the appropriate mean levels of ITI responses for females and males.

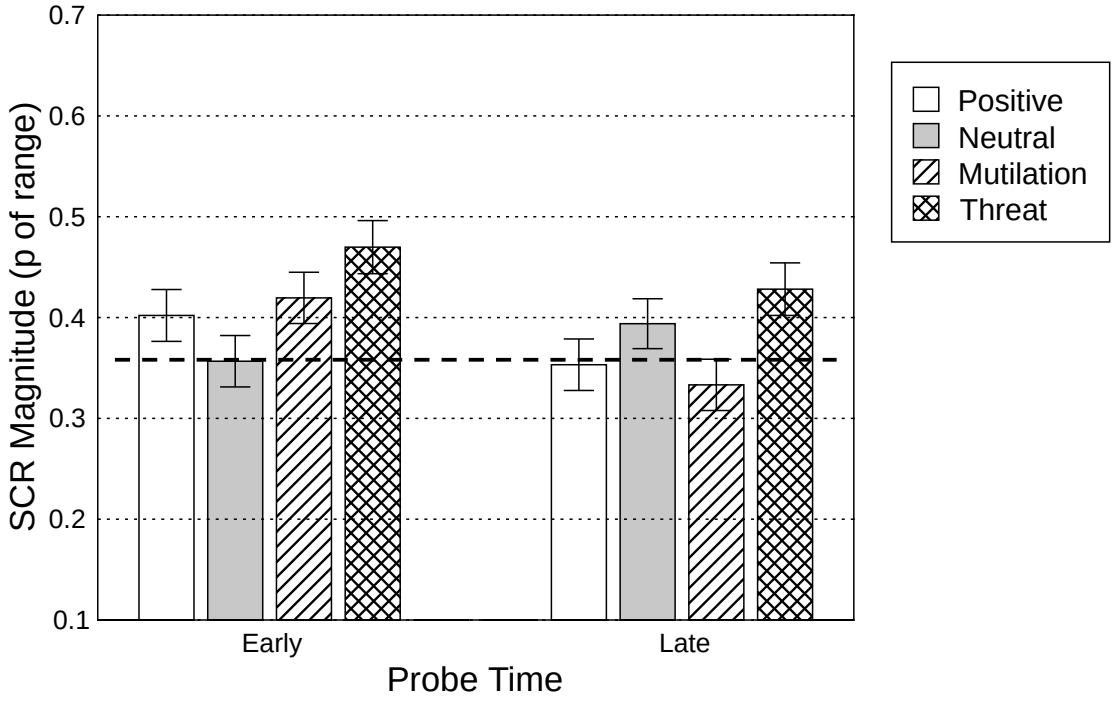


Figure 22. Mean standardised SCR Magnitude by Emotional Category, at the early and late Probe Times. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

significant, F (1, 40) = 11.49, p = .002. Mutilation contents also showed a significant quadratic effect, with greater SCR magnitude during mutilation and positive pictures compared to neutral, F (1, 40) = 6.1, p = .018. Threat contents were also associated with greater SCR magnitudes than positive contents, linear F (1, 40) = 5.92, p = .02. The linear trend for mutilation content was not significant, F (1, 40) = .45, p = .506.

The right hand side of Figure 22 shows the late Probe Time SCR data averaged over both Picture Combinations. For the late Probe Time condition, the interaction between Emotional Category and Picture Combination was significant, F (3, 120) = 4.48, $p = .006$, ε = .96. For the first Picture Combination, there was no significant effect for Emotional Category, F (3, 60) = 1.85, $p = .157$, ε = .87. For the second Picture Combination, the main effect for Emotional Category was significant, F (3, 60) = 8.45, $p < .001$, ε = .93. The pattern of results for these participants at this Probe Time are the same as for the late Probe Time trend shown in Figure 22 (averaged over both Picture Combinations). SCR magnitudes were potentiated in this group for threat contents compared to positive, linear F (1, 20) = 25.51, $p < .001$. The quadratic effect for threat content was not significant, F (1, 20) = 1.53, p = .23. For mutilation contents, there was a significant quadratic effect, with SCRs during positive and mutilation contents being of smaller magnitude than SCRs for neutral contents, F (1, 20) = 9.08, p = .007. The linear comparison for mutilation pictures was not significant, F (1, 20) = .97, p = .337.

SCR Magnitude and MQ Score

The ANOVA looking at SCR magnitude for both high and low MQ score participants found a main effect for Emotional Category, F (3, 123) = 11.34, $p < .001$, ε = .9. There were also interactions between Emotional Category and Probe Time, F (3, 123) = 2.84, $p = .042$, ε = .98, and between Emotional Category and MQ score group, F (3, 123) = 3.9, p = .014.

For the low MQ-score group (n = 22), there was a significant main effect of Probe Time on SCR magnitude, F (1, 21) = 5.61, p = .028, with early Probe Time SCRs (M = .43) being of greater magnitude than late Probe Time SCRs (M = .37). There was no main effect for Emotional

Category, F (3, 63) = 1.5, $p = .226$, ε = .94, and the interaction between Emotional Category and Probe Time was not significant, F (3, 63) = 2.23, $p = .1$, ε = .91. SCR magnitude data for these participants are presented in Figure 23.

Data for the above-median MQ score participants' (n = 21) SCR magnitude data is presented in Figure 24. There was a significant main effect for Emotional Category in this condition, F (3, 60) = 11.66, $p < .001$, ε = .77. At the early Probe Time, there was a significant difference between threat and positive content SCRs, linear F (1, 20) = 7.2, p = .014. A quadratic effect was also significant for threat contents, with threat and positive content SCRs greater in magnitude, on average, than neutral SCRs, F (1, 20) = 14.99, $p < .001$. The quadratic trend for mutilation approached significance, F (1, 20) = 3.03, p = .097.

For late startle probes, threat content SCR magnitudes were enhanced relative to positive contents, linear F (1, 20) = 11.81, p = .003. No other contrasts were significant, indicating a lack of SCR potentiation for positive and mutilation contents relative to neutral, Fs (1, 20) < 1.2, ps $> .288$.

SCR Magnitude and FSS Score

The general ANOVA on SCR magnitude incorporating both high and low FSS score groups had a main effect for Emotional Category, F (3, 123) = 10.54, $p < .001$, ε = .92, as well as a significant interaction between Emotional Category and Probe Time, F (3, 123) = 2.99, $p = .034$, ε = .996. The interaction between FSS score group and Emotional Category approached significance, F (3, 123) = 2.43, p = .074, and the interaction between Emotional Category, Probe Time, and FSS score group was significant, F (3, 123) = 2.85, p = .04.

For the low FSS score group (n = 21), whose SCR magnitude data are presented in Figure 25, the ANOVA revealed a main effect for Emotional Category, F (3, 60) = 3.91, $p = .014$, ε = .97. For early Probe Time SCR magnitudes, threat contents were significantly greater than positive contents, linear F (1, 20) = 5.58, p = .028. Neither quadratic effect was significant, nor were

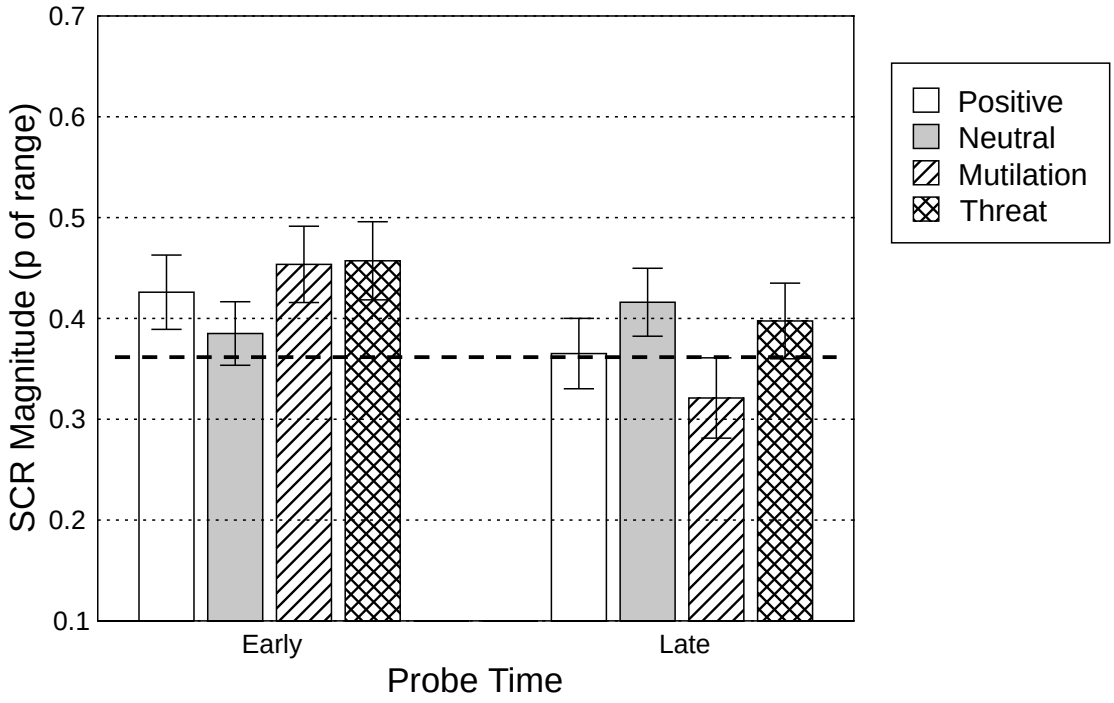


Figure 23. Mean standardised SCR magnitude by Emotional Category, at the early and late Probe Times, for participants scoring at or below the median on the MQ. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

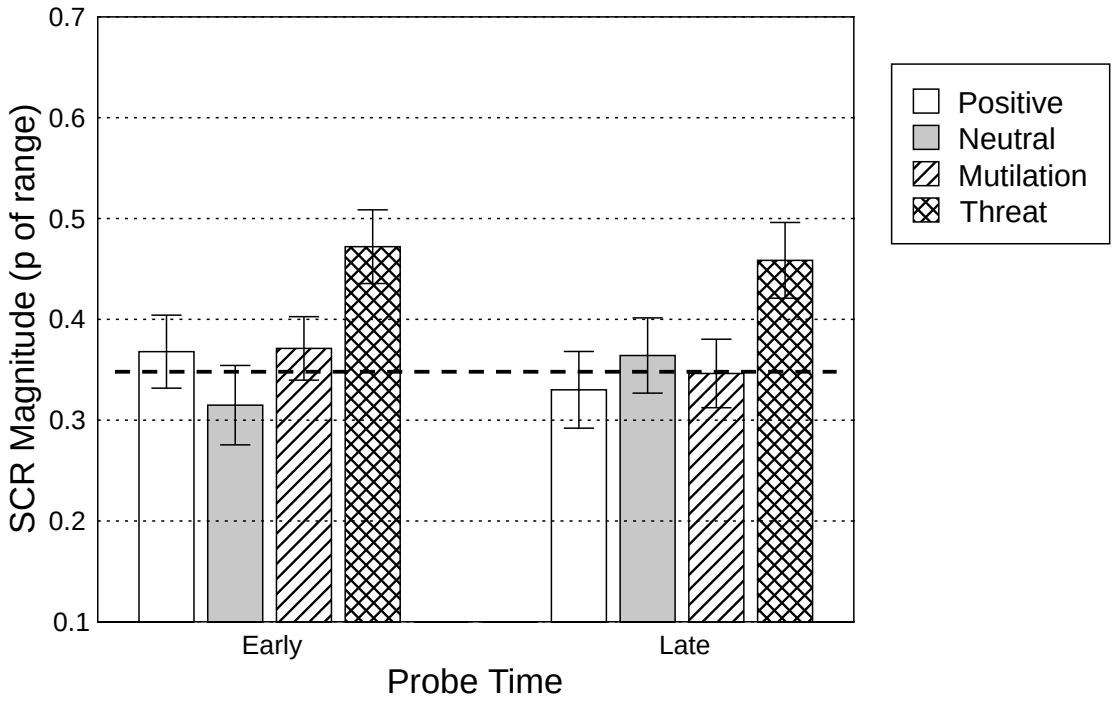


Figure 24. Mean standardised SCR magnitude by Emotional Category, at the early and late Probe Times, for participants scoring above the median on the MQ. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

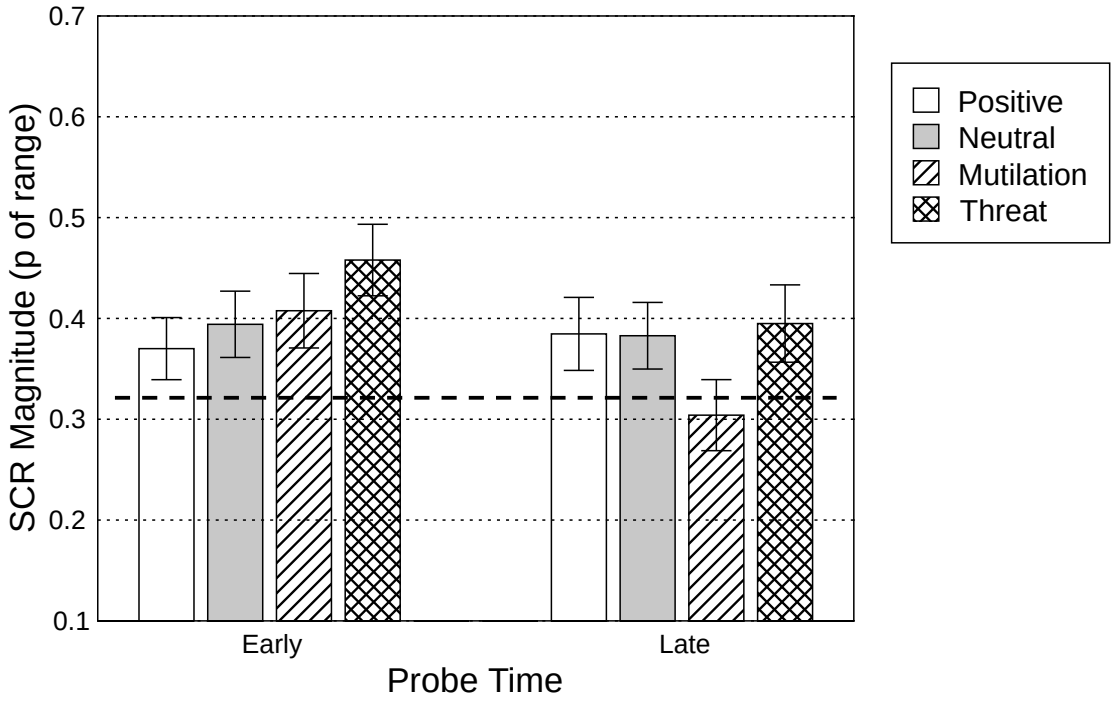


Figure 25. Mean standardised SCR magnitude by Emotional Category, at the early and late Probe Times, for participants scoring below the median on the FSS. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

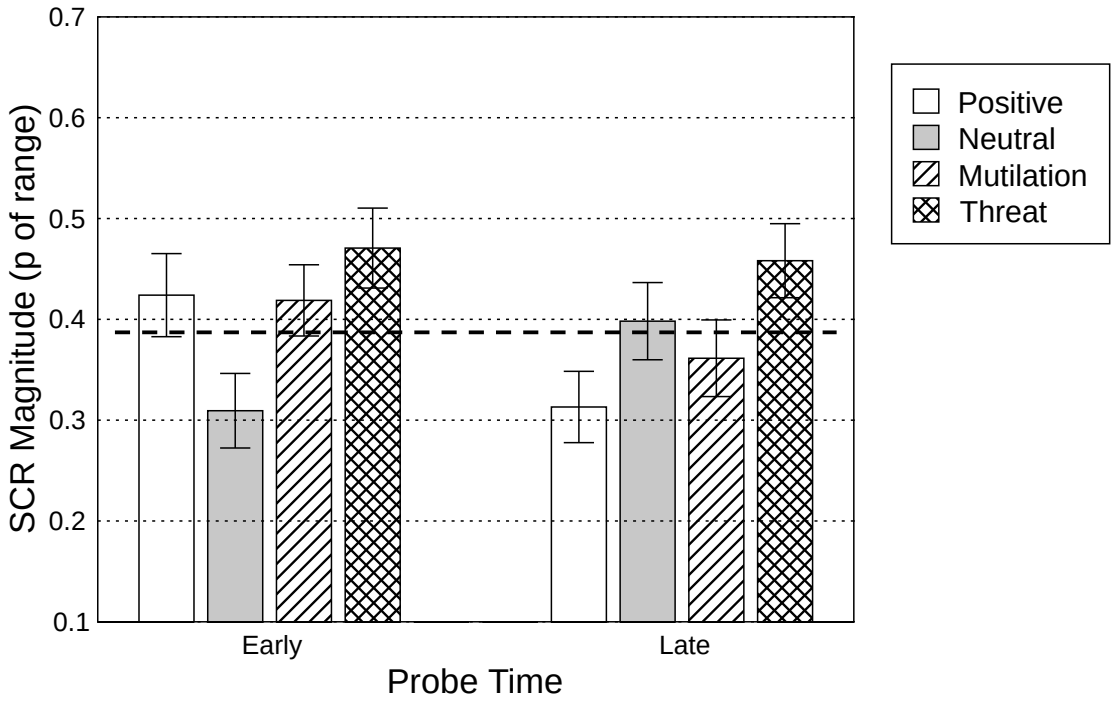


Figure 26. Mean standardised SCR magnitude by Emotional Category, at the early and late Probe Times, for participants scoring above the median on the FSS. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

mutilation content SCRs different from positive content SCRs, *F*s (1, 20) $< .75$, *p*s $> .396$.

For the late Probe Time data, SCRs were smaller for the mutilation contents compared to positive, and this linear effect approached significance, F (1, 4) = 3.71, $p = .069$. Other contrasts were not significant for this group, *F*s (1, 20) < 1.48, *p*s $> .239$.

For participants scoring above the median on the FSS (n = 22), there was a significant effect for Emotional Category, F (3, 63) = 8.6, $p < .001$, $\varepsilon = .83$, as well as an interaction between Emotional Category and Probe Time, F (3, 63) = 4.44, $p = .009$, $\varepsilon = .91$. This interaction is depicted in Figure 26. At the early Probe Time, there were significant quadratic effects for both the threat and mutilation contrasts, *F*s (1, 21) = 20.39 and 11.6, both *p*s $< .003$. In the absence of significant linear effects, these results indicate greater SCR magnitude in this fear score group/Probe Time condition for all three affective contents, relative to neutral; *F*s (1, 21) < 1.2, *p*s $> .287$, for the linear contrasts.

Threat content pictures were associated with greater SCR magnitudes than positive contents at the late Probe Time, linear F (1, 21) = 16.77, $p < .001$. The quadratic contrast for mutilation contents approached significance, with a trend toward greater SCR magnitudes in the neutral than in the mutilation and positive contents, F (1, 21) = 3.38, $p = .08$. Other comparisons at this Probe Time were not significant, *F*s (1, 21) < 2.18, *p*s $> .154$.

SCR Latency to Peak

All variables were included in the ANOVA model. The between subject factors, Gender and Picture Combination, were not significant as main effects or as interactions with one another, *F*s (1, 40) $< .35$, *p*s $> .562$. There was also no main effect for Emotional Category, F (3, 120) = 1.34, $p = .266$, $\varepsilon = .86$. There was a main effect for Probe Time on SCR latency to peak, as well as a significant interaction between Probe Time and Picture Combination, *F*s (1, 40) = 8.56 and 4.49, *p*s = .006 and .04. In the first Picture Combination, SCRs reached their peak magnitude more quickly at the late Probe Time (M = 4385.67 ms) than at the early

Probe Time(M = 4628.99 ms), p = .005. The difference between the second Picture Combination's early (M = 4402.61 ms) and late (M = 4363.74 ms) SCR latencies to peak was not significant, $p = .94$.

Of the interactions involving Emotional Category, two approached significance; that between Emotional Category and Picture Combination, F (3, 120) = 2.44, p = .078; and that between Emotional Category, Probe Time, Picture Combination, and Gender, F (3, 120) = 2.44, $p = .068$, ε = .83.

Figure 27 shows the early and late Probe Time data for SCR latency to peak. The only planned contrast to approach significance was the quadratic effect for mutilation contents at the late Probe Time, F (1, 40) = 3.2, p = .081. All other contrasts, Fs (1, 40) $< .66$, ps $> .421$.

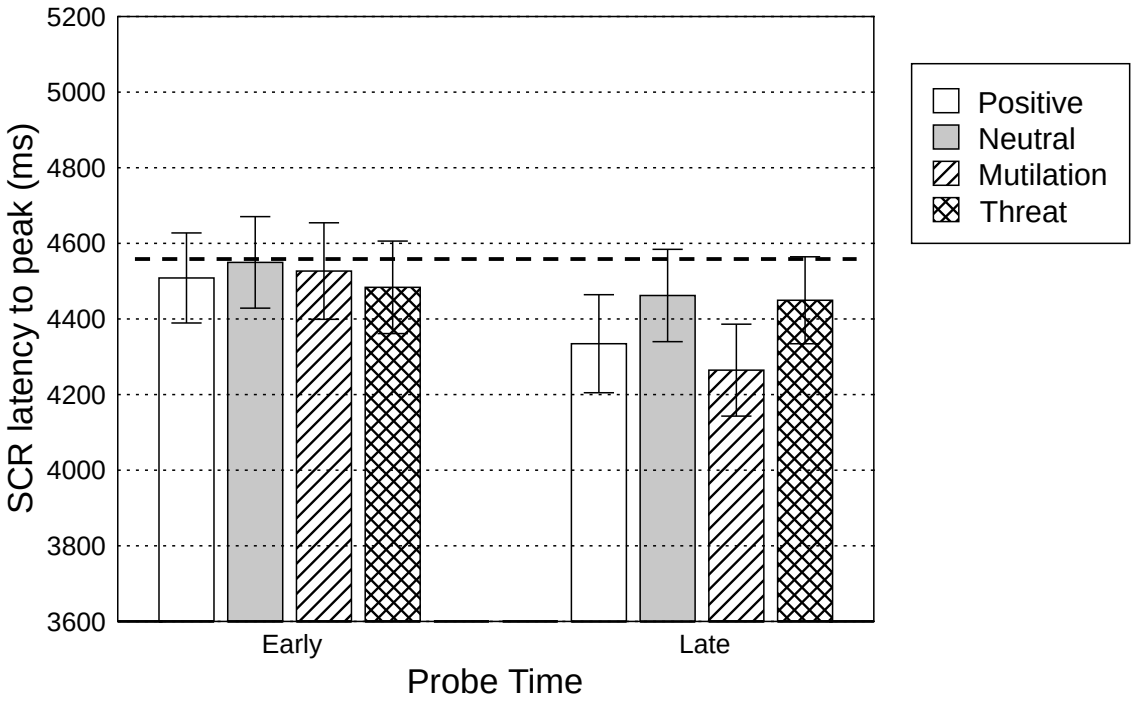


Figure 27. Mean SCR latency to peak by Emotional Category, at the early and late Probe Times. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

Discussion

Blink Magnitude Results

The blink magnitude analysis showed linearity across positive, neutral, and threat contents at both early and late Probe Times. This is a replication of the results of Study 2 in a within-subjects design, with new picture sets and a different composition for the threat condition (combining both human and animal threat pictures from Study 2). Mutilation content blinks were potentiated at the late Probe Time, but these pictures showed no potentiation of blink magnitude when probes were presented at 300 ms. These results are in line with the hypothesis that threatening picture contents would be processed to allow startle blink potentiation by 300 ms, but mutilation or disgusting picture contents would not be processed by this stage. As this pattern of results is qualified by the analysis incorporating FSS scores, theoretical implications will be described following these.

Blink Magnitude and Participant Fearfulness

For low-fear participants (defined by a median split on the FSS-II-R measure), startle potentiation after several seconds of picture viewing was largely the same as expected on the basis of previous experiments. Threat contents were associated with heightened blink response magnitudes compared to positive contents, although inhibition of blink magnitude was not observed for positive contents compared to neutral (as indicated by a significant linear trend and a quadratic trend that approached significance). These participants did not show significant blink potentiation for mutilation contents after several seconds of picture viewing.

These low FSS-score participants showed no significant blink modification at the early Probe Time, for any picture content. These results are more in line with those studies previously reporting no potentiation for negative contents when probed at 300 ms (Bradley, Cuthbert, & Lang, 1993; Codispoti et al., 2001; Levenston et al., 2000). It must be noted that, with the

exception of Codispoti et al., those studies just cited all found significant inhibition of blink magnitude at the 300 ms Probe Time for emotionally valent picture contents, which was not observed in the current experiment. Comparisons between studies will be dealt with in the section discussing theoretical implications of these results.

High FSS-score participants showed patterns of results that were in line with Globisch et al. (1999): Early potentiation of blink magnitude for threat contents, and blink inhibition for positive contents. Effects for mutilation contents on early startle modification only approached significance, and probably indicate blink inhibition for positive contents rather than potentiation for mutilation contents (see Figure 19).

Late Probe Time blink modification for the high FSS-score participants indicated linearly ascending blink magnitude across positive, neutral, and negative contents, for both threat and mutilation negative categories.

Implications of Blink Magnitude Results

Early potentiation of the startle blink reflex was limited in this study to participants scoring above median on the FSS-questionnaires administered. This places the findings of this study alongside previously observed early blink potentiation for highly-fearful participants during their feared stimuli (Globisch et al., 1999).

The current study differed from Globisch et al. (1999) in ways additional to the classification of participants into high- and low-fear groups (discussed following the results of Study 2). The main difference between these studies was the nature of the negative stimuli viewed by participants. Globisch et al. (1999) used negative stimuli that were related to each participant's fear of specific small animals. The current study used two categories of negative stimuli, threat and mutilation/disgust contents. Early startle potentiation was limited to threat stimuli for high fear participants.

There was also no evidence for differences in startle modification between high and low mutilation fear participants, assessed by the MQ measure. On the basis of Hamm et al. (1997), it would be predicted that only high mutilation-fear participants would show startle potentiation for mutilation contents, and Globisch et al. (1999) might predict early startle potentiation for such contents with these high-fear participants (although interpretations from that experiment should rightly be limited to threat stimuli). The analysis of blink magnitude by MQ score showed no such effects, although the FSS-score analysis showed that late startle potentiation for mutilation contents was limited to high general-fear participants.

Low-fear participants (as defined by FSS score) did not show any early startle modification, which is more in line with previous results from those studies using unselected samples (e.g., Bradley, Cuthbert, & Lang, 1993; Codispoti et al., 2001; Levenston et al., 2000; the non-psychopathic prisoners in the latter study are considered unselected in terms of fear levels). It is important to note that, when the participant sample in the present study was considered as a whole, early blink potentiation was observed for threat contents. As none of the studies cited above split participants post hoc on the basis of fear questionnaire score levels, the results of the current study, which also used an unselected sample, are still distinct from these other studies. As noted previously, these other studies (with the exception of Codispoti et al., 2001, where early negative and neutral blink magnitudes were not significantly different) found inhibition for negative contents at a 300 ms probe time. This was never the case in the present experiment, for participants in any fear condition.

SCR Magnitude

To summarise the SCR magnitude results, at the early Probe Time, SCR magnitudes were enhanced for all three affective contents relative to neutral. Threat content SCRs were also of greater magnitude than positive content SCRs at the early Probe Time. At the late Probe Time, SCR magnitude effects were limited to only one of the two Picture Combinations. Threat contents were associated with enhanced SCRs relative to neutral, and both mutilation and positive content SCRs were of smaller magnitude than neutral responses.

The SCR magnitude results, like blink magnitude, were quite different when considered by fear condition. Low-fear participants (whether indicated by MQ or FSS scores) showed few significant effects of emotional content on SCR magnitude. High-fear participants (again defined by either MQ or FSS score) showed significant SCR modification across Emotional Category at the early Probe Time, with greater SCR magnitude during affective contents than neutral. At the late Probe Time, linearity of SCR magnitude was observed over positive, neutral, and threat contents. Positive and mutilation content SCRs were not potentiated at the late Probe Time for high-fear participants.

An interaction between Gender and Emotional Category indicated that, averaged over both Probe Times, SCR enhancement was significant for threat contents only. For females, SCR magnitude for positive contents was not significantly different from neutral, but for males SCR magnitude for positive contents was lower than for neutral contents. This result is limited somewhat by consideration of differences between early and late SCR modification, discussed below.

Implications of SCR Magnitude Results

The late Probe Time SCR magnitude results in this study converged with those observed in Study 2. First, note that picture content only really modified SCR magnitude for high-fear participants. Despite the fact that high-fear participants consistently showed enhanced SCR magnitude for affective contents at the early Probe Time, only threat contents showed enhanced SCR magnitude relative to neutral at the late Probe Time. In fact, looking at all fear groups, the modal result for mutilation content SCRs at the late Probe Time was inhibition relative to neutral (as indicated by quadratic or linear effects; most of these only approached significance). The interaction observed between Picture Combination and Emotional Category for the late Probe Time SCRs is taken here as further evidence that the measurement of these late SCRs is unreliable. There are no additional explanations for this phenomenon than those offered in the discussion of Study 2.

The most interesting point to note regarding early SCR modification (which was suggested as a good indication of emotional arousal in the discussion to Study 2) is that these results were (mostly) significant only for high-fear participants. These were the only participants to show startle blink modification at 300 ms, which suggests that early startle modification is mediated by either high-fear in the participant or high stimulus intensity (which would be modulated by participant fearfulness also). The links between stimulus intensity, fearfulness and early startle modification are explicitly tested in Study 4.

Response Latencies to Peak

There were few manifest differences on the latency to peak results for blinks and SCRs. Blink latency to peak did not differ on the basis of Emotional Category, except at the late Probe Time where responses reached peak faster for positive than for threat contents.

SCR latency to peak was shorter for late Probe Time instances than for early Probe Time instances (although this effect was only significant for one of the two Picture Combinations). This may in fact be limited evidence in favour of the SCR summation hypothesis advanced in the discussion of Study 2 (Figure 16), as an initial SCR to the picture should be returning toward baseline at the time of the second SCR (to the probe). This could shift the recorded peak of the late probe SCR forward in time.

Theoretical Implications, and the Next Study

This experiment indicated early startle potentiation during negative stimuli for high-fear participants and threat contents only, a result that was congruent with the previously published literature but out of line with the results of Study 2. The discussion above differentiates the current experiment from other studies on the time course of startle potentiation, on the basis of the multiple negative picture categories used as well as the post hoc subdivision of participants into high and low fear individuals. The results still indicate an extension on previous work, showing

that early startle potentiation for threatening images is apparent when considered across the entire unselected sample, as well as a difference at 300 ms in the efficacy of potentiation for threat and mutilation/disgust contents.

The next study is basically a replication of this study, with one important difference. It was decided to control for the possibility that participants may not be attending to the computer screen at the time of picture presentation. As timing is the most important part of the experimental design, it is vital that the participant is looking at the picture from the moment of onset. Otherwise, the actual amount of time spent processing the picture content could vary unpredictably between individuals, and could be far shorter than the stipulated 300 milliseconds. Given the short latency between picture and probe onset in the early Probe Time condition in the following study, a warning was given to participants in the following study that the picture was about to be presented. This took the form of a small white fixation cross, presented for half a second prior to picture onset.

The only other experimental difference was that startle probes were only presented on pictures that had not been probed in the present study. This was done to test whether the effects observed in the current study would generalise to a different sample of pictures, or if they were specific to this study's picture set only.

Study 3b

Method

Participants

The experiment was completed by 47 participants (29 females), all of whom were first-year psychology students from the University of Otago. Participants received course credit after participating in the experiment. Age ranged from 18 to 22 years, with a median age of 18 years; the mean was 18.87 years.

One participant did not complete the experiment due to a poor EMG signal at the outset of the experiment. Another participant was excluded from all data analyses because they were currently undergoing treatment for depression.

Of those who completed the study, 41 participants (24 females) contributed data to the blink magnitude analyses, and 35 participants (20 females) contributed to the SCR analyses. Exclusion criteria were identical to Study 3a. One potential SCR analysis participant who made the inclusion criterion was excluded from the analysis due to having zero magnitude responses for the entirety of one Emotional Category/Probe Time combination.

Methodological Differences from Study 3a

The only differences between this study and Study 3a were in the participant sample used, the picture sets viewed, and the presentation of a fixation point prior to picture onset.

Selection of the picture stimuli was again on the basis of valence and arousal ratings collected

Table 13: Mean Valence and Arousal Ratings for Pictures Used in Study 3b.

Dimension	Positive	Neutral	Mutilation	Threat
Valence	7.79	5.33	1.84	3.33
Arousal	3.57	1.81	6.19	5.35

in Study 1. Table 13 reports means and standard errors of valence and arousal from Study 1 for the four picture categories. Appendix F lists the actual pictures included for each Emotional Category.

Positive and neutral pictures were the same as those used in Study 3a; however, startle probes were presented only on pictures where startle had not been elicited in Study 3a.

As there were only ten pictures in the threat and mutilation picture sets in Study 3a, two new pictures had to be added to each of these picture sets so that startle would only be elicited for pictures not probed in Study 3a. For the mutilation pictures, these were IAPS pictures 3051 and 9433; for the threat pictures, these were IAPS pictures 6243 and 6510. These new pictures were selected as being similar in content to the probed pictures from Study 3a that they replaced. Picture ratings for some pictures in this experiment were not available from Study 1, and so the standardised ratings reported in the IAPS manual (Lang et al., 1999b) were used instead. These pictures are marked with an asterisk in Table F1.

As mentioned in the preamble, the second addition to this study was the presentation of a fixation cross prior to picture presentation. The fixation cross consisted of two intersecting 3-cm white lines, presented in the middle of the computer screen for 500 ms prior to picture onset. No cross was presented prior to the ITI startle probes.

Results

Summary of Physiological Variables and Number of Valid Participants

Table 14 summarises descriptive statistics for the four physiological dependent variables, averaged across the early and late Probe Time conditions. Both raw and transformed data are presented for the blink and SCR magnitude, although only standardised data were used for the following analyses. The number of participants included for the blink and SCR analyses is noted by the blink magnitude and SCR magnitude summaries.

Table 14: Physiological Dependent Variable Means and Standard Errors, by Emotional Category of Picture, Averaged Across Probe Time.

Physiological measure	Positive	Neutral	Mutilation	Threat
Blink magnitude *n* = 41				
Raw (μV)	54.39	51.18	54.56	57.59
(S.E.)	(5.45)	(5.3)	(5.46)	(5.75)
Standardised (T-score)	49.58	48.70	50.61	51.1
(S.E.)	(.63)	(.44)	(.54)	(.55)
Blink latency to peak (ms)	75.32	74.78	75.17	75.2
(S.E.)	(1.29)	(1.28)	(1.67)	(1.5)
SCR magnitude *n* = 36				
Raw (μS)	1.95	1.92	1.97	2.44
(S.E.)	(.27)	(.26)	(.27)	(.29)
Standardised (p of range)	.35	.34	.35	.45
(S.E.)	(.03)	(.03)	(.03)	(.03)
SCR latency to peak (ms)	4546.28	4492.26	4469.7	4556.22
(S.E.)	(140.24)	(139.13)	(133.54)	(137.28)

Table 15: Descriptive Statistics for MQ and FSS Questionnaires, Between Gender.

Questionnaire	Females	Males	All	Median
n	28	19	47	47
MQ	10.77	7.89	9.61	8
(S.E.)	(1.3)	(.96)	(.88)	
FSS	123.57	107.47	117.06	120
(S.E.)	(5.58)	(5.43)	(4.11)	

Questionnaire Results

Table 15 reports means and standard errors for the two questionnaires for both males and females. There were no differences in questionnaire score by Gender on the MQ measure, F (1, 45) = 2.48, p = .122. For the FSS measure, the main effect for Gender approached significance, F (1, 45) = 3.8, p = .058. Scores did not vary across Picture Combination nor as an interaction between Gender and Picture Combination, for either questionnaire, Fs (1, 45) $<$ .518, ps $>$ .475. Table 15 also reports the medians for the entire sample for both questionnaires. These medians are used to split participants into high and low-score groups for the following analyses by questionnaire score; participants whose scores were on the median were allocated to the low-score group in all instances.

Blink Magnitude

In the analysis of standardised blink magnitude with all variables in the model, neither Gender nor Picture Combination approached significance as main effects or in any interaction involving Emotional Category, Fs (3, 111) $<$ 1.98, ps $>$ .122, $\varepsilon = .98$, epsilon value for highest F interaction. Picture Combination and Gender were thus excluded from the following analysis model.

There was a significant main effect of Emotional Category, F (3, 120) = 3.21, $p = .029$, ε = .92.

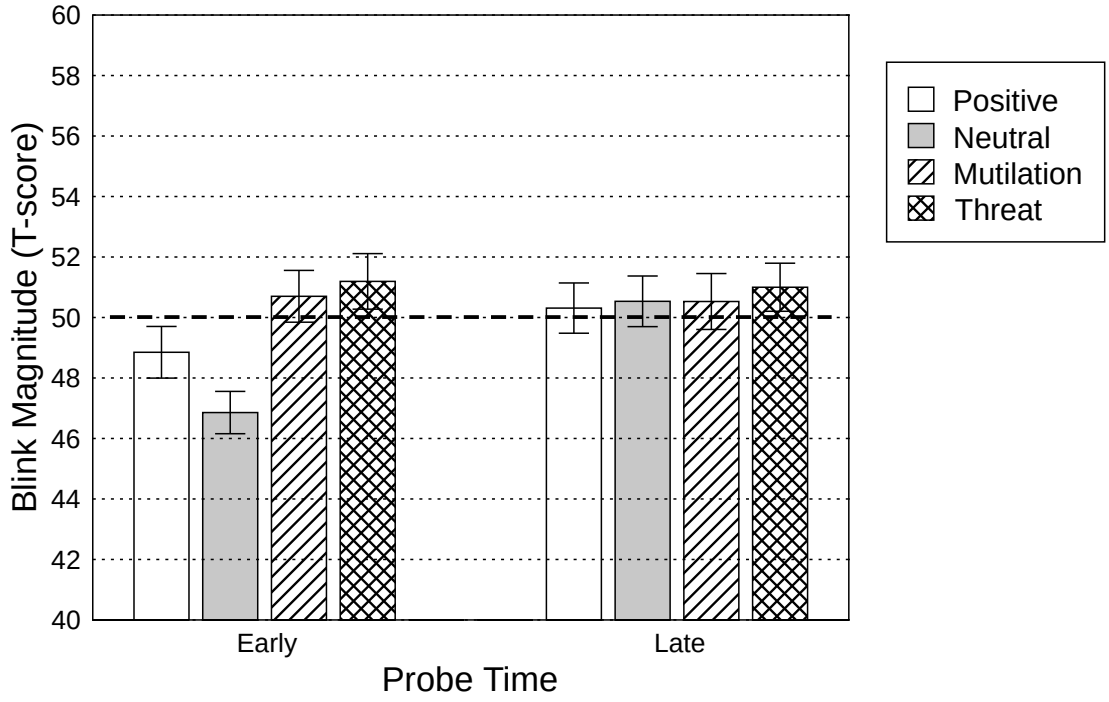


Figure 28. Mean standardised blink magnitude by Emotional Category, at the early and late Probe Times. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

The main effect for Probe Time approached significance, F (1, 40) = 2.95, p = .094, as did the interaction between Emotional Category and Probe Time, F (3, 120) = 2.15, p = .099, ε = .97. The data for this interaction are represented in Figure 28.

Planned comparisons at the early Probe Time showed a linear effect for threat that approached significance, F (1, 40) = 3.56, p = .067. The quadratic effect for threat was significant, indicating greater blink magnitude in the positive and threat conditions than in the neutral condition, F (1, 40) = 12.39, p = .001. The quadratic effect for mutilation was also significant, indicating that mutilation content blink magnitudes were also enhanced relative to neutral, F (1, 40) = 9.42, p = .004. The difference between mutilation and positive content blinks was not significant, linear F (1, 40) = 2.16, p = .149.

As should be clear from Figure 28, blink response magnitudes at the late Probe Time were not different from one another, all contrast Fs (1, 40) $<$ .35, ps $>$ .559.

Blink Magnitude by MQ Score

The analysis for blink magnitude by MQ score-group showed a main effect for Emotional Category, F (3, 117) = 3.14, $p = .032$, ε = .92. The interaction between Emotional Category and Probe Time approached significance, F (3, 117) = 2.21, $p = .093$, ε = .97. MQ score did not interact with Emotional Category, nor with Emotional Category and Probe Time, Fs (3, 117) = .08 and 1.09, ps = .962 and .354. An interaction between Probe Time and MQ score approached significance, F (1, 39) = 2.91, p = .096.

Blink Magnitude and FSS Score

There was no main effect for FSS score on blink magnitude, F (1, 39) = .04, p = .837. There was a significant main effect for Emotional Category, F (1, 39) = 3.28, $p = .027$, ε = .92. The interactions involving Emotional Category and FSS score group were not significant, Fs (1, 39) < 1.3, ps $> .283$, $\varepsilon < .98$.

Blink Latency to Peak

Gender did not approach significance for any terms in the ANOVA model for blink latency to peak, highest F (3, 111) = .92, $p = .409$, ε = .71. The following analysis includes Emotional Category, Probe Time, and Picture Combination as independent variables.

The main effect for Emotional Category was not significant, F (3, 117) = .1, $p = .959$, ε = .72. There was a significant interaction between Emotional Category and Probe Time, F (3, 117) = 3.02, $p = .036$, ε = .94. The data for this interaction are presented in Figure 29. Planned contrasts showed no significant contrasts for Emotional Category on blink latency to peak within either Probe Time, Fs (1, 39) < 2.38, ps $> .131$.

A further significant interaction occurred between Emotional Category and Picture Combination, F (3, 117) = 3.61, p = .028. Separate ANOVAs for the two Picture Combinations found no

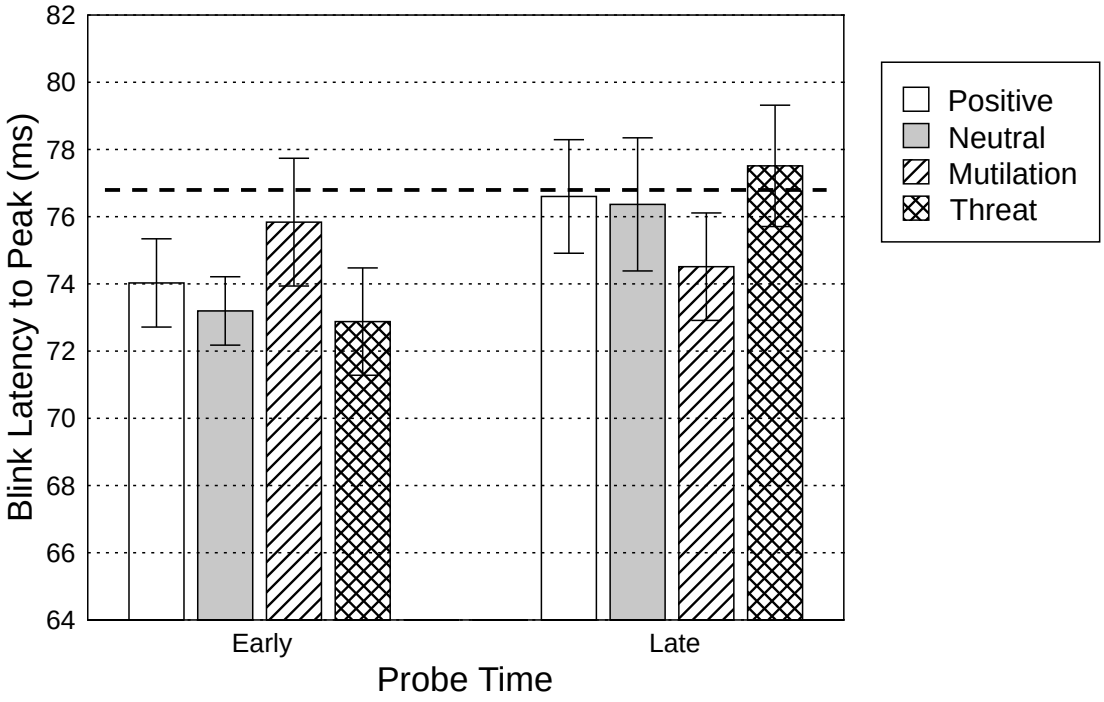


Figure 29. Mean blink latency to peak by Emotional Category, at the early and late Probe Times. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

main effects for Emotional Category, *F*s (3, 60) = 2.13 and 1.68, *p*s = .134 and .198, ε s = .65 and .71, for the first and second Picture Combinations respectively.

SCR Magnitude

The initial ANOVA for SCR magnitude included all possible independent variables, but Gender and Picture Combination were again removed because they did not approach significance, highest *F*s (3, 93) = 1.92 and 1.67, *p*s = .14 and .186, ε = .88 and .86.

In the analysis including Emotional Category and Probe Time, there was a main effect for Emotional Category, F (3, 102) = 10.01, $p < .001$, ε = .9. Probe Time was also significant as a main effect, with SCR magnitudes being larger on average at the early Probe Time (M = .39) than at the late Probe Time (M = .35), F (1, 34) = 5.69, p = 0.023. The interaction between Emotional Category and Probe Time was not significant, F (3, 102) = 1.99, $p = .13$, ε = .86.

The following comparisons can be followed in Figure 30. At the early Probe Time, threat con-

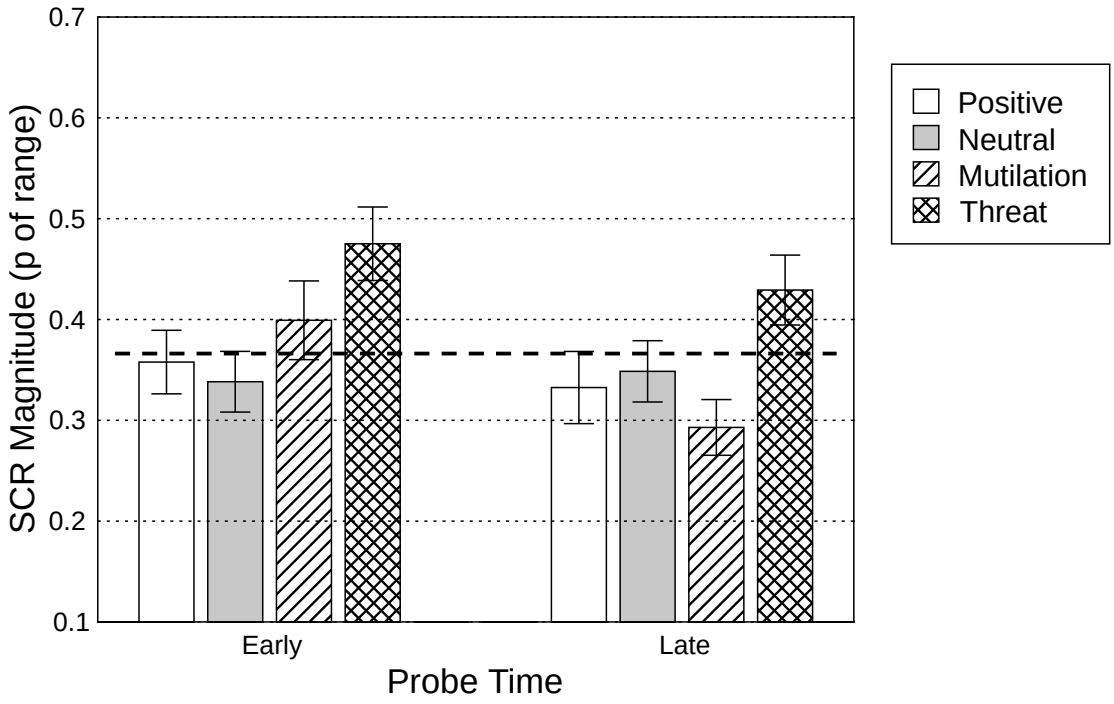


Figure 30. Mean standardised SCR Magnitude by Emotional Category, at the early and late Probe Times. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

tent pictures were associated with greater SCR magnitudes than positive content pictures, linear F (1, 34) = 12.94, p = .001. The threat quadratic trend was also significant, F (1, 34) = 11.37, p = .002, although it can be seen in Figure 30 that positive and neutral content SCR magnitudes were not significantly different at this Probe Time. The linear and quadratic effects for mutilation contents at the early Probe Time were not significant, Fs (1, 34) $<$ 2.33, ps $>$ .136.

At the late Probe Time, threat content SCRs were again of greater magnitude than positive content SCRs, linear F (1, 34) = 6.6, p = .015. The quadratic trend for threat contents was not significant, F (1, 34) = 1.38, p = .248. These two results indicate increasing SCR magnitude across positive, neutral, and threat contents. Neither of the mutilation contrasts were significant, Fs (1, 34) = 1.22 and 2.12, ps = .277 and .155, for linear and quadratic respectively.

SCR Magnitude and Questionnaire Results

The ANOVA looking at SCR magnitude for both high and low MQ score participants found a main effect for Emotional Category, F (3, 123) = 11.34, $p < .001$, ε = .9. There were also

interactions between Emotional Category and Probe Time, F (3, 123) = 2.84, $p = .042$, ε = .98, and between Emotional Category and MQ score group, F (3, 123) = 3.9, p = .014.

For the low MQ-score group, there was a significant main effect of Probe Time on SCR magnitude, F (1, 21) = 5.61, p = .028, with early Probe Time SCRs (M = .43) being of greater magnitude than late Probe Time SCRs (M = .37). There was no main effect for Emotional Category, F (3, 63) = 1.5, $p = .226$, ε = .94, and the interaction between Emotional Category and Probe Time was not significant, F (3, 63) = 2.23, $p = .1$, ε = .91. SCR magnitude data for the below median MQ score participants are presented in Figure 31.

At the late Probe Time, SCR magnitudes increased linearly across positive, neutral, and threat contents; linear F (1, 16) = 4.80, p = .044, quadratic F (1, 16) = .8, p = .385. The linear and quadratic trends were not significant for mutilation contents at the late Probe Time, Fs (1, 16) = .52 and 2.33, ps = .481 and .147.

Data for the above median MQ score SCR magnitudes are presented in Figure 32. There was a significant main effect for Emotional Category in this condition, F (3, 51) = 3.84, $p = .021$, ε = .84. At the early Probe Time, there were significant linear and quadratic trends for threat, Fs (1, 17) = 5.05 and 8.52, ps = .038 and .01. The two contrasts for mutilation contents at this Probe Time were not significant, Fs (1, 17) = .9 and 1.21, ps = .355 and .286, for linear and quadratic.

For late startle probe SCR magnitudes, no contrast was significant, Fs (1, 17) < 2.04, ps $> .171$.

SCR Magnitude and FSS Score

For the analysis of SCR magnitude by FSS score group, there was a main effect for Emotional Category, F (3, 99) = 9.6, $p < .001$, ε = .9. Interactions between Emotional Category and FSS score group were not significant, Fs (3, 99) $< .2$, ps $> .876$, $\varepsilon = .86$; epsilon value for interaction of Emotional Category, Probe Time, and FSS score group.

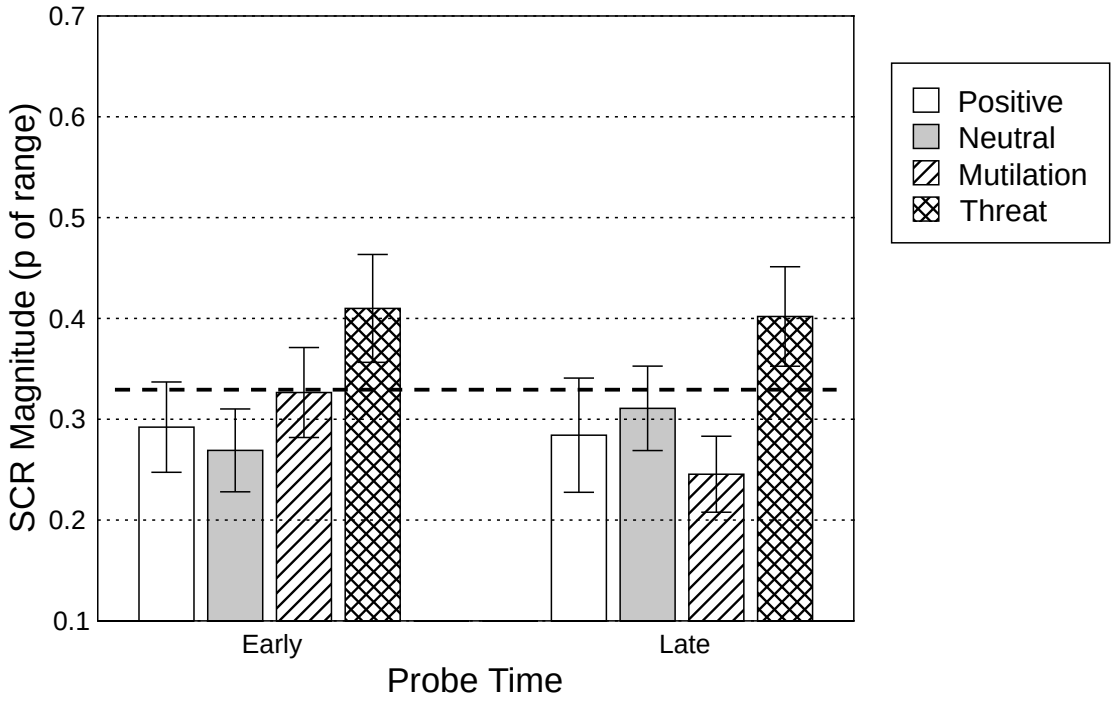


Figure 31. Mean standardised SCR magnitude by Emotional Category, at the early and late Probe Times, for participants scoring at or below the median on the MQ. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

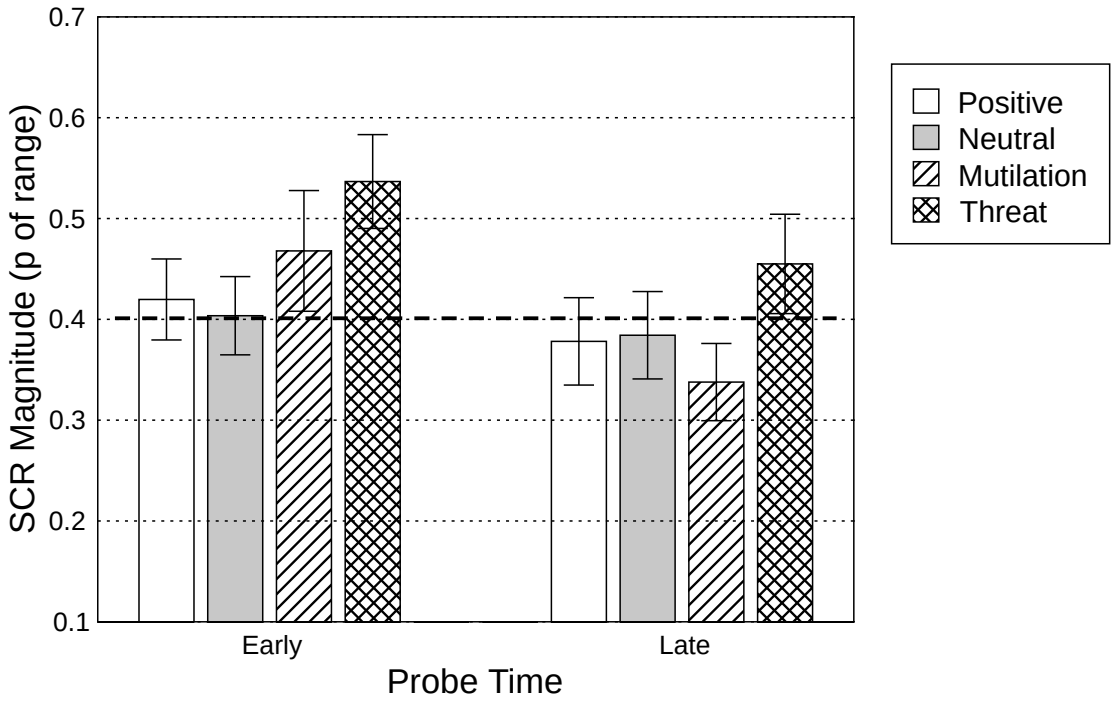


Figure 32. Mean standardised SCR magnitude by Emotional Category, at the early and late Probe Times, for participants scoring above the median on the MQ. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

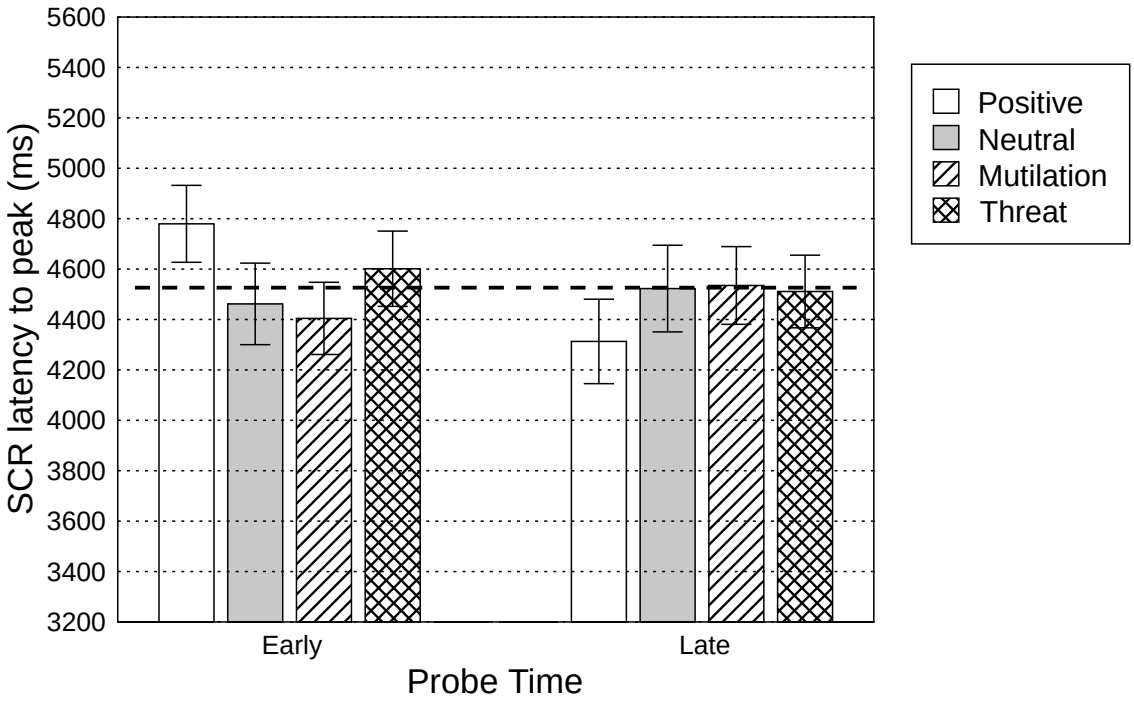


Figure 33. Mean SCR latency to peak by Emotional Category, at the early and late Probe Times. Error bars indicate one standard error. Dotted line represents mean level of ITI responses.

SCR Latency to Peak

All variables were included in the ANOVA model. There was a significant interaction between Gender and Picture Combination, F (1, 31) = 5.54, p = .025. SCRs reached their peak more quickly for male participants in the second Picture Combination (M = 3962.13 ms) than for female participants in the first Picture Combination (M = 4528.84 ms), p = .041. These variables were not involved in any interactions with Emotional Category or Probe Time, Fs (3, 93) $<$ 1.3, ps $>$ .263. The Planned Comparisons below were conducted from within the model including both of these between-subject variables.

The main effect for Emotional Category was not significant, F (3, 93) = .36, p = .742, ε = .82. There was a significant interaction between Emotional Category and Probe Time, F (3, 93) = 3.32, p = .031, ε = .84, the data for which are displayed in Figure 33.

Figure 33 shows the early and late Probe Time data for SCR latency to peak. At the early Probe Time, there was a significant linear effect for mutilation contents, with SCR latency to peak

being shorter for mutilation compared to positive contents, F (1, 31) = 6.29, p = .018. There was also a significant quadratic trend for threat contents, indicating longer SCR latency to peak for positive and threat contents relative to neutral, F (1, 31) = 5.14, p = .03. At the late Probe Time, no contrasts were significant, Fs (1, 31) $<$ 2.21, ps $>$ .147.

Discussion

Summary of Results

Blink Magnitude

The blink magnitude results for this study can be summarised as follows. Blink modification was not apparent for any Emotional Category after several seconds of picture viewing. At the 300 ms Probe Time, positive stimuli and both types of negative stimuli potentiated startle blink magnitude relative to neutral. There were no interactions between Emotional Category and fear-group, as defined by either the MQ or FSS score.

SCR Magnitude

At both early and late Probe Times, SCRs for threat contents were enhanced relative to neutral content SCRs. SCR magnitude was never potentiated for positive or mutilation contents. This was true for both high- and low-fear individuals.

Implications of Results

The results of this experiment are inconsistent with any previously published studies. The pictures failed to modulate startle after several seconds of viewing. In the absence of blink modification at the late Probe Time, it would be imprudent to attribute the early startle modification results to emotional causes. This discussion will first address the lack of emotional modification of startle at the late Probe Time, and then possible causes of the observed early Probe Time startle modulation.

The first point regarding the lack of emotional startle modification is that the probed pictures in this study were those photographs in Study 3a on which startle had not been elicited. The

lack of emotional modification at the late Probe Time could represent a failure of stimulus generalisability for the results of Study 3a — either those earlier results were specific to the pictures probed in the earlier study, or the current results were specific to the pictures used in the present study.

The use of the fixation stimulus in this study is another possible influence on the results. The presentation of the fixation cross may concentrate participant attention on the early part of the picture presentation period. Focusing attention on the early stages of picture presentation may lead to a cessation of emotional processing by the time of the late startle probes, so that startle modification after a few seconds is equivalent to that seen after picture offset in studies that do not use a fixation stimulus (e.g., Bradley, Cuthbert, & Lang, 1993). This seems unlikely. An alternative hypothesis, which presumes that the fixation stimulus influences participants into thinking that only the early stages of picture viewing are important, is that the participants may have stopped looking at the picture after the early startle probe has not appeared. Again this seems unlikely.

Any hypothesis on this lack of late startle modification would also have to account for the blink potentiation observed for all affective categories at 300 ms, rather than just for negative category pictures. This effect suggests that attention or arousal characteristics (rather than valence) are mediating this early modification. However, SCR magnitude (an indicator of emotional arousal) was never potentiated for any content other than threat, which casts some doubt on this explanation.

Resolution of the results of Studies 3a and 3b is not possible at this point. If both studies had used the same picture set, or the second study had used a different picture set but excluded the fixation stimulus, it might be possible to offer a more conclusive report on the observed differences in results.

The Next Experiment

Study 3b was envisaged as a replication and (minor) extension of Study 3a. The dissimilarity of results between the two studies is thus a major setback. The next study was designed as a refinement of the Study 3 experimental design, introducing foreground arousal as an experimental factor, while retaining the fixation point used in Study 3b. If the fixation cross has an influence on early and late startle modification, the results of Study 3b should be replicated in Study 4. In this instance, the arousal manipulation should clarify whether the early potentiation of startle blinks observed during positive contents is related to arousal and/or attention, which would be indicated by differential early blink modification for high- and low-arousal positive stimuli.

It is also possible that the results of Study 4 will be more similar to those obtained in Study 3a, in which case the results of Study 3b could be attributed to properties of the picture stimuli used or a sampling error.

Before describing the experimental design, the introduction to Study 4 includes a discussion of startle modification and arousal characteristics that expands on the corresponding section in the general introduction by considering differences in responding between specific negative emotions, as well as the interaction between arousal and the time of probe presentation.

Study 4

The Nature of Subjective Arousal, Specific Emotional Content, and Startle Reflex Modification

Studies 3a and 3b produced conflicting results, with Study 3a showing consistent startle potentiation across both early and late probe times for both threat and mutilation contents. Study 3b showed no startle modification at the late probe time, and early startle potentiation for all affective contents relative to neutral. Two hypotheses were advanced regarding this discrepancy. Firstly, the fixation point introduced in Study 3b could be influencing participant responding. Secondly, the pictures used in Study 3b may have been incapable or unlikely to produce startle potentiation. This second hypothesis does not address why early startle probe responses showed the pattern of results observed.

The next study investigates how the arousal/intensity dimension of emotional stimuli interacts with specific negative emotional content types, with the aim of resolving the issues raised by the discordant results of Studies 3a and 3b.

Conflation of Arousal and Specific Emotional Content

One major problem with many studies purporting to examine differences in blink modification for specific emotional contents is that stimulus arousal characteristics are often not matched between content types. This was previously mentioned with regards to Bernat, Patrick, Steffen, and Sass (2002).

Some emotional states (e.g., fear, or anger) are by nature more intense than others (e.g., sadness), and so could not possibly be compared at the same intensity level, proposed here as

necessary for testing the emotional specificity of startle modification. For the considerations of this thesis, arousal and specific emotional content have been conflated in several studies, and these studies have all shown changes in startle blink magnitude for specific negative contents that mirror the changes in the arousal dimension for these contents (e.g., Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley, Codispoti, Sabatinelli, & Lang, 2001; Bernat, Patrick, Steffen, & Sass, 2002). The imagery studies of Witvliet and Vrana (1995, 2000), with high and low arousal negative and positive scripts (fear, joy, sadness, pleasant relaxation), also conflate valence, arousal, and specific content, although the last was not of interest to them.

Cook et al. (1991) used imagery scripts matched on both arousal and valence for their anger and fear categories, while their sad script was matched with these on valence but not on arousal. Imagery for all of these negative scripts showed similar levels of startle potentiation relative to the neutral script. Likewise, Vrana (1994) found equal levels of startle blink magnitude on imagery for anger and disgust scripts, even though these varied in subjective unpleasantness and arousal, with anger being associated with more extreme ratings on both. In these studies startle modification was equivalent across negative emotional categories, although predictions based on arousal ratings would have suggested otherwise.

Even when valence ratings are less extreme for fear than for other negative emotional stimuli (e.g., disgust in Balaban & Taussig, 1994, pity in Lang, 1995), startle potentiation has been absent in these non-fear conditions; furthermore, in the case of ‘pity’, subjective arousal as well as unpleasantness was higher for pity evoking than for the fear evoking stimuli (Lang, 1995). Levenston et al. (2000) also showed differential startle between threat and victim contents, with greater potentiation for threat than mutilation contents (see reservations on page 114), despite a lack of differences in valence and arousal ratings.

Yartz and Hawk (2002) also found differences in valence and arousal ratings for their photographic materials. Disgust stimuli were rated as less pleasant than fear stimuli, and within the disgust category, blood-content pictures were rated as less pleasant than the non-blood disgust contents. Arousal ratings for the combined disgust category and fear were equivalent, although

disgust-blood contents were again rated as more arousing than disgust-other contents. The valence/arousal ratings are in line with the startle reflex magnitudes so that the most arousing/least pleasant stimuli (disgust-blood) produced the greatest startle potentiation, while fear stimuli (less extreme on valence, but not arousal, ratings) produced the smallest degree of potentiation.

The same contention regarding conflated arousal and specific content could be raised regarding Cuthbert et al. (1996) and their conclusions on varying arousal levels and startle modification. To summarise their findings again, only highly arousing negative stimuli potentiated startle blink magnitude, while medium- and low-arousal negative stimuli blinks did not differ from neutral. These high, medium, and low arousal negative categories differed in terms of their specific contents as well as their subjective arousal, so that only the high-arousal condition contained any threat stimuli (two of six, as defined by this author, with the remainder being mutilation contents). The remainder of pictures at the other arousal levels consisted of mutilation, injury, contamination, and socially aversive content photographs. If startle blink modification is sensitive to both specific content and arousal, then separating these potential effects into two factors will give a clearer indication of their relative contributions.

The Experiment

The experiment described here attempts to resolve the differences between Studies 3a and 3b by splitting each emotional category into high and low arousal conditions (equivalent to the high and medium arousal categories in Cuthbert et al., 1996), thus testing whether stimulus intensity influences startle responding in the same way across specific emotional categories. Once again, the primary point of interest is the Probe Time manipulation, and whether stimuli modify the startle response consistently at early and late Probe Times. These times were the same as in previous studies in this thesis.

The other change in this study was the use of the State-Trait Anxiety Inventory (STAI; Spielberger, 1983), which was administered to participants in place of the FSS-II-R measure in this study. This change occurred primarily because of an earlier analysis strategy in which Studies

3a and 3b were analysed as a single experiment. This analysis suggested that FSS scores did not impact on startle modification, and so the STAI was introduced into the current study to test whether participants' anxiety levels influenced the pattern of startle modification. It has been suggested that the FSS measure taps into a dimension similar to trait anxiety (Cook, 1999), and so the STAI was expected to fulfill a similar role to the FSS in the current experiment, while being a more standardised measure than the FSS. The MQ questionnaire was retained for this study.

Method

Participants

The participants were 58 first-year psychology students (25 female) at the University of Otago. Median age was 19 years, with a mean of 20.4 years. All received course credit for participating.

Data from one additional participant was excluded from analysis because they were receiving treatment for clinical depression, while another participant did not contribute data to the study as they were allergic to the skin preparation solution.

Picture Stimuli

Pictures were chosen for this study to fit into the four categories of emotional content used in Studies 3a and 3b. Each category's pictures were also divided into high and low arousal exemplars, corresponding to the high and medium arousal categories used in Cuthbert et al. (1996). Pictures used for the positive and neutral categories were exactly the same as used by Cuthbert et al. (1996), while for the threat and mutilation/disgust conditions, pictures with the appropriate content were matched as closely as possible on standardised ratings of valence (Lang et al., 1999b). Arousal ratings were matched (within each arousal condition) across the positive and the two negative picture categories (see mean ratings in Table 16). The pictures used are listed in Appendix G. An additional 8 positive, 8 neutral, and 6 negative pictures were included as filler, and startle was never elicited on these pictures.

Experimental Design

Pictures were divided into three blocks with 24 pictures (16 probed, 8 filler) in each block. Emotional Category, Probe Time, and Arousal were all within-subject factors, with three pictures contributing data to each Emotional Category/Probe Time/Arousal condition (a total of 48

Table 16: Mean Valence and Arousal Ratings for High and Low Arousal Pictures Used in Study 4.

Category	Dimension	Arousal Condition High	Low
Threat	Valence	2.87	3.27
	Arousal	6.85	5.76
Mutilation	Valence	2.07	2.22
	Arousal	6.81	5.74
Neutral	Valence	5.26	5.14
	Arousal	4.35	3.38
Positive	Valence	7.47	7.57
	Arousal	6.58	5.39

probed pictures). There were four possible Picture Combinations, with startle probes presented for different combinations of pictures at Probe Times in each of these. Each Picture Combination had three possible block presentation orders. Gender and Picture Combination viewed were initially included as between-subjects factors in the analysis for each dependent variable.

Due to the large number of startle probes presented during pictures, only two ITI startle probes were presented in each of the three blocks, making a total of six ITI probe instances for each participant.

There was a problem with the SCR recordings in this study. SCRs for participants showed very little change in skin conductance level during the course of the experiment. It eventuated that the liquid soap with which participants washed their hands (not used in previous studies: There was a change in facilities before this study began) contained moisturisers that were probably occluding changes in sweat gland activation. After the first seventeen participants, the soap was changed back to a non-moisturising bar of soap, and the observed SCRs returned to the normal range of activity.

Procedure

Procedure was the same as for previous experiments, with the fixation cross being presented for 500 ms prior to picture onset (as in Study 3b). The questionnaires used were the MQ and the State/Trait Anxiety Inventory (Spielberger, 1983).

Data Analysis

Data analysis was in line with previous experiments in this thesis. The exclusion criteria were more than one quarter of all responses falling below 10 μV, for blinks, or having zero magnitude for SCRs. The maximum number of small responses for inclusion in analysis was twelve for both variables . Planned contrasts were performed between Emotional Categories within each Probe Time/Arousal condition (e.g., early, low arousal stimuli).

Results

Summary of Physiological Variables and Number of Valid Participants

Participant data for all dependent variables are summarised in Table 17, for each Emotional Category averaged across both Probe Times and both levels of Arousal. The number of participants contributing data to the blink and SCR analyses are also summarised within Table 17.

Table 17: Physiological Dependent Variable Means and Standard Errors, by Emotional Category of Picture, Averaged Across Probe Time and Arousal.

Physiological measure	Positive	Neutral	Mutilation	Threat
Blink magnitude *n* = 42				
Raw (μV)	59.27	63.07	65.66	71.95
(S.E.)	(5.49)	(5.23)	(5.64)	(5.48)
Standardised (T-score)	48.12	49.57	50.87	53.11
(S.E.)	(.32)	(.29)	(.46)	(.44)
Blink latency to peak (ms)	74.27	74.86	74.82	73.87
(S.E.)	(.93)	(.88)	(.98)	(.91)
SCR magnitude *n* = 39				
Raw (μS)	2.02	1.86	2.25	2.74
(S.E.)	(.28)	(.25)	(.30)	(.40)
Standardised (p of range)	.28	.26	.32	.39
(S.E.)	(.02)	(.02)	(.02)	(.02)
SCR latency to peak (ms)	4102.88	4060.18	4145.71	4237.96
(S.E.)	(111.81)	(108.69)	(115.06)	(115.26)

Questionnaire Results

Table 18 reports means and standard errors for scores on the MQ, and the state (STAI-S) and trait (STAI-T) scores from the STAI. Median scores are also reported for each questionnaire,

Table 18: Descriptive Statistics for MQ and STAI Questionnaires, Between Gender.

Questionnaire	Females	Males	All	Median
n	25	30	55	
MQ	9.47	7.85	8.59	9
(S.E.)	(.64)	(.91)	(.58)	
STAI-S	39.26	36.63	37.83	37
(S.E.)	(1.83)	(1.4)	(1.13)	
STAI-T	39.94	40.43	40.21	39
(S.E.)	(1.85)	(1.82)	(1.29)	

and these medians were used to divide participants into high and low score groups for analyses of blink and SCR magnitude.

For the MQ questionnaire, the interaction between Gender and Picture Combination was significant, F (3, 47) = 3.49, p = .023. In the first Picture Combination, females (M = 11.83) scored higher than males (M = 4.88) on this measure, p = .044; all other comparisons, $p > .116$. Differences between males and females on the STAI-S and STAI-T were not significant, Fs (1, 47) = 1.13 and .06, ps = .293 and .809, respectively. Neither Picture Combination as a main effect, nor the interaction between this factor and Gender were significant for either STAI measure, Fs (3, 47) < 1.27, ps $> .298$.

Blink Magnitude

In the original model for blink magnitude, Picture Combination was not significant as a main effect or in interaction with any other factor, highest F (9, 102) = 1.71, $p = .118$, ε = .77. This factor was removed from the model. In the new model, Gender, Probe Time, and Arousal did not appear as main effects or in any two-way interaction, Fs (1, 40) < 2.19, ps $> .146$. The three-way interaction between these factors approached significance, F (1, 40) = 3.95, p = .054.

Emotional Category was a significant main effect, F (3, 120) = 23.63, $p < .001$, ε = .79. The in-

teraction between Emotional Category and Arousal approached significance, F (3, 120) = 2.17, $p = .099$, ε = .94. No other interaction involving Emotional Category approached significance, Fs (3, 120) < 1.14, ps $> .335$; epsilon values ranged from .79 to .98. The nature of the interaction between Emotional Category and Arousal is covered by the planned contrasts at the two Probe Times, below, conducted from within the model with all four Emotional Categories.

At the early Probe Time (data presented in the top panel of Figure 34), both high-arousal threat and mutilation content blinks were of significantly greater magnitude than positive content blinks, linear Fs (1, 40) = 11.06 and 5.13, ps = .002 and .029, respectively. Quadratic trends here were not significant, indicating linearly increasing blink magnitude across high arousal positive, neutral, and negative categories, quadratic Fs (1, 40) = 2.36 and .27, ps = .133 and .605, for threat and mutilation respectively. For low-arousal stimuli at the early Probe Time, threat content blinks were potentiated relative to positive content blinks, linear F (1, 40) = 14.8, $p < .001$, and the absence of a significant quadratic trend for low arousal threat suggested blink inhibition for positive contents relative to neutral, quadratic F (1, 40) = 2.15, p = .151. As shown in Figure 34, these two categories did not significantly differ. There was no difference between low-arousal mutilation and positive content blinks at this Probe Time, linear F (1, 40) = .22, p = .639.

The bottom panel of Figure 34 represents blink magnitude data from the late Probe Time condition. The high-arousal threat and mutilation comparisons showed linearly increasing blink magnitude across positive, neutral, and negative contents; linear Fs (1, 40) = 25.62 and 27.63, both ps $< .001$, quadratic Fs (1, 40) = .3 and .07, ps = .588 and .793. Low-arousal threat contents showed the same pattern of blink responding; linear F (1, 40) = 23.35, $p < .001$, quadratic F (1, 40) = .55, p = .462. For the low-arousal mutilation contents, blink magnitude was not potentiated relative to positive contents, linear F (1, 40) = 2.57, p = .117.

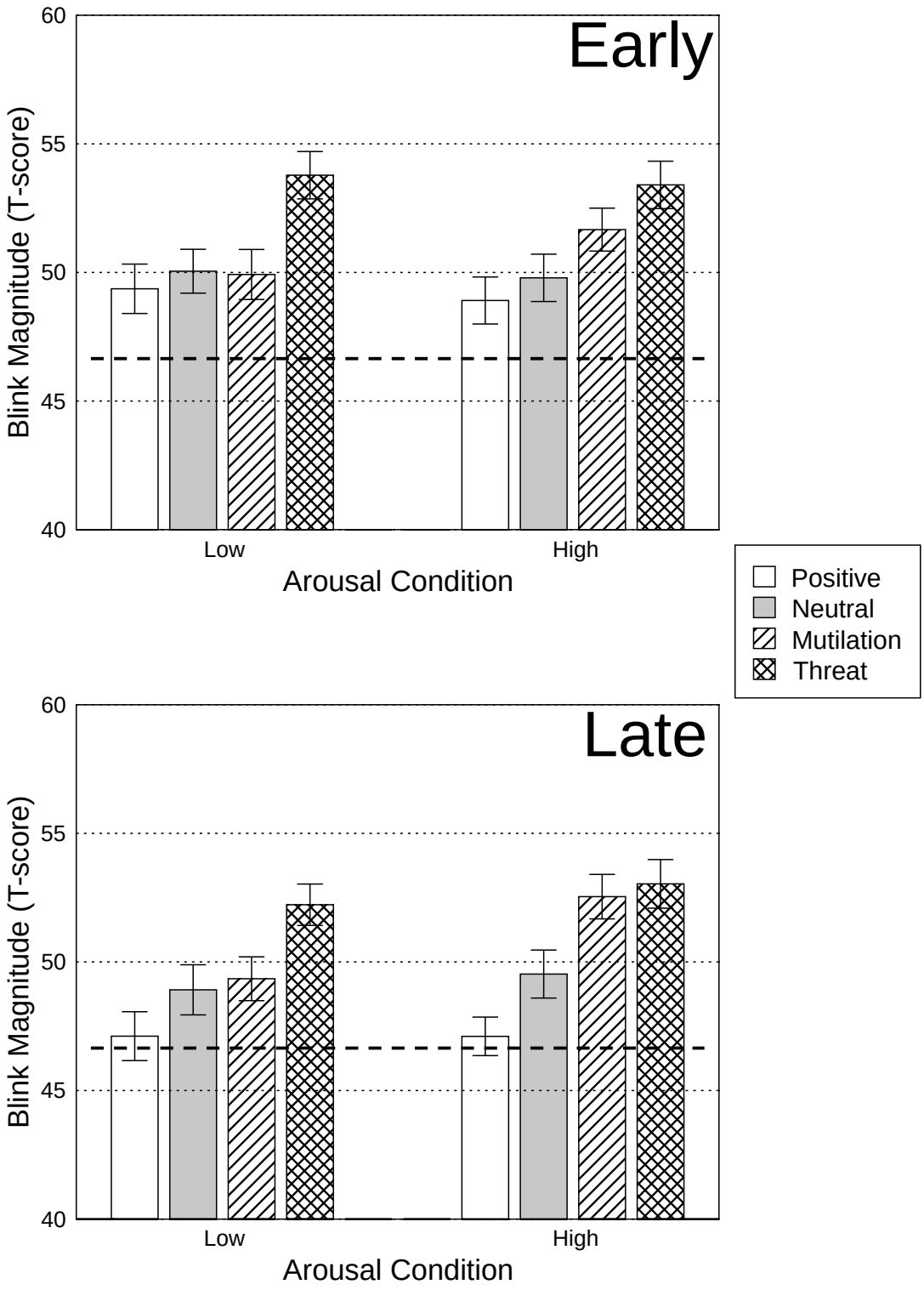


Figure 34. Mean standardised blink magnitude by Emotional Category, for high and low arousal contents at the early and late Probe Times. Data are presented in the upper panel for the early probe time, and in the lower panel for the late probe time. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

Blink Magnitude and Questionnaire Score

The analysis of blink magnitude by MQ score group showed no significant interactions between MQ score group and Emotional Category or any other factor, *F*s (3, 120) $< .85$, *p*s $> .449$; epsilon values ranged from .78 to .98. Group sizes were not quite equal for the below-median ($n = 25$) and above-median ($n = 17$) MQ score groups.

For the blink magnitude analysis by State anxiety score on the STAI, interactions between STAI-S score and Emotional Category were not significant, *F*s (3, 120) < 1.2, *p*s $> .315$; epsilon values ranged from .79 to .99. An interaction between STAI-S score-group and Arousal approached significance, F (1, 40) = 3.62, $p = .064$. The non-significant trend suggested that the differences in blink magnitude between low and high arousal pictures was greater in the high STAI-S participants than in the low STAI-S participants. The number of participants contributing data to each group was again not quite equal ($n = 19$ for the low-score group, $n = 23$ for the high-score group).

A similar pattern was observed for the analysis by Trait anxiety score, with no observed interactions involving Emotional Category and STAI-T score-group, *F*s (3, 120) < 1.61, *p*s $> .194$; epsilon values ranged from .79 to .99. The groups here were not identical to the STAI-S analysis, with 23 participants in the below-median STAI-T group and 19 in the above-median STAI-T group. The interaction between STAI-T score group and Arousal approached significance, F (1, 40) = 3.11, $p = .086$, with results in the same direction as for the STAI-S analysis.

Blink Latency to Peak.

For blink latency to peak, all five factors were included in the final analysis model. The only significant main effect was for Probe Time, F (1, 34) = 22.61, $p < .001$. Probe Time also produced a significant interaction with Arousal, F (1, 34) = 6.22, $p = .018$, as well as a three-way interaction with Arousal and Picture Combination, F (3, 34) = 7.57, $p < .001$. Blink latency to peak was generally shorter in the early, compared to the late, Probe Time. This

effect was significant for high-arousal pictures in all Picture Combinations but the second, and for low-arousal pictures in the third Picture Combination, *p*s $< .014$. All other comparisons within each Picture Combination/Arousal condition were not significant, *p*s $> .334$. The four-way interaction between Probe Time, Arousal, Picture Combination, and Gender approached significance, F (3, 34) = 2.42, $p = .083$.

Emotional Category was not significant as a main effect, F (3, 102) = .94, $p = .409$, $\varepsilon = .82$. The interaction between Emotional Category and Arousal approached significance, F (3, 102) = 2.37, $p = .095$, $\varepsilon = .73$.

For the planned contrasts at the early Probe Time (upper panel of Figure 35), there were no significant differences between the low-arousal Emotional Categories, *F*s (1, 34) < 2.03, *p*s $> .163$. For the high-arousal pictures at this Probe Time, blinks during threat and positive contents reached their peak more quickly than blinks during neutral contents, quadratic F (1, 34) = 7.48, $p = .01$.

At the late Probe Time (lower panel of Figure 35), low-arousal Emotional Category blink latencies were once again not significantly different between categories, *F*s (1, 34) < 1.38, *p*s $> .248$. As at the early Probe Time, high-arousal threat and positive content blinks reached their peaks more quickly than neutral content blinks, although this effect only approached significance here, quadratic F (1, 34) = 3.5, $p = .07$.

SCR Magnitude

For the analysis of SCR magnitude, all five factors were again included in the final model. Significant main effects were present for Emotional Category, F (3, 93) = 37.18, $p < .001$, $\varepsilon = .93$, and Arousal, F (1, 31) = 5.5, $p = .026$. The main effect for Probe Time approached significance, F (1, 31) = 3.18, $p = .084$. Emotional Category interacted significantly with every other variable, and there were also a large number of three-way interactions. These are not detailed as all were subsumed under a four-way interaction between Emotional Category, Probe

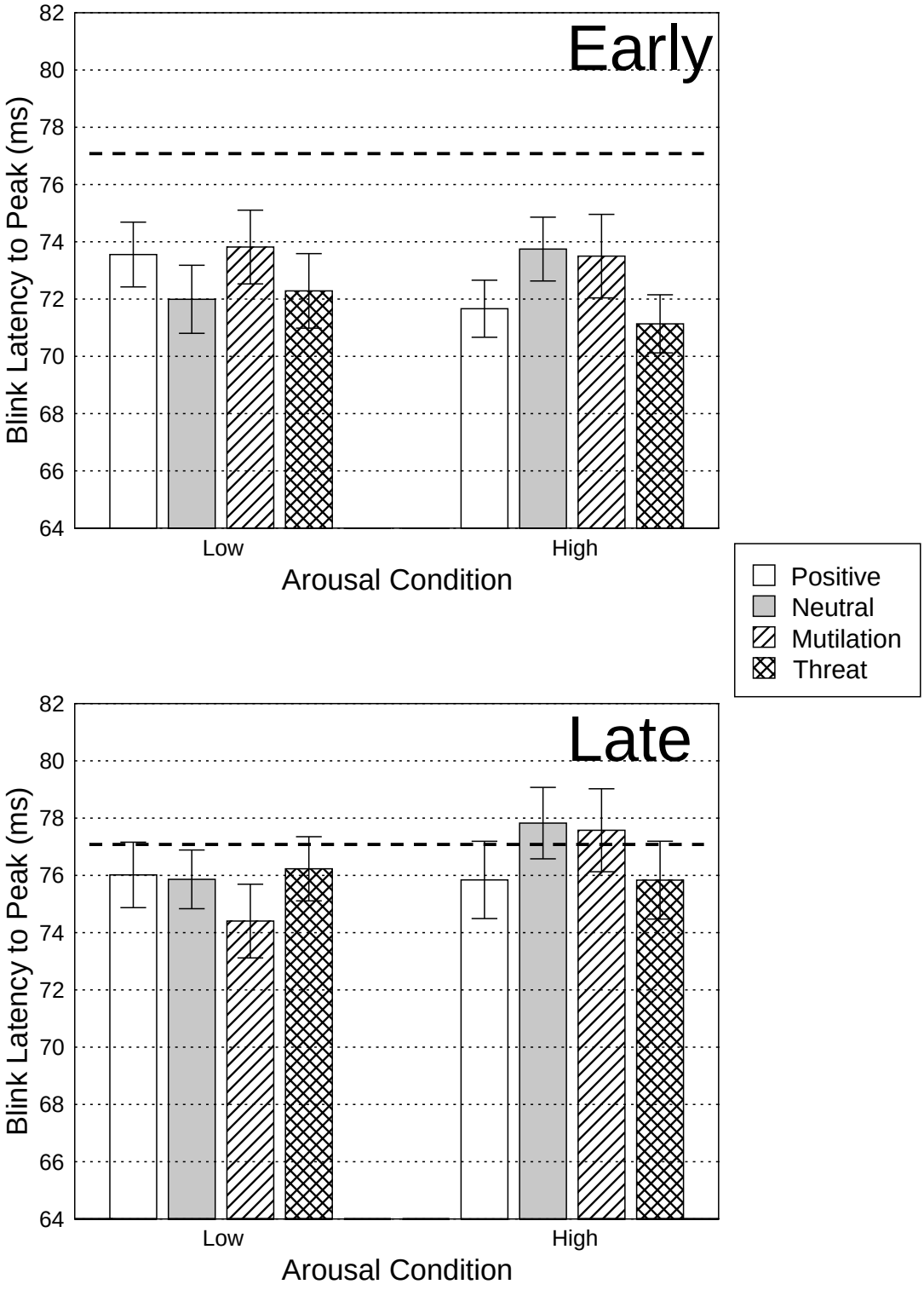


Figure 35. Mean blink latency to peak by Emotional Category, for high and low arousal contents at the early and late Probe Times. Data are presented in the upper panel for the early probe time, and in the lower panel for the late probe time. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

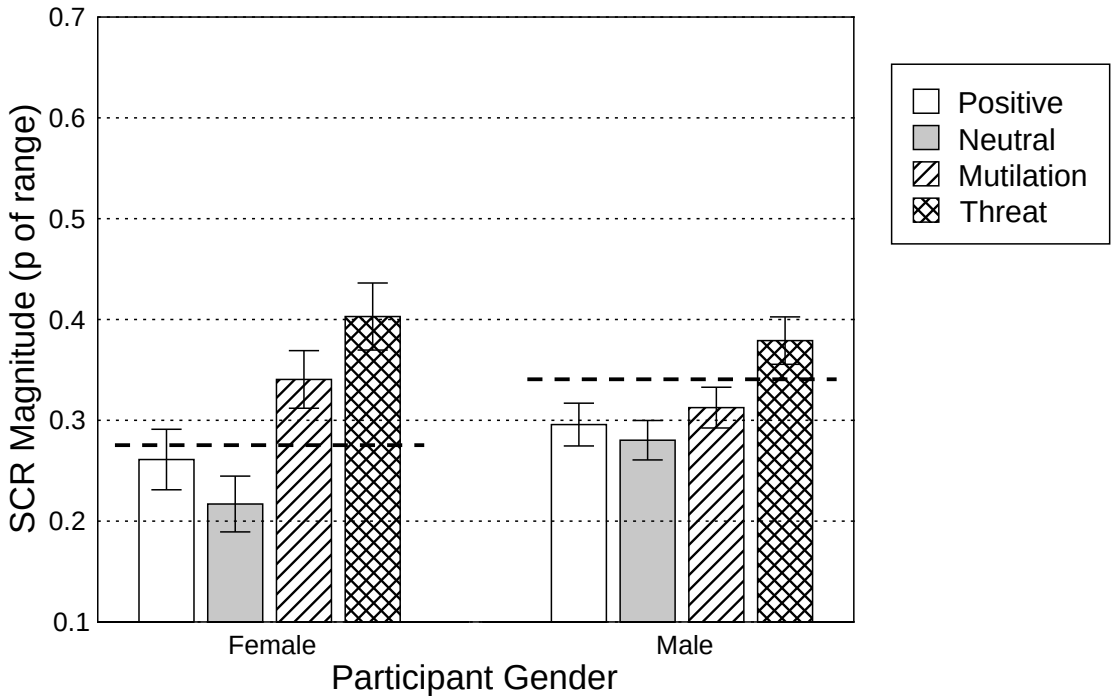


Figure 36. Mean SCR magnitude for female and male participants by Emotional Category, averaged over Probe Time and Arousal. Error bars indicate one standard error. Dotted line represents mean ITI level.

Time, Arousal, and Picture Combination, F (9, 93) = 2.43, $p = .016$, $\varepsilon = .72$.

The only interaction not covered by this four-way interaction was between Gender and Emotional Category, F (3, 93) = 6.14, $p = .001$, $\varepsilon = .93$. This interaction is presented in Figure 36. On average across Probe Times and Arousal levels, female participants showed greater SCR magnitude during affective contents than for neutral contents, quadratic Fs (1, 31) = 31.97 and 18.8, both ps $< .001$, for threat and mutilation respectively. SCR magnitude was also greater during negative than positive contents, linear Fs (1, 31) = 30.02 and 12.95, both ps $< .002$, for threat and mutilation contrasts respectively. For male participants, SCR magnitude was enhanced for threat contents only, linear F (1, 31) = 18.37, $p < .001$. As can be seen in Figure 36, positive content SCRs did not differ from neutral. Contrasts for mutilation contents were not significant for male participants, Fs (1, 31) = .25 and 1.92, ps = .618 and .176, for linear and quadratic respectively.

The planned comparisons for SCR magnitude are reported below with the understanding that the four-way interaction limits these findings to certain Picture Combinations. The data for the

early Probe Time are presented in the top panel of Figure 37; data for the late Probe Time are in the bottom panel of the same figure.

For the low-arousal pictures at the early Probe Time, both threat and mutilation content SCR magnitudes were potentiated relative to positive, *F*s (1, 31) = 14.52 and 37.89, both *p*s $< .001$. SCR magnitudes during positive contents were not significantly different from neutral, as can be seen in the top panel of Figure 37; mutilation quadratic *F* (1, 31) = 7.27, *p* = .011. High-arousal picture SCR magnitudes at the early Probe Time were potentiated for affective compared to neutral contents, quadratic *F*s (1, 31) = 15.02 and 6.29, both *p*s $< .018$, *F* values for threat and mutilation contrasts respectively. There were no differences in SCR magnitude between either negative category and the positive category, linear *F*s (1, 31) = 1.36 and 1.47, *p*s = .253 and .235, for threat and mutilation respectively.

For low-arousal pictures at the late Probe Time, both threat and mutilation content SCRs were of greater magnitude than positive content SCRs, linear *F*s (1, 31) = 28.36 and 4.45, both *p*s $< .044$. The quadratic trend for threat was also significant, and as can be seen in the bottom panel of Figure 37, SCRs for positive pictures were not significantly different from neutral, *F* (1, 31) = 9.97, *p* = .004. High-arousal picture SCRs were greater for threat than positive contents here, linear *F* (1, 31) = 15.58, $p < .001$. A significant quadratic trend for threat contents showed that positive SCR magnitudes were not lower than neutral SCRs, *F* (1, 31) = 15.34, $p < .001$. Neither contrast for high-arousal mutilation contents was significant, *F*s (1, 31) < 1.84, *p*s $> .185$.

The interaction between Emotional Category, Probe Time, Arousal, and Picture Combination was tested by decomposing the ANOVA into smaller analyses. Starting from the full model, responses were analysed in separate ANOVAs for the early and late Probe Times, as the late Probe Time SCR data were probably not accurate. Group sizes for Picture Combination were approximately equal (9 participants in the first group, 10 participants in the other three groups).

At the early Probe Time, the interaction between Emotional Category, Arousal, and Picture

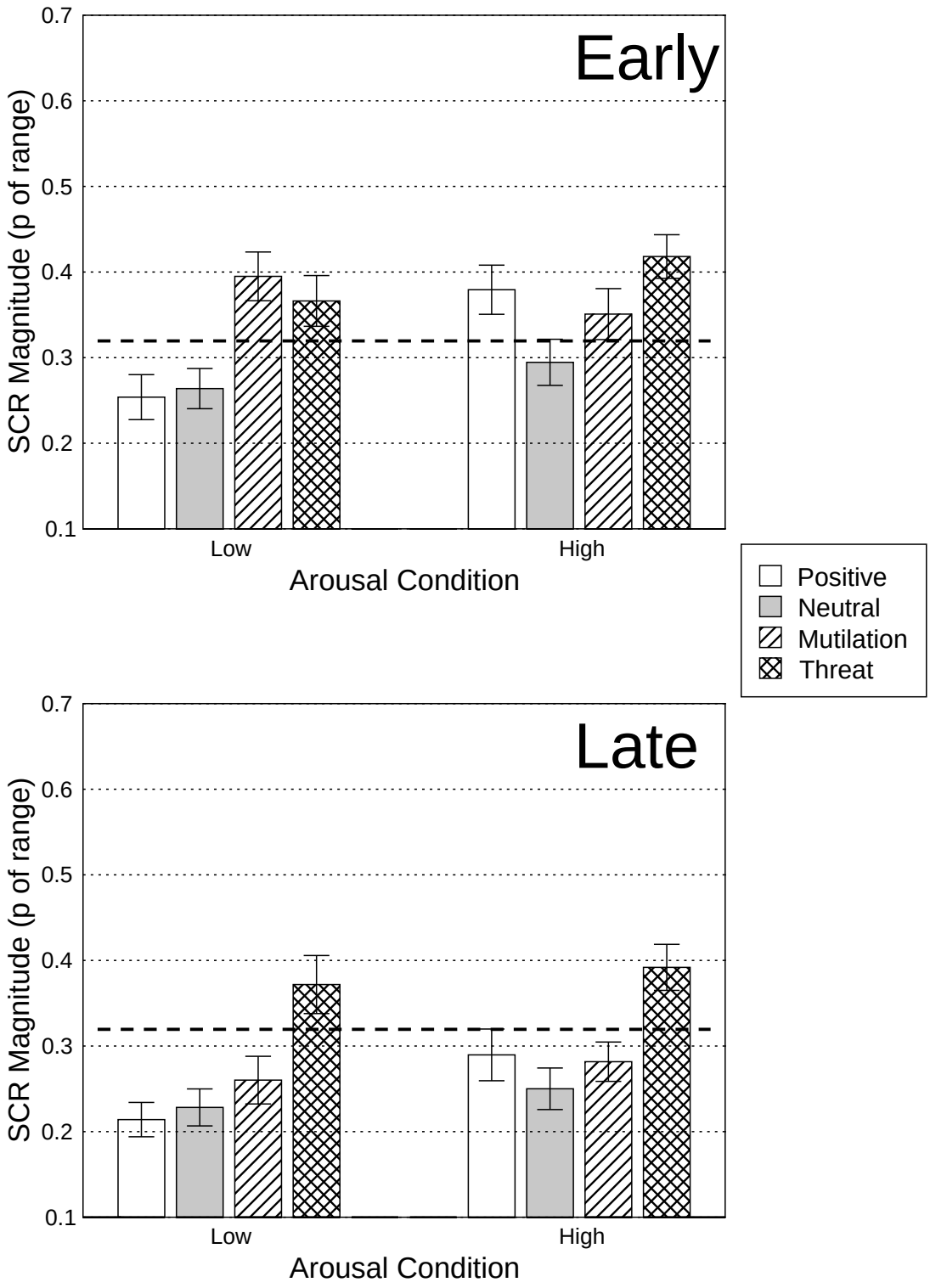


Figure 37. Mean SCR magnitudes by Emotional Category, for high and low arousal contents at the early and late Probe Times. Data are presented in the upper panel for the early probe time, and in the lower panel for the late probe time. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

Combination was significant, F (9, 93) = 2.31, $p = .028$, ε = .88. Separate ANOVAs were performed on SCR magnitude for the two Arousal conditions, with Emotional Category and Picture Combination as factors. For the high-arousal contents, there was no interaction between Emotional Category and Picture Combination, F (3, 93) = 1.66, $p = .127$, ε = .82. These data have also been described in the planned contrast analysis.

For the low-arousal condition, the interaction between Emotional Category and Picture Combination approached significance, F (9, 93) = 1.91, $p = .074$, ε = .83. The low-arousal SCR magnitude data were then analysed separately for each Picture Combination, the results of which are summarised without reporting of the statistical values. Planned contrasts (linear and quadratic) were tested between the levels of Emotional Category at a probability level of .05, and can be summarised as follows: Picture Combinations 2 and 4 had enhanced SCRs for both threat and mutilation low-arousal contents relative to positive; Combinations 2 and 3 had enhanced SCRs for mutilation contents only; and Combination 2 was the only group showing any SCR enhancement for low-arousal positive contents relative to neutral.

At the late Probe Time, there was a significant interaction between Emotional Category, Arousal, and Picture Combination, F (9, 93) = 2.76, $p = .009$, ε = .9. Separate ANOVAs were then performed on the high- and low-arousal picture responses. For the high-arousal responses, there was no significant interaction between Emotional Category and Picture Combination, F (9, 93) = 1.2, $p = .308$, ε = .9. The differences between Emotional Categories at this Probe Time have already been described in the planned contrast analysis. For the low-arousal contents, there was a significant interaction between Emotional Category and Picture Combination, F (9, 93) = 3.62, $p = .001$, ε = .87. The low-arousal SCR magnitude data were then analysed separately for each Picture Combination, the results of which are summarised without reporting of the statistical values. Planned contrasts (linear and quadratic) were tested between the levels of Emotional Category at a probability level of .05, and can be summarised as follows: Threat content SCRs were enhanced relative to neutral and positive content SCRs for Picture Combinations 1, 2, and 3, and SCR enhancement was not observed for mutilation or positive contents in any of these groups; there were no significant contrasts in the fourth Picture

Combination.

To sum up these results: SCR modification for high-arousal contents was consistent between Picture Combinations at the early and late Probe Times. Early SCR enhancement was consistently observed in all Picture Combinations for low-arousal mutilation contents, but not for low-arousal threat contents. Low-arousal content SCR enhancement at the late Probe Time was limited to threat contents, and one Picture Combination showed no differences between Emotional Categories here.

SCR Magnitude by Questionnaire Score.

Questionnaire data were missing for one participant included in the general SCR analysis, and so the total *n* for these analyses was 38. For the analysis of SCR magnitude by MQ score, the number of participants in the low- ($n = 24$) and high-score ($n = 14$) groups was uneven. The ANOVA also indicated an interaction between Emotional Category and MQ score-group, F (3, 108) = 3.03, $p = .035$, ε = .95. Further ANOVAs were performed separately for the low and high MQ score groups, with Emotional Category, Probe Time, and Arousal as factors.

For the below-median MQ group, there were significant main effects for both Emotional Category, F (3, 69) = 11.99, $p < .001$, ε = .89, and for Arousal, F (1, 23) = 9.13, p = .006. These factors also produced a significant interaction, F (3, 69) = 6.09, $p = .002$, ε = .81. The interaction between Emotional Category and Arousal for these low MQ-score participants is shown in Figure 38. Averaged over both Probe Times, low-arousal content SCRs increased across positive, neutral, and negative for both threat and mutilation contents, respective Fs (1, 23) = 22.17 and 12.88, both ps $< .002$. Positive content SCRs were not larger than neutral SCRs, quadratic Fs (1, 23) = .99 and .27, ps = .33 and .606, for threat and mutilation contrasts respectively. For high-arousal contents, SCR magnitude was greater for threat and positive contents than for neutral, quadratic F (1, 23) = 15.09, $p < .001$. As can be seen in Figure 38, mutilation content SCRs were not significantly different from neutral, and were of smaller magnitude than positive content SCRs, linear F (1, 23) = 5.59, p = .027.

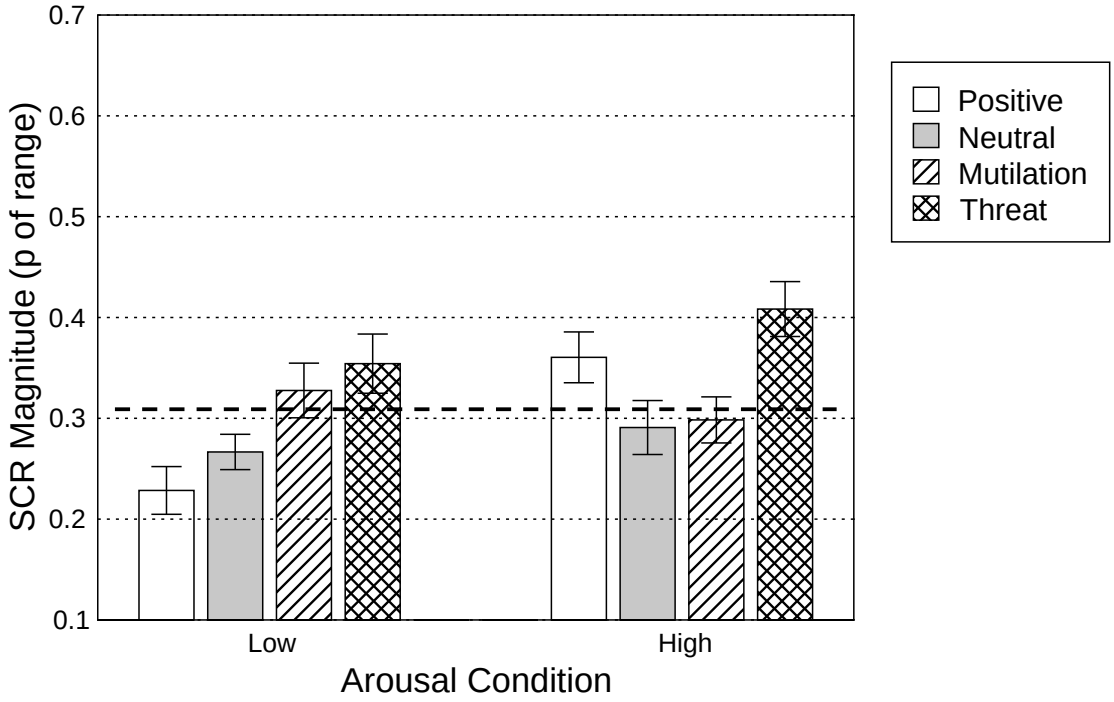


Figure 38. Mean standardised SCR magnitude by Emotional Category, for low and high arousal contents, for below-median MQ score participants, on average over Probe Time. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

For the above-median MQ score participants, there was a significant main effect for Emotional Category, F (3, 39) = 22.01, $p < .001$, ε = .94. No higher order interaction was significant, highest F (3, 39) = 1.45, $p = .251$, ε = .77, for interaction of Probe Time and Emotional Category. In this high-MQ group, affective content SCRs were of greater magnitude than neutral (M = .234) contents, quadratic Fs (1, 13) = 27.6 and 18.82, both ps $< .001$ for threat and mutilation contrasts respectively. Threat (M = .405) and mutilation (M = .347) content SCRs were also significantly larger than positive content SCRs (M = .277), linear Fs (1, 13) = 32.95 and 7.7, both ps $< .016$.

Both the analysis of SCR magnitude by STAI-S score and STAI-T score (19 participants in both the high- and low-score groups in each analysis) did not show any significant interactions involving questionnaire score and Emotional Category, maximum Fs (3, 108) = 2.09 and .96, ps = .126 and .409, ε = .73 and .92, in the STAI-S and STAI-T analyses respectively.

SCR Latency to Peak

Gender was removed from the model for SCR latency to peak because it did not reach significance as a main effect or as an interaction; the closest effect was the interaction between Gender, Emotional Category, Probe Time, and Picture Combination, F (9, 93) = 1.64, $p = .127$, $\varepsilon = .87$.

In the new model, there was a significant main effect for Probe Time, F (1, 35) = 28.33, $p < .001$, and an interaction between Probe Time and Picture Combination, F (1, 35) = 4.76, $p = .007$. SCRs generally reached their peak more quickly for late startle probe presentations than for early presentations; this difference was only significant for the fourth Picture Combination, $p < .001$. There was also a significant main effect for Emotional Category and an interaction between Emotional Category and Probe Time, Fs (3, 105) = 5.67 and 3.17, ps = .002 and .032, $\varepsilon = .87$ and .91. This interaction is covered under the planned comparisons below. Figure 39 presents SCR latency to peak data broken down by Emotional Category, Arousal, and Probe Time.

At the early Probe Time (data in the upper panel of Figure 39), low-arousal threat and mutilation content SCRs reached their peak more slowly than neutral and positive contents; linear Fs (1, 35) = 6.06 and 4.33, ps = .019 and .045; quadratic Fs (1, 35) = 11.26 and 7.91, ps = .002 and .008; for threat and mutilation, respectively. For high-arousal content early probes, SCR latencies to peak were faster for neutral than affective contents, quadratic Fs (1, 35) > 9.47, ps $< .005$ for threat and mutilation contrasts.

For late Probe Time SCR latencies to peak (lower panel of Figure 39), no contrasts were significant for low-arousal pictures, Fs (1, 35) $< .83$, ps $> .369$. For high-arousal pictures, mutilation and positive content SCRs reached their peak more quickly than neutral, quadratic F (1, 35) = 4.8, $p = .035$. No other contrasts were significant, Fs (1, 35) < 2.64, ps $> .113$.

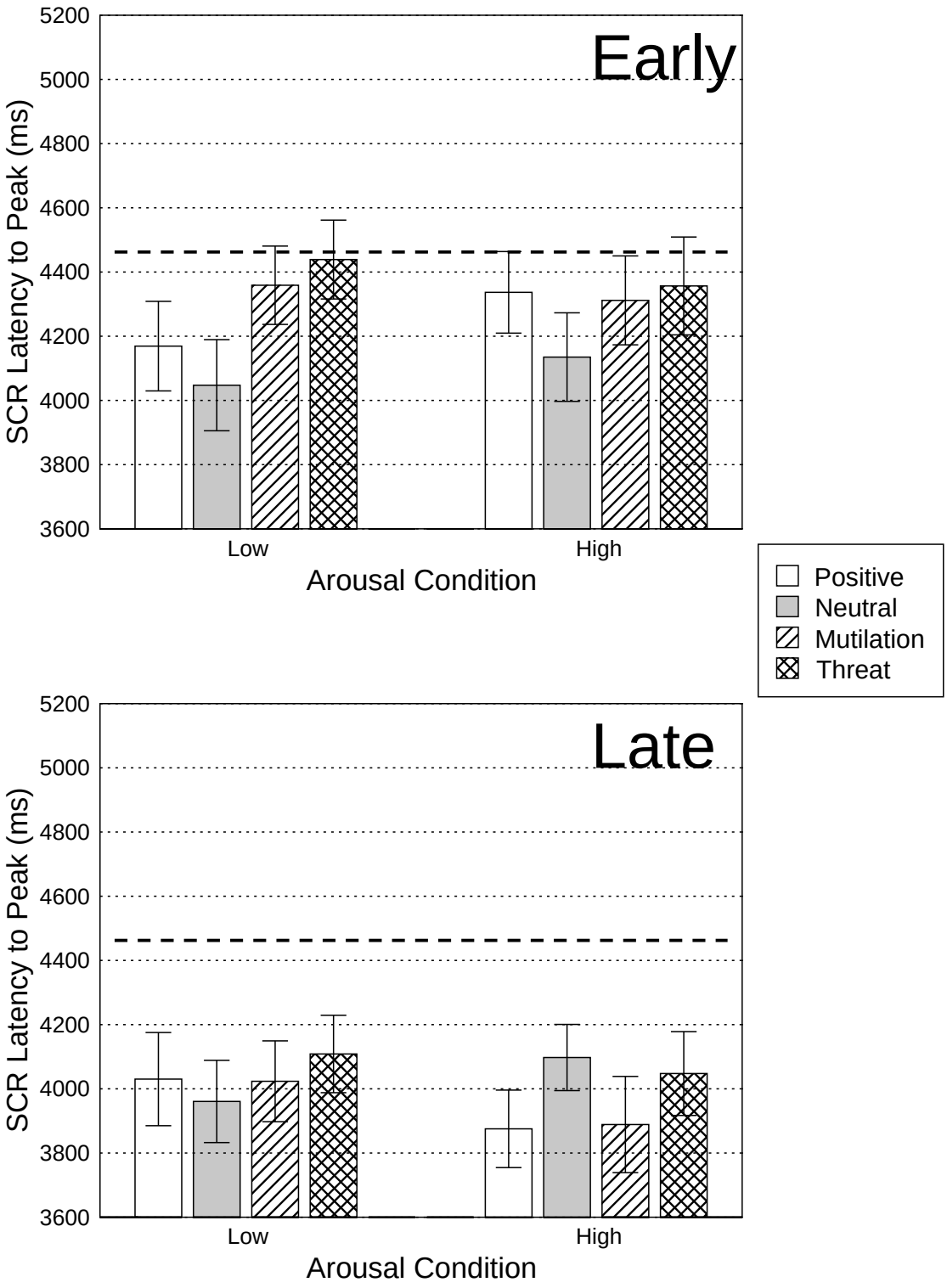


Figure 39. Mean SCR latency to peak by Emotional Category, for high and low arousal contents at the early and late Probe Times. Data are presented in the upper panel for the early probe time, and in the lower panel for the late probe time. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

Discussion

Blink Magnitude

The blink magnitude results for this study showed early potentiation for high-arousal threat and mutilation contents, as well as for low-arousal threat contents. The same effects were apparent for the late Probe Time. The low-arousal mutilation contents did not potentiate startle at either Probe Time.

These results suggest that the observed effects in Study 3b were due either to an inappropriate picture set or a sampling error, but there is still no explanation for the anomalous early startle modification observed in that study.

Startle modification was consistent between early and late stages of picture viewing, and a specific sub-category of negative pictures, the low-arousal mutilation contents, showed no startle modification at either Probe Time. The late Probe Time blink magnitude result for low-arousal mutilation contents is consistent with Cuthbert et al. (1996), this category corresponding to their medium arousal negative category. This study shows that the effects of varying the arousal dimension depend on the specific emotional content of negative pictures. Firstly, the effects of varying arousal on blink magnitude was apparent only for mutilation content pictures. High-arousal, but not low-arousal, mutilation contents potentiated startle, and these effects were consistent at the two Probe Times. This effect suggests that the arousal manipulation in Cuthbert et al. (1996) was confounded with specific emotional categories, as hypothesised in the introduction. Low-arousal positive content blinks were not inhibited at the early Probe Time.

Secondly, blink magnitude results were consistent between the early and late Probe Time, which suggests that low-arousal, non-threat negative picture contents may be responsible for the lack of early startle potentiation generally reported in the literature, as summarised in the introductions to this study and Study 3. More specific testing of this assumption requires the use of negative emotional categories other than threat/fear and mutilation/disgust.

What is problematic about this conclusion is that most previous studies on the time course of startle modification (e.g., Bradley, Cuthbert, & Lang, 1993) showed inconsistent results for negative content blinks between early and late stages of picture viewing — inhibition at 300 ms, potentiation during later stages. This suggests that some pictures will potentiate startle at a late stage of picture viewing, but not at an early stage. As picture assignment to probe time conditions is usually randomised, it would be unlikely that previous studies had uneven distributions of specific content type or arousal groups in their different probe time conditions, which might have explained these results. This leaves the hypothesis that there are some negative picture contents, as yet not identified, for which startle will be potentiated at a late stage of picture viewing but not an early stage. This seems unpalatable. These concerns will be covered in the General Discussion.

Blink Magnitude and Fear/Anxiety

The analysis of blink magnitude by questionnaire score did not show any effects of fear group (i.e., by MQ score) or anxiety group (i.e., by STAI-S or STAI-T) on valence modification of startle. There was some evidence that low-anxiety participants (as defined by either of the STAI measures) showed a greater difference in the magnitude of blink responses for high compared to low arousal stimuli (averaged over Emotional Category) than high-anxiety participants.

Cook (1999) reported that participants who scored relatively low on measures of fear (as opposed to anxiety, measured in the present study) showed blink inhibition for affective contents (i.e., both positive and negative arousing pictures) relative to neutral: Startle modification is driven by arousal, rather than valence, for these participants (Cook, Goates, Hawk, & Palmatier, 1996, cited in Cook, 1999, p. 195-198).

The results of the current study suggest that emotional modification of startle is the same for high- and low-anxiety participants, but that low-anxiety individuals are more responsive to the intensity dimension of the stimuli. This could indicate that higher anxiety participants respond in the same way to a wider range of stimuli, with similar response magnitudes to high and low

arousal stimuli. It is impossible to attribute this effect to either heightened responsitivity for low-arousal stimuli, or diminished responsitivity for high-arousal stimuli. Similarly, for low-anxiety individuals, changes in response levels between arousal conditions cannot be attributed to differential sensitivity at one, but not the other, level of intensity.

Testing participants specifically preselected for low or high anxiety levels would be a more powerful design for testing these differences, and also for testing whether differences between these anxiety groups in responding to high and low arousal stimuli is generalised across all pictures (as suggested by the current results) or is specific to certain emotional contents (e.g., to negative but not positive contents).

Skin Conductance

The SCR magnitude results were limited to specific Picture Combinations. Considering just the early Probe Time data, both negative content categories were associated with enhanced SCR magnitudes, regardless of arousal condition. Positive contents only produced potentiated SCR magnitude for high-arousal contents. An interaction indicated that SCR potentiation for mutilation contents only occurred for female participants.

At the late Probe Time, threat content SCR magnitudes were enhanced for both low- and high-arousal pictures. Mutilation content SCRs were of greater magnitude than neutral for low-arousal pictures only. The SCR magnitude analysis by MQ score group revealed some further points that relate to the issues previously raised (mainly in the discussion to Study 2) about problems in calculation SCR modification at the late Probe Time.

An interaction between Emotional Category, Probe Time, Arousal, and Picture Combination suggested that these effects were not consistently observed over all of the Picture Combination groups. Decomposing the ANOVA found that SCR enhancement was consistent between these groups for high-arousal contents, but not for low-arousal contents. For early Probe Time low-arousal content data, only mutilation content SCRs were consistently enhanced relative to

neutral SCRs over all Picture Combinations. At the late Probe Time, low-arousal content SCR enhancement was observed for threat contents in three of the four Picture Combination groups.

The below-median MQ score group showed greater SCR magnitude for mutilation contents relative to neutral, but only for low-arousal contents (averaged over Probe Time). It is unreasonable to assume that individuals with low levels of mutilation fear will be less responsive on skin conductance with increases in the intensity of mutilation stimuli, as SCRs should increase with subjective arousal (Cuthbert et al., 1996).

Combining this with the fact that, across the entire sample, late probe SCRs during mutilation contents were only enhanced relative to neutral for low-arousal pictures, there is more evidence here to suggest that SCRs to the picture content are interfering with the recording/calculation of SCR magnitude for the late startle probe.

Mutilation picture contents usually produce greater magnitude SCRs than human (but not animal) attack pictures (Bradley, Codispoti, Cuthbert, & Lang, 2001). Presuming that responses to high-arousal mutilation picture contents (in the absence of startle probe presentation) should be greater than for any other content/arousal condition, the lack of late probe SCR differences between these contents and neutral provides the strongest logical basis yet for the hypothesis that SCRs to picture content alone are influencing calculations of late Probe Time startle SCR magnitudes, at least in this laboratory.

The SCR latency to peak data support this hypothesis in that late Probe Time, high-arousal mutilation content SCRs reached their peak more quickly than neutral SCRs, while early Probe Time mutilation and threat content SCRs were slower to reach their peaks. These results are consistent with the idea (raised in the discussion to Study 3a) that shortened latency to peak for late Probe Time SCRs indicates the presence of a previous SCR to picture onset.

Blink Latency to Peak

There was some consistency in the observed blink latencies to peak in this study. Low-arousal content latencies to peak were no different in comparisons between Emotional Category at either Probe Time. High-arousal threat and positive content blinks reached peak more quickly than neutral blinks at the early Probe Time, although this approached significance at the late stage of picture viewing. The difference observed here between low and high arousal blink latency patterns may explain the lack of consistent differences in previous studies of this thesis, where picture category contents were mixed in arousal qualities. It is interesting to note that latencies to peak for mutilation content blinks were never significantly different from neutral, indicating either a lack of facilitation of blink speed or greater variability in blink responding for these contents.

Combining Blink Response and SCR Results

When considering early Probe Time data only, low-arousal mutilation content SCRs were enhanced relative to neutral, while blink magnitude was never potentiated for these pictures. This seems to indicate a different pattern of response outputs following processing of these pictures compared to the other negative contents in this study (threat contents, and high-arousal mutilation contents), so that skin conductance is modulated but startle responding is not. Hamm et al. (1997) observed the same result for low mutilation-fear participants: SCRs were enhanced, but blink magnitude was at the same level as neutral. High mutilation-fear participants showed both SCR and blink potentiation for these picture contents. These participants tended to rate the mutilation contents as primarily 'fearful' more frequently than the low mutilation fear participants (true for 19% of high-fear participants, compared to 6.3% of low-fear participants), although most high mutilation-fear participants rated these pictures as primarily 'disgusting' (70% of these participants; Hamm et al., 1997). It is possible that only fear-evoking mutilation content pictures potentiate startle, and that the highly-arousing condition mutilation pictures in the present study contained a higher proportion of such pictures than the low-arousal condition.

Summary

The experiment showed consistent patterns of startle responding between early and late Probe Times. This occurred with the use of a pre-picture fixation point (compare Study 3b). The results suggested that arousal effects on startle potentiation differ by specific emotional content. The low-arousal mutilation content pictures failed to potentiate startle at either Probe Time, while a matched low-arousal threat content condition potentiated startle at both Probe Times. Fear-evoking characteristics of mutilation stimuli were proposed as a possible mediating factor for these differences.

This is the third study in this thesis showing startle potentiation for one or more negative picture categories at a 300 ms Probe Time. The next study introduces a picture complexity manipulation, as well as measuring startle responding to an even earlier probe time (150 ms).

Study 5

Several of the preceding studies in this thesis have provided supporting evidence for emotional modification of startle within 300 ms of picture onset. The following study used a shorter picture to probe onset latency (150 ms) to test whether startle modification is apparent at an even earlier stage of processing. Previous studies looking at probe times earlier than 300 ms have encountered some methodological problems (detailed below) that are avoided in the present design. The design also included a stimulus-complexity manipulation to test how this factor affects processing of emotional stimuli. The pictures presented were either full-colour photographs or black and white silhouettes of a target object (e.g., spider, fork, flower).

Experimental Precedents

Startle Modification at Probe Times Earlier than 300 Milliseconds

Two published studies have elicited the startle probe earlier than 300 ms after picture onset. Globisch et al. (1999) used a 120 ms probe time condition but did not find any effects of emotional content on responding: Picture presentation generally elicited a blink reflex, and acoustic probe presentation at 120 ms produced a second reflex that was superimposed on the initial reflex to picture onset. These very early blinks were potentiated relative to ITI blinks, suggesting that the blink magnitude calculated at the 120 ms probe time was thus a summated response to two separate stimuli (Globisch et al., 1999).

This is perhaps indicative of methodological differences between studies using traditional slide presentation procedures (e.g., Globisch et al., 1999) and those that use computer monitors to present picture stimuli (e.g., the studies in this thesis). In the studies reported in this thesis, blink reflexes to picture onset were very rare (based on casual observation by the author during

data collection; a systematic investigation of this issue regarding data from the current study is presented in the discussion). The underlying reason for this probably lies in the change in overall contrast between ITI intervals and picture presentations. It may be the case that these changes in contrast are more extreme for traditional slide presentations (for example, a slide projected onto a white wall, as in Globisch et al., 1999) than for computer presentation (in this thesis, the ITI display was a black screen), and this would explain differences in blink responding to picture onset. Slide projectors are usually acoustically isolated from the participant; this makes it unlikely that blinks to picture onset are caused by noise from the projector.

Blink reflexes due to picture onset present a major problem for testing early startle reflex modification, and this issue is taken up at some length in the discussion for this study.

A second study including a 120 ms probe time (Vanman et al., 1998) found differential startle blink responding for negative and positive stimuli at this very early probe time, although only for participants scoring highly on the BDI measure of depression. This experiment has already been criticised in Chapter 3 for two reasons: (a) no neutral picture condition was included, and so it is unclear whether differences between positive and negative stimulus blinks are due to inhibition, potentiation, or both, and (b) participants previewed the pictures prior to the startle elicitation section of the experiment, to allow an attentional manipulation.

Given these objections, the results of this experiment are not conclusive with regards to whether this very early startle modification in these high BDI-score participants is caused by negative or positive pictures, or the extent to which this effect is mediated by picture previewing. It does suggest that some kind of emotional startle reflex modification can occur by 120 ms after picture onset.

Startle Modification During Simplified Picture Contents

Although not investigating the time course of startle modification, Bradley, Codispoti, Cuthbert, and Lang (2001, described in some detail in the introduction to Study 3) included one

experimental manipulation that is relevant to the current study. Half of their participants viewed full-colour, standard IAPS images, while the other half viewed grayscale versions of the same images (i.e., black and white). The colour versus black and white distinction did not influence any of the emotional response systems they measured (self-report, startle blink magnitude, other physiological systems).

Experimental Design and Picture Selection

Study 5 leaves behind the issue of emotional specificity in startle potentiation to look at how the complexity of a visual stimulus influences emotional startle modification. The experiment itself used a sample of moderate to high spider-fear participants, and compared startle reflex modification between complex, full-colour photographs and simple, monotone silhouettes.

The negative category was comprised of spiders because (a) these stimuli are easily recognisable in silhouette form (compare a gun being pointed at the screen); and (b) as a negative stimulus, there is a significant proportion of the population who find spider stimuli aversive (compare snakes). The study was limited to female participants with some fear of spiders.

The primary differences between the full colour photographs and the silhouettes are the removal of the background from the target object, the absence of any colour information, and the removal of fine detail on the target foreground (e.g., markings, shading).

The experiment retains the early and late startle probe methodology used in other studies in this thesis, except the earliest startle probe was presented at 150 ms rather than 300 ms, and is referred to as the ‘very early’ Probe Time in the following sections. Logically, if early startle modification is mediated by both emotional content and attentional capacity, then startle modification by emotional content may be apparent at this very early stage of picture viewing for simple images but not for complex images. It is also possible that emotional modification of startle will not be apparent by 150 ms, regardless of picture complexity. The differential startle observed by Vanman et al. (1998) suggests that startle modification may be observed by this

probe time, and the inclusion of the complexity manipulation may increase the likelihood of observing such effects.

The late probe time period was retained in this experiment to check on startle modification after several seconds of picture viewing. Two characteristics of the stimuli emphasise the importance of this. Firstly, silhouettes have not previously been used in startle modification experiments, and it is possible that these 'simplified' stimuli may not be realistic enough to engender startle modification. Presentation of a picture of a spider is not analogous to presenting an actual spider, and it would be expected that fear responses to the former would be less intense. A spider silhouette is even further removed from a real spider, and it is reasonable to assume that fear responses to such a stimulus might be less intense than those to more realistic images.

This consideration of stimulus 'naturalism' is concerned more with responding when the picture has been viewed for several seconds. At very early stages of picture viewing we might anticipate more equivocal levels of responding to silhouette and photographic stimuli. The experiment asks the following questions:

1. Do silhouettes of spiders elicit the same degree of defensive preparedness (indexed by the startle reflex) as full-colour photographs?

2. Does the removal of extraneous visual information (background, colour, and fine detail) allow faster activation of startle modification circuits?

Method

Participants

The participants were 45 female psychology students at the University of Otago, with a median age of 19 years (*M* = 19.69 years). Participants were assigned to the experiment if they scored a 3 or higher on the 'spider' fear item of the FSS-II-R (see Appendix C), which was administered at the outset of the experiment. Those who scored below 3 on this item were assigned to a different experiment (not reported in this thesis).

Data for each participant were included in the analyses if they had a score of 5 or higher (out of 31) on the SPQ measure of spider fear (Appendix B), this being the median SPQ score for the 64 females who completed the SPQ questionnaire in Study 1. This left a pool of data from 42 participants who met these criteria.

Picture Stimuli

Each picture belonged to one of three emotional categories: Positive (food and flower stimuli), neutral (household objects, mushrooms), and spider stimuli. Each of these three categories was divided into 2 subcategories, simple and complex pictures. There were six pictures in each subcategory.

Simple pictures were white silhouettes of the target object (e.g., an apple, a hammer, a spider) on a black background. These are presented in miniature in Appendix H. The appendix notes the silhouettes that were created for this study from photographs taken by the author, and the IAPS numbers of the photographs from which the remaining silhouettes were adapted. Figure 40 presents an example from each of the Emotional Categories used in this study.

The complex pictures were generally IAPS pictures with similar contents to the silhouette images, and these are listed and described in Table H1 of Appendix H. Some new photographs

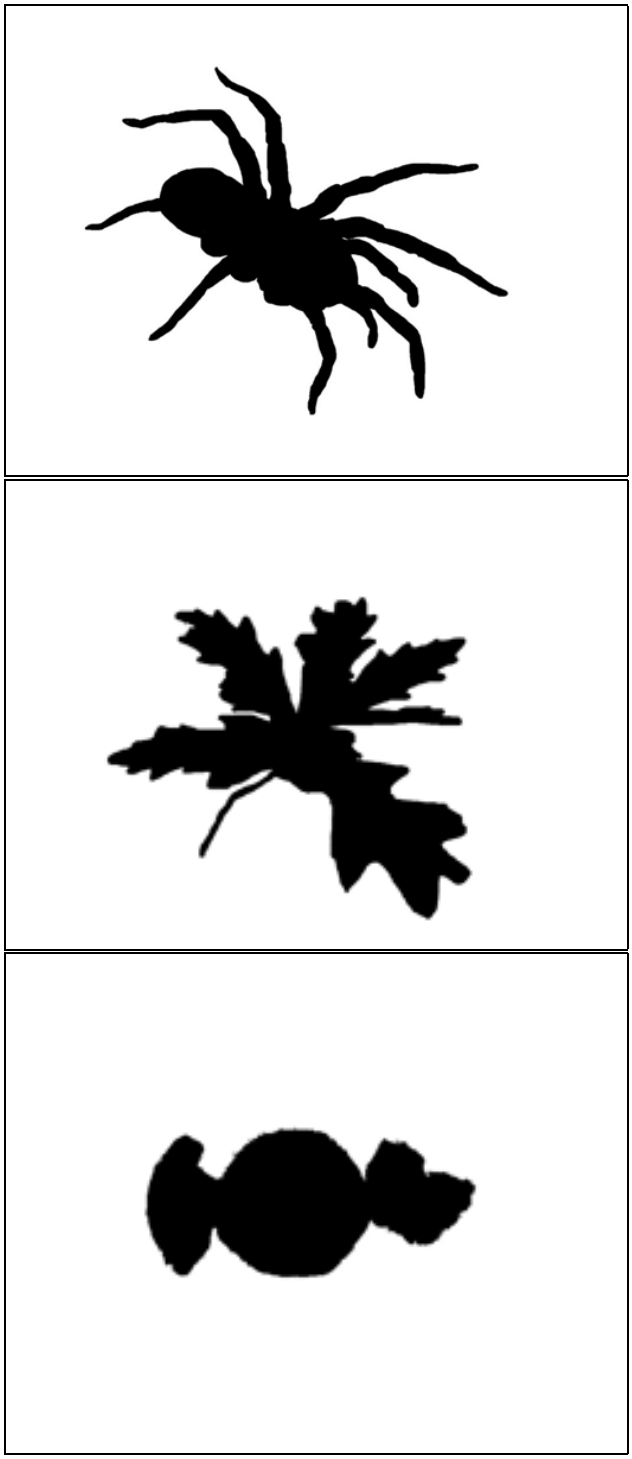


Figure 40. Spider (top panel), neutral (middle panel), and positive (bottom panel) condition silhouettes used in Study 5.

in the complex/positive condition were taken by the author to allow closer matching of materials to the simple condition silhouettes. Other pictures were foreground objects (e.g., a banana) superimposed on an IAPS background (e.g., a checkerboard pattern). Details are listed in Appendix H, where filler pictures are also listed in Table H2.

Experimental Design

Startle probes were presented at the 150 ms very early Probe Time for half of the pictures in each Probe Time/Complexity condition, with the remainder being probed between 2 and 5 seconds after picture onset. An additional twelve full-colour IAPS photographs (4 each of positive, neutral, and negative content) were included as filler stimuli on which startle probes were never presented. These pictures are also listed in Appendix H.

Pictures were divided into three blocks, with equal numbers of positive, neutral, spider, and filler content pictures in each block. The number of simple/complex and early/late Probe Time instances were also equal between blocks, so that each block contained one picture from each Emotional Category/Probe Time/Complexity condition. A single ITI startle probe was presented in each block.

There were two possible Picture Combinations, with early and late probes assigned to different pictures in each combination. For both picture combinations, there were three possible block presentation orders.

Exclusion Criteria, Analysis, and Standardisation

Exclusion criteria were different for this study than for previous studies. The following change was made so as to better identify participants with missing data for cells in the design. Data from participants meeting the SPQ inclusion criterion were included in the blink and SCR analyses only if each condition (Emotional Category by Probe Time by Complexity) contained at least two adequate responses, from the three possible responses in each condition. Adequate

responses were defined as in previous studies, being not less than 10 μV in magnitude for blink responses, and greater than zero magnitude for SCRs.

The new exclusion criteria discriminates between participants who show small responses across the experiment as a whole (who may have been excluded under the old criteria), and those who are missing data in specific conditions.

For the analysis of blink and skin conductance responses, Picture Combination was the sole between-subjects factor. Emotional Category, Probe Time, and Complexity were all within-subjects factors. Planned comparisons between the levels of Emotional Category were performed in each Probe Time/Complexity condition.

For the analyses of blink and SCR magnitude by questionnaire score, median splits on the FSS and SPQ measures were used as between-subjects factors.

Results

Summary of Physiological Variables and Number of Valid Participants

Table 19 presents means and standard errors for all variables recorded in this study, for the positive, neutral, and spider picture conditions. Data for each emotional category are averaged across Probe Times and Complexity conditions.

Table 19: Physiological Dependent Variable Means and Standard Errors, by Emotional Category of Picture, Averaged Across Probe Time and Complexity.

Physiological measure	Positive	Neutral	Spiders
Blink magnitude *n* = 37			
Raw (μV)	91.44	93.51	97.54
(S.E.)	7.92	7.92	8.39
Standardised (T-score)	49.36	50.08	51.08
(S.E.)	(.37)	(.43)	(.42)
Blink latency to peak (ms)	69.80	71.32	70.95
(S.E.)	(1.15)	(1.28)	(1.18)
SCR magnitude *n* = 18			
Raw (μS)	2.63	2.64	2.96
(S.E.)	(.40)	(.36)	(.41)
Standardised (p of range)	.37	.37	.41
(S.E.)	(.04)	(.04)	(.04)
SCR latency to peak (ms)	4070.87	4088.84	4096.52
(S.E.)	(96.19)	(108.18)	(121.19)

Questionnaire Scores

Table 20 presents means, standard errors and medians for the SPQ and FSS questionnaires. These were calculated for all participants who met the SPQ eligibility criteria for this study (i.e., those with a score greater than five), and so represents the total pool of participants available

Table 20: Descriptive Statistics for SPQ and FSS Questionnaires, for Participants Meeting the SPQ Score Criterion.

Questionnaire	Mean	Median
SPQ	13.67	13
(S.E.)	(.76)	
FSS	121.17	120.5
(S.E.)	(3.65)	

prior to assessment of the blink and SCR exclusion criteria (n = 42). Neither SPQ nor FSS scores differed between the two Picture Combinations, Fs (1, 40) = .81 and 1.35, ps = .373 and .253, respectively.

Blink Magnitude

The first ANOVA model for blink magnitude contained Emotional Category, Probe Time, and Picture Complexity as within-subject factors, and Picture Combination as a between-subject factor. Picture Combination was not significant as a main effect or as an interaction and was removed from the model, highest F (1, 35) = 2.51, p = .122.

In the new model, there were significant main effects for Probe Time, F (1, 36) = 18.49, $p < .001$, and Emotional Category, F (2, 72) = 3.22, $p = .047$, ε = .99. Blinks were larger at the late Probe Time (M = 51.96) compared to the very-early Probe Time (M = 48.39). The main effect for Complexity approached significance, F (1, 36) = 2.98, p = .093. Interactions between Emotional Category, Probe Time, and Complexity were not significant, Fs (2, 27) < 1.76, ps $> .18$; epsilon values ranged from .89 to .97.

Planned comparisons between Emotional Category within each Probe Time/Complexity condition were not significant, Fs (1, 36) < 1.71, ps $> .2$. The exception to this was for complex pictures at the very-early Probe Time, linear F (1, 36) = 8.71, p = .006. This result indi-

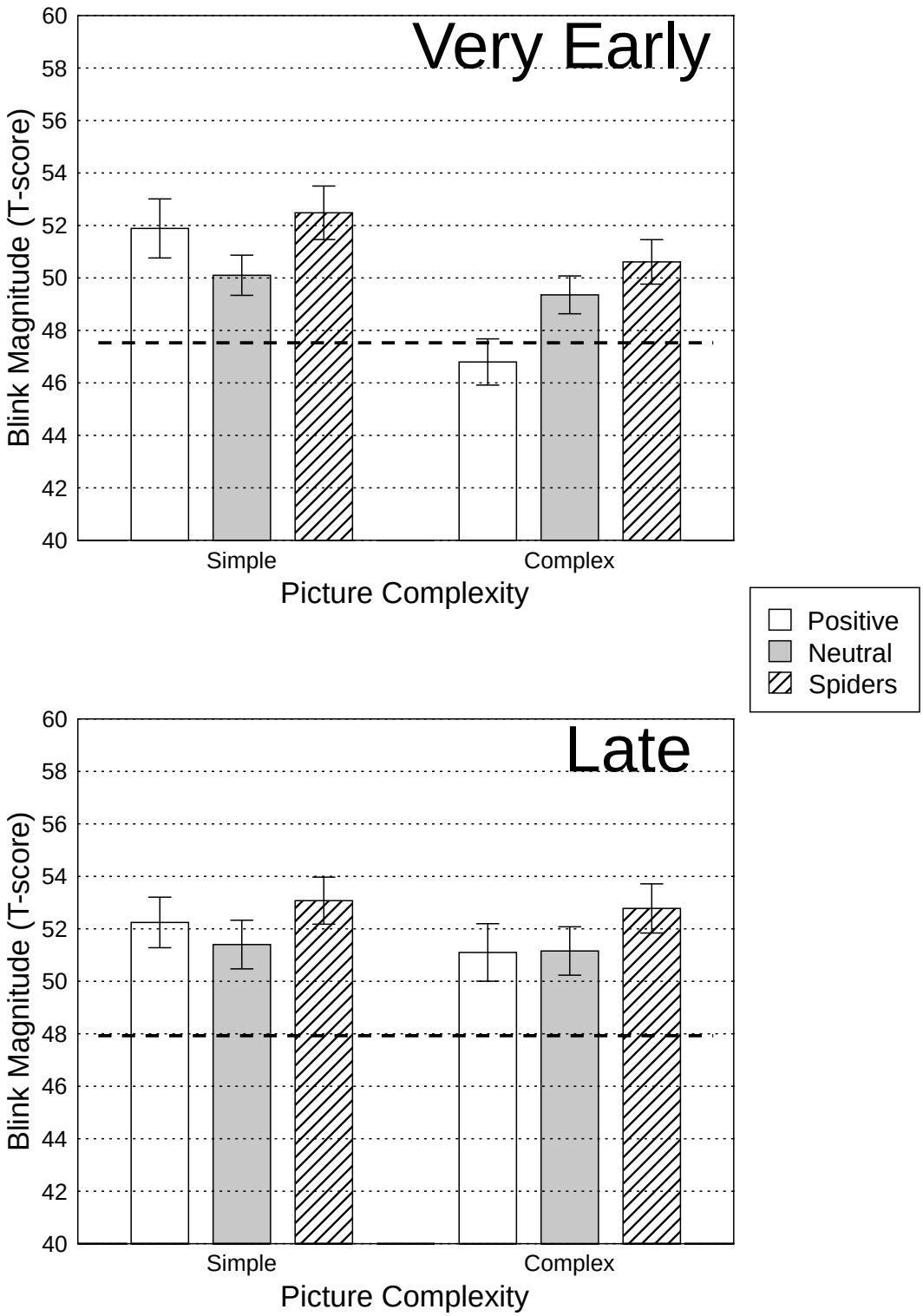


Figure 41. Mean standardised blink magnitude by Emotional Category, for simple and complex pictures at the very-early and late Probe Times. Very-early probe time data are in the upper panel, and late probe time data in the lower panel. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

cated significant blink inhibition for complex positive pictures (relative to complex neutral pictures) at the very-early Probe Time. The quadratic trend in this condition was not significant, F (1, 36) = 2.84, p = .1. These data are presented in Figure 41.

For planned comparisons between the levels of Emotional Category, on average over Probe Time and Complexity (i.e., within the significant main effect), there was a significant linear trend, with increasing blink magnitude across the positive, neutral, and spider categories, linear F (1, 36) = 7.11, p = .011; quadratic F (1, 36) = .05, p = .817.

Blink Magnitude and SPQ score

Incorporating a median split on the SPQ measure into the ANOVA model for blink magnitude did not produce any interactions involving SPQ score-group, highest F (2, 70) = 2.19, $p = .122$, ε = .96. Group sizes were not quite equal for the two groups (n = 22 for the below-median condition, n = 15 for the above-median condition).

Blink Magnitude and FSS score

The following analysis incorporated a median split on FSS score as a between-subjects variable. There was a significant interaction between Emotional Category, Probe Time, and FSS score-group, F (2, 70) = 3.6, $p = .035$, ε = .95. Separate ANOVAs were then performed for the low and high FSS-score participants.

For the low FSS-score participants (n = 22), the interaction between Emotional Category and Probe Time was significant, F (2, 42) = 4.15, $p = .024$, ε = .96. As can be seen in Figure 42, at the very-early Probe Time blink magnitude increased across positive, neutral, and spider contents, linear F (1, 21) = 14.81, $p < .001$; quadratic F (1, 21) = .55, p = .465. At the late Probe Time, neither contrast was significant, Fs (1, 21) = .18 and 2.62, ps = .672 and .121, for linear and quadratic contrasts respectively.

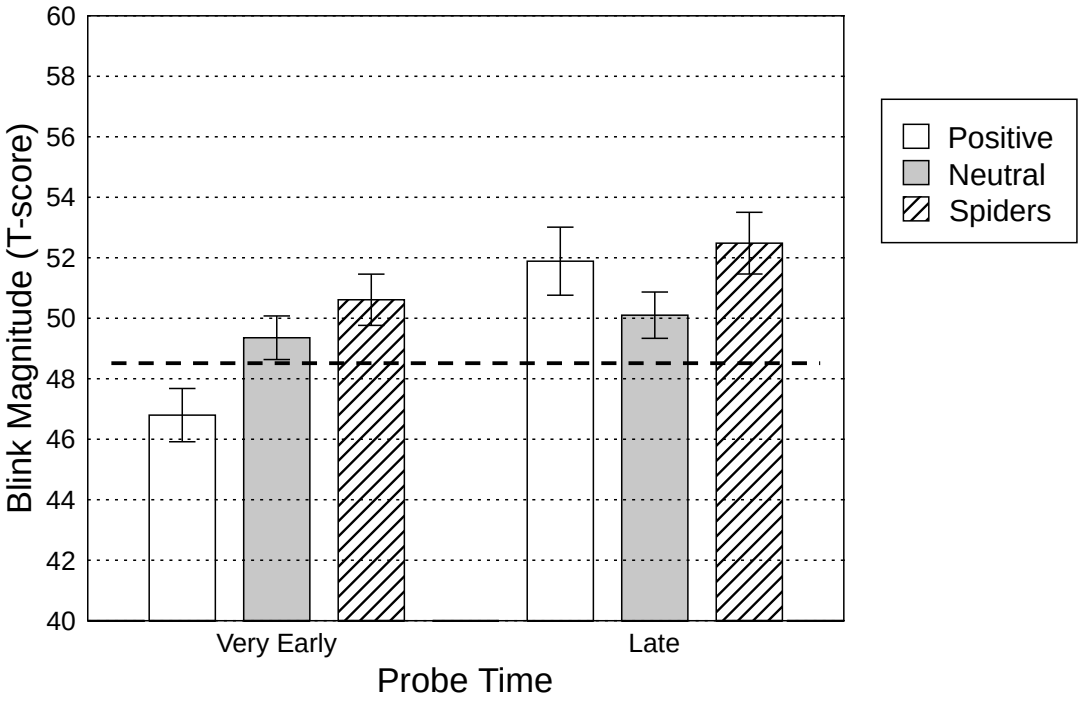


Figure 42. Mean standardised blink magnitude by Emotional Category for participants scoring at or below the median on the FSS measure, at the very-early and late Probe Times averaged over complexity. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

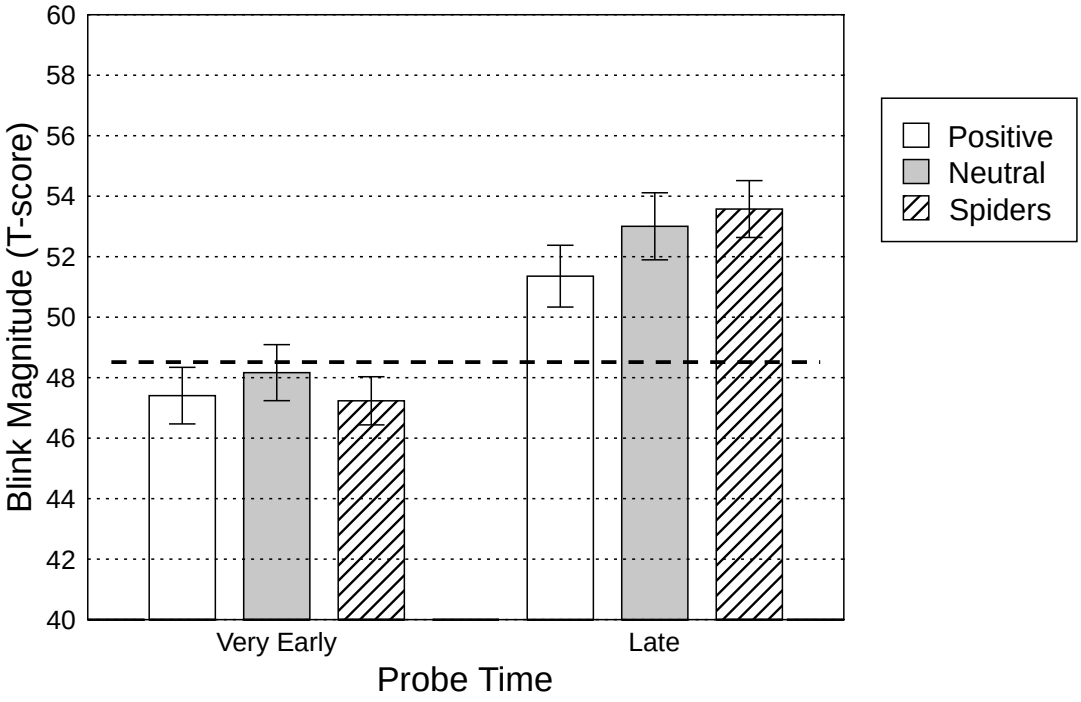


Figure 43. Mean standardised blink magnitude by Emotional Category for participants scoring above the median on the FSS, at the very-early and late Probe Times averaged over complexity. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

For the high FSS-score participants (n = 15), there was neither a main effect for Emotional Category, nor any significant interaction between Emotional Category, Probe Time, or Complexity, Fs (2, 28) < 1.07, ps $> .348$; epsilon values ranged from .84 to .96. These participants' data for the Emotional Category by Probe Time interaction are portrayed in Figure 43.

Blink Latency to Peak

In the initial analysis of blink latency to peak, there were no significant effects or interactions involving Picture Combination, Fs (1, 70) < 1.41, ps $> .77$, epsilon values ranged from .77 to .99. In the model containing only Emotional Category, Probe Time, and Complexity, there were significant main effects for Probe Time, F (1, 36) = 36.43, $p < .001$, and Emotional Category, F (2, 72) = 4.27, $p = .018$, ε = .99. Blinks reached their peak faster at the very-early (M = 68.12 ms) compared to the late (M = 73.26 ms) Probe Time, on average over Emotional Category and Complexity.

For the planned comparisons in each Probe Time/Complexity condition, simple pictures at the late Probe Time showed a linear trend that approached significance, F (1, 36) = 3.51, p = .069. The quadratic trend for complex pictures at the very-early Probe Time also approached significance, F (1, 36) = 3.5, p = .07. No other contrasts were significant, Fs (1, 36) < 1.85, ps $> .183$. These data are portrayed in Figure 44.

Averaged across Probe Time and Complexity, blinks generally reached their peak more quickly for spiders than neutral or positive contents, linear F (1, 36) = 4.14, p = .049; quadratic F (1, 36) = 4.44, p = .042. These data are presented in Figure 45.

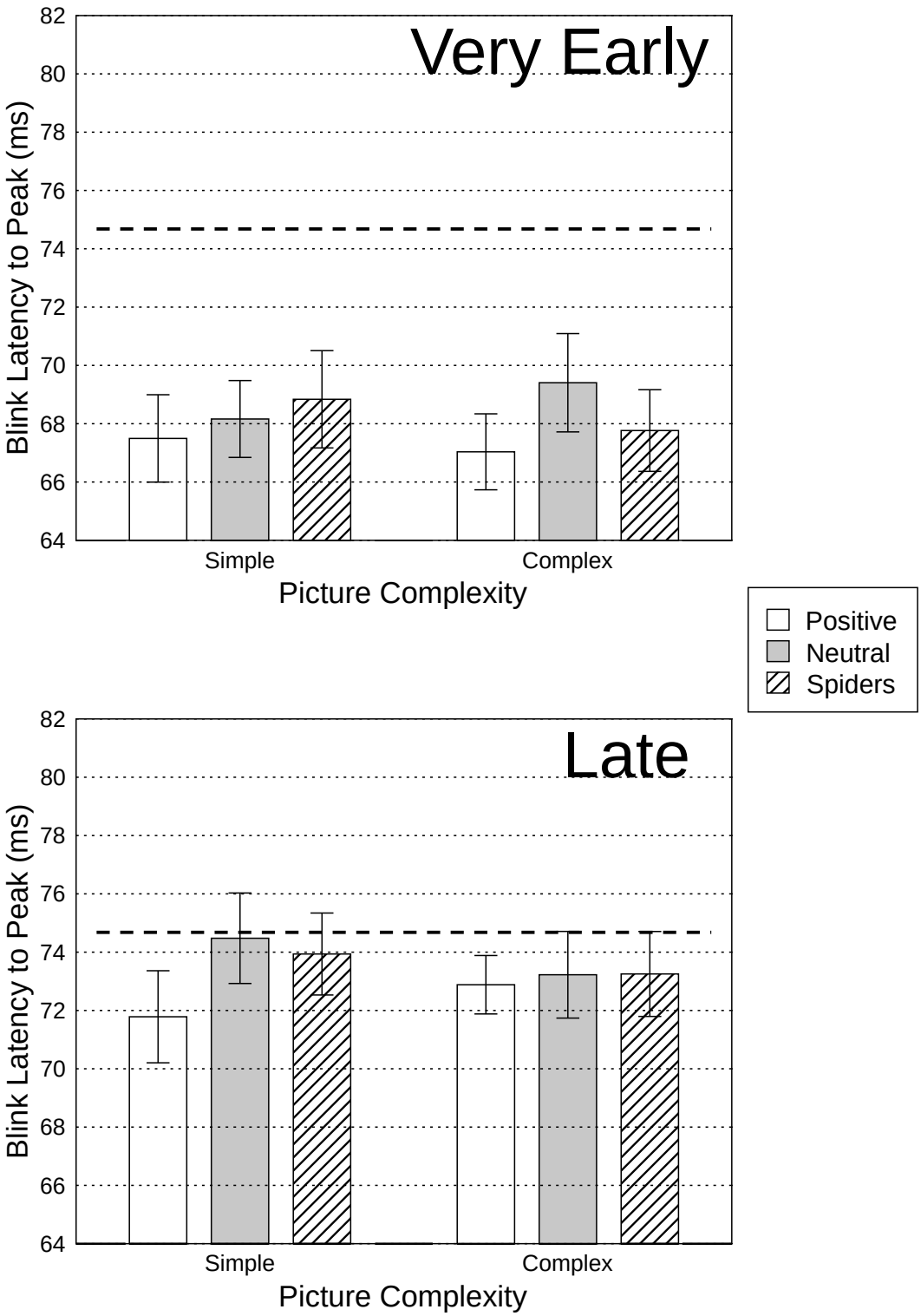


Figure 44. Mean blink latency to peak by Emotional Category, for simple and complex pictures at the very-early and late Probe Times. Very-early probe time data are in the upper panel, and late probe time data in the lower panel. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

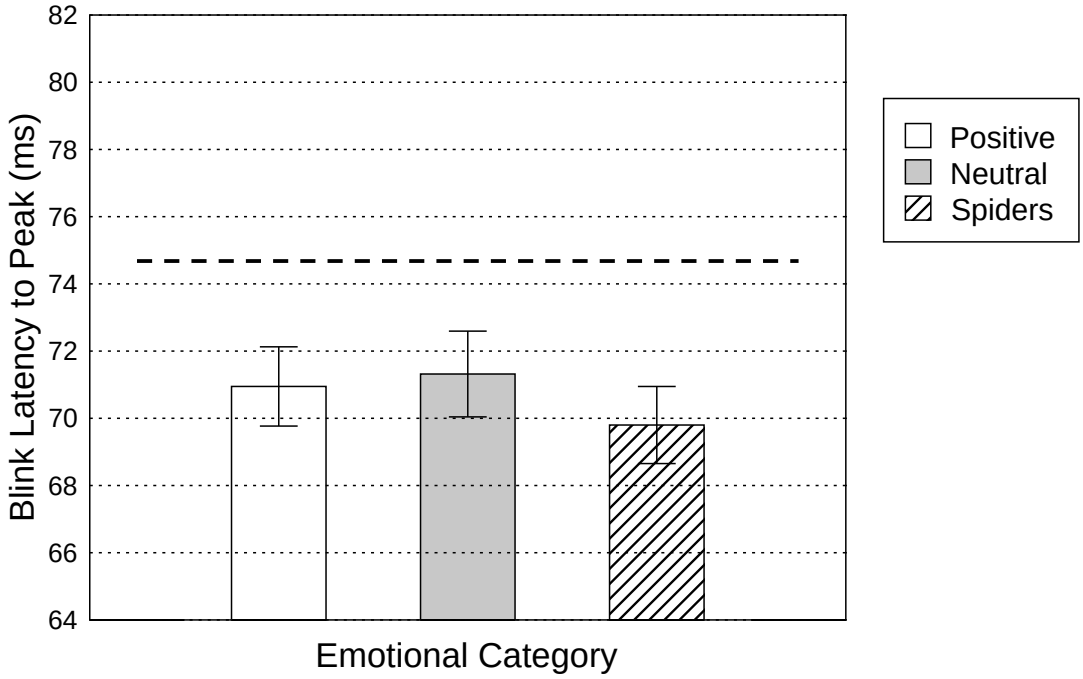


Figure 45. Mean blink latency to peak by Emotional Category, averaged over Probe Time and Complexity. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

SCR Magnitude

The model for the SCR magnitude ANOVA included all four independent factors. There were significant main effects for Emotional Category, F (2, 32) = 4.06, $p = .03$, $\varepsilon = .94$, and Probe Time, F (1, 16) = 12.92, $p = .002$. The main effect for Complexity approached significance, F (1, 16) = 3.28, $p = .089$.

The four-way interaction between these within-subjects factors and Picture Combination was also significant, F (2, 32) = 7.67, $p = .003$. Separate ANOVAs for the within-subjects factors were performed for each of the two Picture Combinations.

For the first Picture Combination (n = 9), there was a significant interaction between Emotional Category, Probe Time, and Complexity, F (2, 16) = 4.39, $p = .032$, $\varepsilon = .96$. This interaction is shown in Figure 46. None of the contrasts within each Probe Time/Complexity condition were significant; for simple picture contrasts, Fs (1, 8) < 3.36, ps $> .104$; for complex picture contrasts, Fs (1, 8) < 1.87, ps $> .209$.

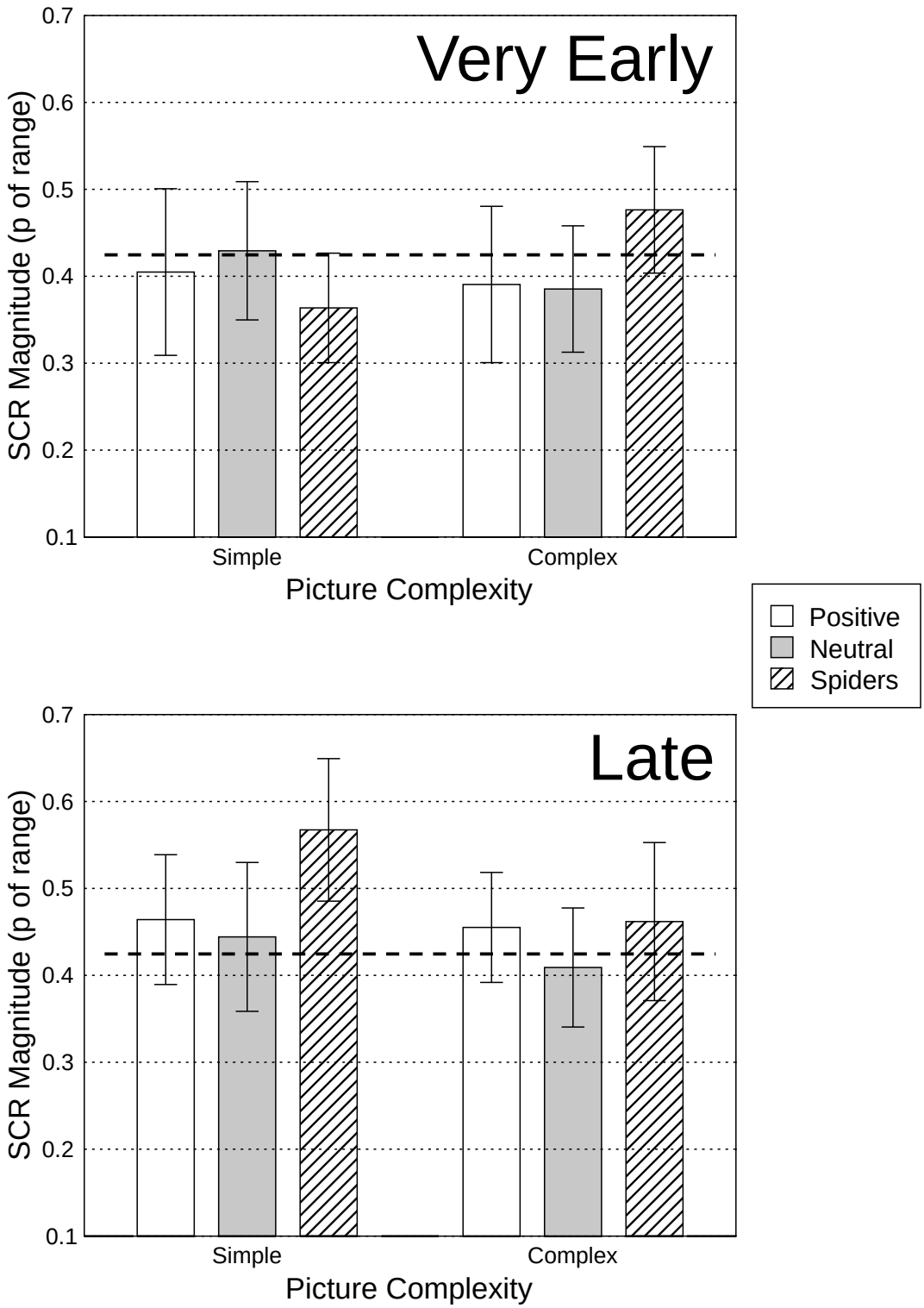


Figure 46. Mean standardised SCR magnitude for participants in the first picture combination by Emotional Category, for simple and complex pictures at the very-early and late Probe Times. Very-early probe time data are in the upper panel, and late probe time data in the lower panel. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

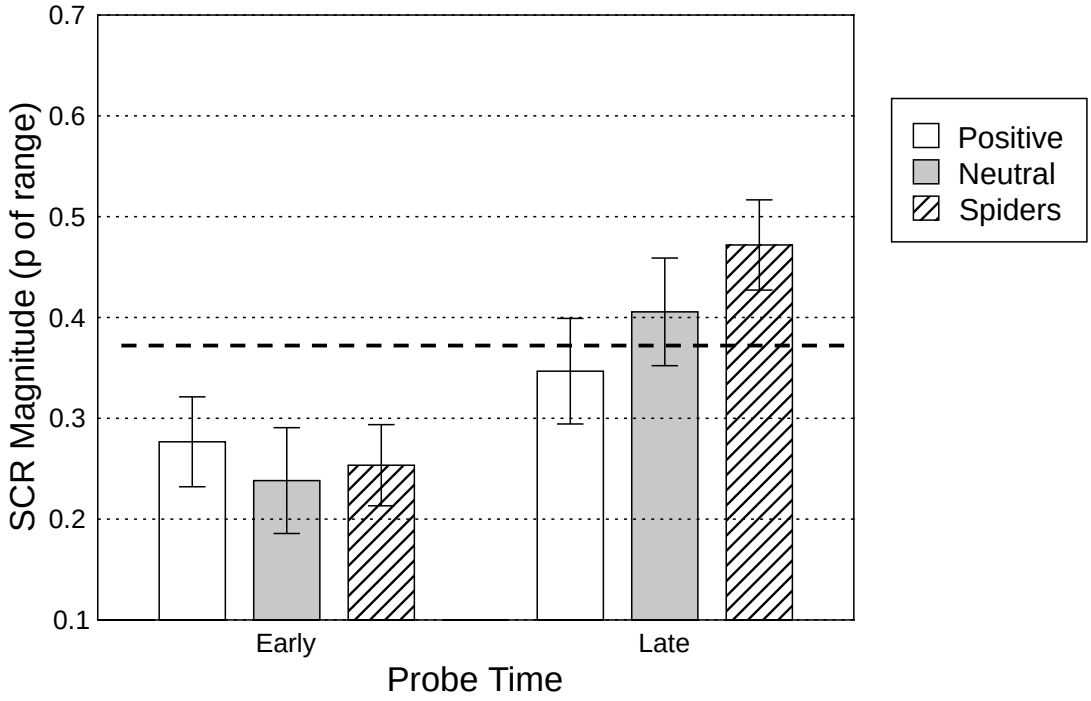


Figure 47. Mean standardised SCR magnitude by Emotional Category for participants in the second picture combination, averaged over Complexity at the very-early and late Probe Times. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

For the second Picture Combination (n = 9), the interaction between Emotional Category, Probe Time, and Complexity approached significance, F (2, 16) = 3.44, $p = .089$, ε = .61. The interaction between Emotional Category and Probe Time was significant, and this interaction is displayed in Figure 47; F (2, 16) = 3.81, $p = .046$, ε = .97. Planned comparisons between the levels of Emotional Category were performed at each Probe Time. Neither contrast was significant at the very-early Probe Time, Fs (1, 8) = 1.17 and 2.01, ps = .31 and .194, for linear and quadratic trends respectively. At the late Probe Time, SCR magnitude was greater for spider pictures than for positive pictures, linear F (1, 8) = 5.61, p = .045. Neutral category SCR magnitudes fell between spider and positive responses, quadratic F (1, 8) = .01, p = .92.

SCR magnitude and SPQ score

Incorporating a median split on the SPQ measure into the ANOVA model for SCR magnitude did not produce any interactions involving SPQ score-group, highest F (2, 32) = 1.93, $p = .171$, ε = .81. Group sizes were once again not quite equal for the two groups (n = 8 for the below-

median condition, n = 10 for the above-median condition).

SCR magnitude and FSS questionnaire scores

The following analysis included a median split on the FSS questionnaire. Group sizes were not quite equal for the below-median (n = 7) and above-median (n = 11) groups. The main effect for FSS score-group approached significance, F (1, 16) = 3.17, p = .094. This factor did not interact with Emotional Category in any interaction, highest F (2, 32) = 2.28, $p = .15$, ε = .86, for the interaction of Emotional Category, Complexity, and FSS score-group.

SCR latency to peak

The ANOVA model for SCR latency to peak included all four factors. There was a main effect for Picture Combination, F (1, 16) = 9.19, p = .008. SCR latencies to peak, averaged over all picture types and both Probe Times, were faster in the first Picture Combination (M = 3836.7 ms) than in the second Picture Combination (M = 4334.12 ms). The only other significant term in the model was the interaction between Emotional Category and Probe Time, F (2, 32) = 4.84, $p = .024$, ε = .76.

Planned comparisons between the levels of Emotional Category at the very-early Probe Time were significant for the comparison between complex spider and positive contents only, linear F (1, 16) = 5.24, p = .036. As can be seen in Figure 48, SCRs for complex spider pictures reached their peak later than did positive picture SCRs.

At the late Probe Time (lower panel of Figure 48), the only significant contrast was again between spider and positive contents, but this time for simple pictures only, linear F (1, 16) = 4.96, p = .041. SCRs reached their peak more quickly for spider picture contents than for positive contents. The quadratic contrast comparing the average of simple spider and positive contents to neutral contents approached significance, F (1, 16) = 3.1, p = .097.

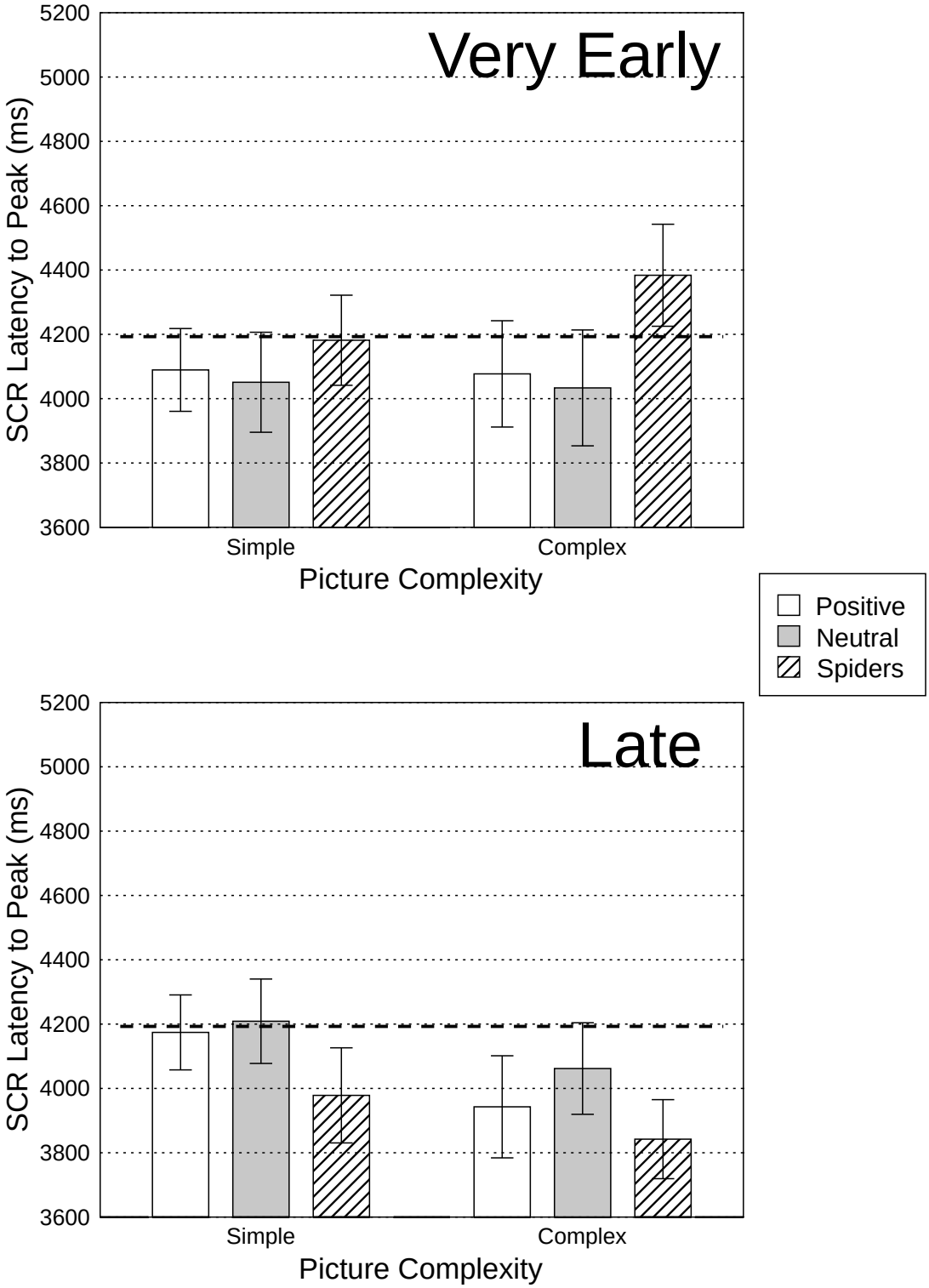


Figure 48. Mean SCR latency to peak by Emotional Category, for simple and complex pictures at the very-early and late Probe Times. Very-early probe time data are in the upper panel, and late probe time data in the lower panel. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

Discussion

This study was conducted on a group of female participants with moderate to high spider fear. The cut-off score on the SPQ measure for inclusion in the study was quite liberal (participants had to score higher than 5), being the median score on this measure in a larger sample of unselected female participants (Study 1). Lifting the required SPQ score to more than 8 reduced the available pool of participants from 42 to 35; a required score of more than 10 would have removed five more participants from the analysis.

Blink Responses

The results of the planned comparisons revealed only one significant difference between Emotional Categories in all of the Probe Time/Complexity conditions, showing early startle inhibition for complex positive images. Averaged over Probe Time and Complexity, blink magnitude increased across positive, neutral, and spider contents. Blink magnitude did not differ on the basis of an SPQ-score median split, so that the responses of participants with moderate SPQ scores (less than 14) were no different from those with high SPQ scores (14 or greater).

When fearfulness was defined by FSS score, high general-fear participants showed no significant modification of startle. Low general-fear participants showed blink modification for 150 ms startle probes (averaged over Complexity), with potentiation of blink magnitude for spider pictures relative to neutral contents, and inhibition for positive relative to neutral responses. At the late Probe Time there were no significant differences in blink magnitude between the three categories of picture content. The absence of late probe time blink modification suggests that the effects observed at the very early probe time were not caused by the pictures' emotional content. The cause of this effect is at present unclear.

Positive pictures were not associated with blink inhibition after several seconds of picture viewing, suggesting that picture contents were either uninteresting or did not produce a positive emotional state, one or both of these being necessary for such inhibition to occur. The pictures

in this category consisted of food and flower stimuli, which are generally rated as highly pleasant but of moderate to low arousal (see Appendix D). Blink inhibition during positive contents seems to be limited to highly-arousing contents such as nudes and other sexually explicit material (Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley, Codispoti, Sabatinelli, & Lang, 2001, reviewed in Chapter 3), and so a defence is required for the choice of positive materials used in this study.

Flowers and food stimuli were chosen for this study primarily to match the spider category pictures in foreground size and complexity, with a secondary criterion of being easily recognisable in silhouette form. Nude and erotic stimuli, unfortunately, meet neither of these criteria. The general absence of startle inhibition during positive stimuli in this study, and in Studies 2, 3a (for low FSS-score participants), and 3b, points to the need for further experiments to clarify the attributes of positive stimuli that lead to startle inhibition. Once these parameters have been ascertained, a new complexity manipulation should be devised that allows the use of more arousing positive materials, as well as a wider range of negative stimuli.

The very-early startle inhibition observed for complex positive pictures is also of interest. If we take the lack of late startle modification for these pictures as evidence that they are not emotionally engaging, then the very-early startle inhibition could indicate an effect of stimulus complexity on early attentional processes. From this assumption we would furthermore predict that increasing the complexity of neutral pictures would also inhibit blink responses (relative to simple neutral pictures). This was not evident from the data in this study. This may reflect a poor match in the amount of background detail between neutral and positive complex pictures, so that the positive condition pictures were actually more complicated than those in the neutral condition.

The blink latency to peak data supported the blink magnitude data, so that blinks were faster to reach their peak for spider contents than for neutral/positive contents, on average over Probe Time and Complexity. Planned comparisons within each Probe Time/Complexity condition were not significant.

Skin Conductance Responses

The number of participants contributing data to the SCR analysis was very small (n = 18), and the data were largely inconclusive. The change in the criterion for inclusion (at least two non-zero responses in each condition) was not wholly responsible for this: only 5 of the participants who failed to meet this criterion would have met the old criterion (less than one-quarter of all possible responses at zero magnitude). In the blink response analyses, only two participants who did not meet the new criterion would have been included under the old method.

The large number of zero magnitude responses, across all participants, may be related to the positive stimuli used — as these were low-arousal contents, the evoked SCR magnitudes would be minimal.

Sample Suitability

As explained in the introduction to the study, spiders were chosen for negative stimuli because they suited the complexity manipulation; leading on from this decision, the study was limited to female participants because of the relatively higher prevalence of spider fear among females, compared to males.

Most experiments looking at startle blink modification have found similar patterns of responding for male and female participants. Some studies have reported gender differences in startle modification. Female participants in Yartz and Hawk (2002) showed greater blink magnitude for disgusting picture contents than for fear evoking contents; male participants did not. Bradley, Codispoti, Sabatinelli, and Lang (2001) found that only females showed startle potentiation across the entire negative picture category (i.e., compared to neutral pictures), while only males showed startle inhibition for the positive category as a whole. These differences may hold true for the stimulus materials and analysis method used in that study, but it seems unlikely that males and females differ in startle modification circuitry.

The results of Bradley, Codispoti, Sabatinelli, and Lang (2001) may be more indicative of the types of photographs included in the IAPS picture set. A simpler explanation of these results is that males and females diverge on the types of material they find pleasant and unpleasant. Looking at the data for specific picture content categories, it seems that gender differences in startle modification are probably absent for highly-arousing negative contents similar to those used in this thesis (threat and mutilation pictures), while responses to less arousing (and perhaps more emotionally ambiguous) negative contents differed more between males and females (Bradley, Codispoti, Sabatinelli, & Lang, 2001). Participant gender did not influence blink modification in the current series of studies (excluding Study 5, of course, where only females were tested).

The pictures used in this study did not seem to activate emotional processing, as suggested by the late probe time blink responses and the lack of consistent SCR enhancement. Collecting picture ratings may have been useful to confirm that the positive pictures were not particularly pleasant or arousing, as well as assessing differences between the silhouettes and the complex photographs; the late probe time blink data and SCR results provided alternative evidence for this hypothesis. It is felt that selecting the silhouette images on the basis of picture ratings would have been superfluous to the experimental design, as these pictures were created to match the full-colour images on shape and size. The startle modification data were used to ask whether these silhouettes engaged emotional processing in the same way as the complex pictures, and so while it might have been informative to compare ratings of valence/arousal between the two categories, the subjective emotional ratings of the silhouette images alone was not of interest.

Blink Responses to Picture Onset

The introduction to this study claimed that blinks elicited by picture onset have been very rare through the course of this thesis. As this study presumes that blinks to the startle probe at 150 ms are not influenced by possible blinks to picture onset, this phenomenon was examined more closely for this study. Figure 49 shows the distribution of participant blinking in response to picture onset. A blink was defined as a response with peak magnitude greater than 10 μV occurring 20 to 150 ms after picture onset, and so prior to startle probe presentation. Blink

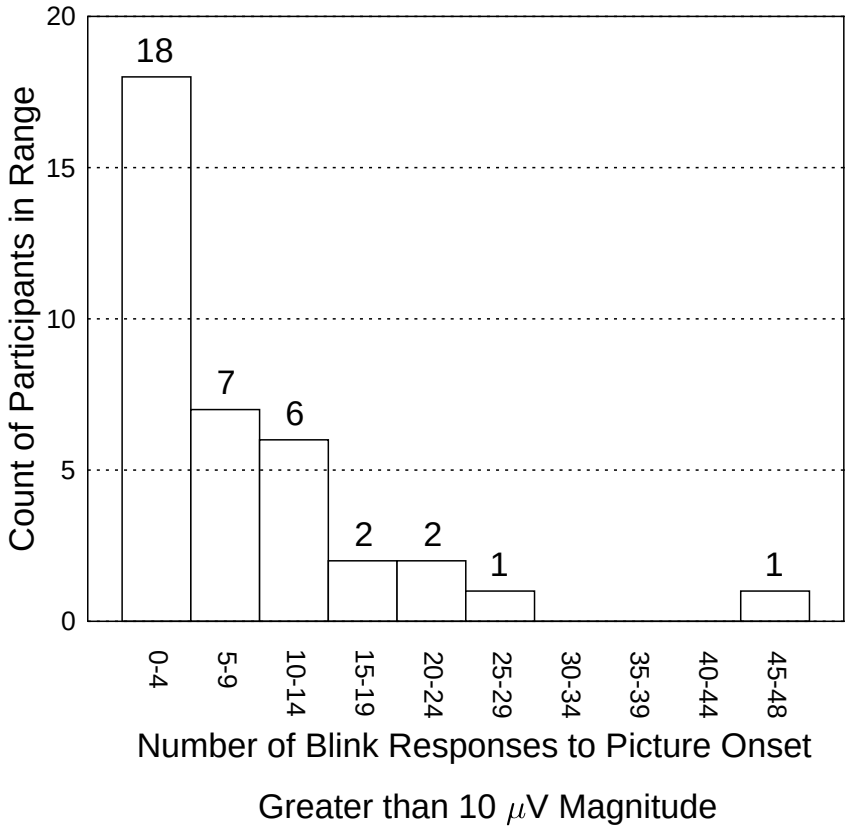


Figure 49. Distribution of participant blink frequency in response to picture onset.

magnitude for picture onset was calculated for all pictures in this study, including those on which no startle probe was presented. There are thus 48 possible blinks to picture onset for each participant.

It can be seen in Figure 49 that the majority of participants rarely blinked at picture onset, while one participant consistently blinked on nearly all pictures (46 out of 48). Figure 50 gives an example of the EMG signal from this participant for a period beginning about 50 ms prior to picture onset and ending 250 ms after a very-early, 120 ms startle probe presentation. The first panel is just the filtered EMG signal, with no rectification (panel A), and clearly shows two blink responses, one to picture onset, another to the startle probe. Panels B and C present rectified signals calculated with time constants of 10 ms (panel B), as used in this thesis, and 120 ms (panel C), as used by some other experiments on startle modification (e.g., Bradley, Cuthbert, & Lang, 1993). The two responses are clearly discriminable in the filtered-only and 10 ms RMS panels, while in the 120 ms RMS panel the two responses overlap.

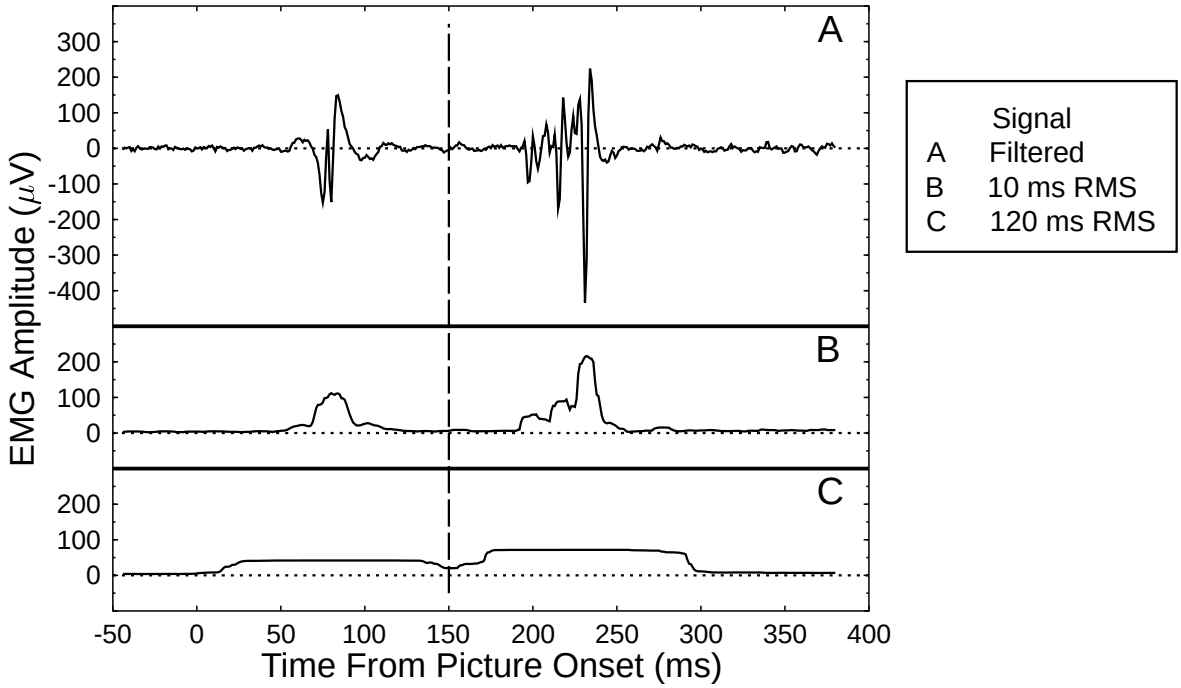


Figure 50. Example filtered and rectified signals for blink responses to picture onset and startle probe. Vertical dashed line represents time of startle probe presentation.

Globisch et al. (1999) disregarded their 120 ms probe time (not to be confused with a 120 ms time-constant) blink data on the basis of participant blinking in response to picture onset, even though their calculation of blink magnitude also bypassed the problem of overlapping rectified responses when the raw signal blinks do not overlap (as in Figure 50). Photic blink reflexes often include a second response component, with an onset latency of approximately 80 ms and lasting well beyond the 120/150 ms mark after stimulus presentation (Hackley & Johnson, 1996), and so the blink response to the startle probe will be superimposed on the second component of the photic reflex in the raw signal, when a two-component blink to picture onset occurs.

It seems that computer based picture presentation is less likely to elicit blink responses to picture onset than slide projection, although Globisch et al. also identified their short picture presentation period condition (150 ms from onset to offset) as a likely influence on the frequency of blinking. With the relative absence of blink responding to picture onset in the current study, it would be reasonable to assume that very-early blink modification was due to picture content (be it the emotional or attentional qualities thereof), as discussed above.

General Discussion

The aim of this thesis was to investigate the factors mediating early startle modification. The discussion will cover the patterns of results for blink magnitude and latency to peak, SCR magnitude and latency to peak, and will then consider implications of the data for startle modification theory, advantages and disadvantages of the experimental designs of these studies, and future directions for research.

Early startle modification has been used to test whether the emotional content of a picture has been processed by the time of startle probe presentation. Studies 2 through 5 addressed several issues regarding early modification of startle, and were initially based on conflicting reports between experiments showing early startle modification in individuals with phobia (Globisch et al., 1999) and other studies showing no emotional modification of startle at early stages of picture viewing in unselected samples (e.g., Bradley, Cuthbert, & Lang, 1993; Codispoti et al., 2001; Levenston et al., 2000). The main questions asked across these studies were (a) is early emotional modification of startle limited to highly fearful participants, and (b) is early startle potentiation limited to certain kinds of negative stimuli, and if so, what are the qualities of these negative stimuli that allow emotional identification by the early probe time?

Study 1 was used to obtain picture ratings to allow selection of suitable pictures for the subsequent studies, and is not discussed here.

Summary of Experimental Results

Blink Magnitude

The blink modification results are summarised below. Particular emphasis is given to the early probe time blinks. The late probe time was primarily included as a check on the emotional qual-

ities of the picture contents: If startle modification was apparent after several seconds of picture viewing, we can be more confident about ascribing early probe time results to the emotional qualities of those picture contents. Discrepancies between early and late startle modification are therefore also highlighted.

In an attempt to answer whether early startle modification was specific to highly-fearful individuals or to a specific subgroup of threatening pictures, Study 2 compared early and late stage blink modification for two types of threatening stimuli, containing either animal threat (similar to the negative category used by Globisch et al., 1999) or human threat images. The early blink potentiation observed for human threat contents in Study 2 was an important extension of the findings of Globisch et al.: Threatening pictures produced startle modification after a very short picture viewing period for a distinct set of pictures from those previously tested, in an unselected sample of participants. The between-subjects probe time manipulation restricted the validity of conclusions that could be drawn comparing early and late probe time responses, and prevented reasonable analysis of the effects of participant fearfulness within this unselected sample.

Having established that early blink modification could occur to some threatening contents in an unselected sample, Study 3a contrasted startle modification between threat and mutilation content picture categories, predicting that early startle modification would only be apparent for the threatening contents. Startle modification differed on the basis of a post hoc comparison between high- and low-fear participants (based on scores on the FSS general fear measure). Low-fear participants did not show any early modification of startle, and late startle potentiation for these participants was restricted to threat contents. High-fear participants showed blink potentiation for threat contents at the early probe time; they also showed startle modification for both negative contents at the late probe time.

Study 3b was an attempted replication of Study 3a, with a change of pictures and the addition of a fixation cross to ensure participants viewed the picture from onset. No blink modification was seen at the late probe time, and blinks were of greater magnitude at the early probe time

for affective contents compared to neutral. The first finding should preclude suggesting a causal role for emotional content at the early probe time. The study used two picture combination conditions, so that the pictures probed at the late probe time in one combination were probed at the early probe time in the other combination, and vice versa. There was no interaction between picture combination, emotional category, and probe time, so the observed effects were not the result of two distinct patterns of responding in the different picture combination groups being superimposed on each other. This suggests that the emotional content of the pictures was not capable of modifying startle blink responses.

The design of Study 4 was the most refined in the thesis, and aimed to test differences between pictures in the threat and mutilation categories. Each emotional category was split into high and low arousal exemplars; startle blink modification was not observed for the low-arousal mutilation contents at either probe time, or for low-arousal positive contents at the early probe time. Threatening pictures and high-arousal mutilation pictures potentiated blink magnitude at both probe times. The experimental design retained the fixation cross introduced in Study 3b, and by varying content intensity, partially addressed the failure of emotional startle modification in that study, suggesting that the results of Study 3b were probably due to poor picture selection.

The final study looked at probe times even earlier than the 300 ms early time used in Studies 2 to 4, and contrasted very early (150 ms) and late startle responses between spider, neutral, and positive contents. Each picture category consisted of six full-colour images, and six silhouette images, to assess whether picture complexity influenced startle modification during the early stages of picture viewing. The sample was also limited to female participants with moderate to high fear of spiders. Study 5 found only weak effects of emotional content on startle blink magnitude, when averaged over probe time and picture complexity, suggesting blink potentiation for spider pictures compared to neutral. In contrasts performed in each probe time/complexity condition, very early blinks to complex positive images were inhibited relative to neutral pictures. A median split on the FSS measure found that very early startle potentiation was apparent for low FSS-score individuals, averaged over complexity conditions. The lack of late probe time startle modification for these participants suggested that the very early startle

potentiation was mediated by an as-yet unidentified characteristic of the picture set.

It is important here to rule out the possibility that blink modification during positive contents was inconsistent across studies (e.g., no inhibition during Study 2 at the late Probe Time) due to the generally aversive nature of the startle modification procedure overcoming the positive nature of these stimuli. The inclusion of a neutral picture condition rules out this possibility: If participants are in a generally negative emotional state, then startle blink magnitude should increase across all emotional categories, rather than just for positive contents, and so the difference between neutral and positive contents would still be significant. The lack of blink inhibition for positive contents in some of these studies would appear to be due to the qualities of these picture stimuli, rather than the individuals' ongoing emotional state.

The early probe time blink magnitude results are primarily discussed in the section on theoretical positions regarding emotional modification of startle, following discussion of the other physiological dependent variables.

Blink Latency to Peak

Most studies that have measured blink latency to onset have found that onset is facilitated during those emotional contents that also show blink magnitude potentiation. In this thesis, there was no consistent pattern of blink latency to peak modification across studies. Studies 2 and 3b found no differences between emotional categories at the early or late probe time. Study 3a showed blink latency facilitation for positive contents compared to threat contents at the late probe time. Study 4 showed no significant differences between low-arousal emotional categories; for the high-arousal contents, positive and threat content blinks were associated with shorter latencies to peak than neutral blinks at both probe times. In Study 5, blink latency to peak was faster for spider contents compared to neutral and positive contents, but as with blink magnitude, this effect was only significant on average over probe time and picture complexity, and not for each probe time/complexity condition.

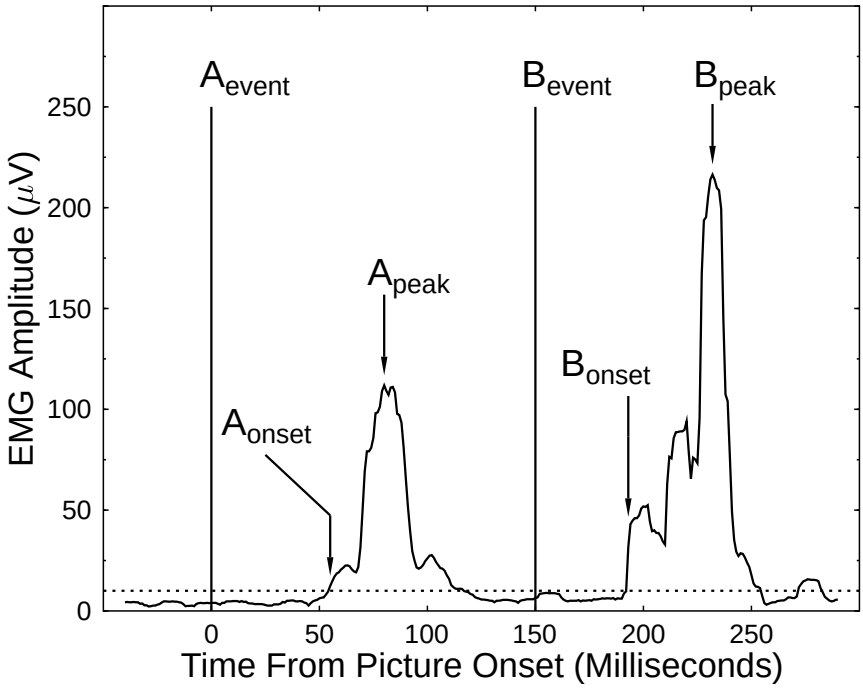


Figure 51. Example rectified blink responses to two events, A and B, showing times considered for onset and peak latency calculations. Dotted line represents threshold for onset calculation.

Part of the problem with accurately measuring blink response latency was due to technical difficulties encountered in calculating latency to onset and latency to peak. These can best be described with the aid of a figure. Figure 51 presents an example of two blinks of differing magnitude and different onset latencies: The signal is the 10 ms rectified data from Figure 50, and so the first blink is a visually elicited (or photic) reflex in response to picture onset (Event A) and the second blink is in response to the startle probe (Event B). These two examples provide a good illustration of the differences in calculating blink latency to onset versus latency to peak.

In the figure, 'Event' marks the occurrence of each blink eliciting event, and the point at which onset and peak latencies would be calculated are marked on the response for each event. For the purpose of this figure, response onset was marked as the first time response amplitude rose above 10 μV.

Blink reflexes elicited by photic stimulation (Event A) generally have shorter onset latencies than blinks elicited by acoustic stimulation (Event B; Dawson et al., 1999). Table 21 reports the latencies to onset and peak for Events A and B.

Table 21: Blink Latencies (ms) to Onset and to Peak for Blink Responses in Figure 51.

	Latency Measure (ms)	
Event	Onset	Peak
Event A	55	80
Event B	43	82

The time between response onset and peak is referred to as rise-time. Both Figure 51 and Table 21 make clear that the larger magnitude response to Event B has a delayed peak, relative to onset, so that the latency to peak measure does not differentiate between the two responses. If this increased rise-time is consistent for larger magnitude responses, then this would obscure blink latency to peak differences between positive content responses (longer onset, short rise-time), negative responses (shorter onset, longer rise-time), and neutral responses (medium onset, medium rise-time). This was the case in Study 2. The null result for blink latency to peak in Study 3b is also consistent with this hypothesis, as blink magnitude modification was not apparent at the late probe time, and early probe time magnitudes were similar across affective contents.

As increases in emotional arousal may also facilitate latency to onset independent of valence (Cook et al., 1991; Witvliet & Vrana, 1995), the observed blink latency to peak results in Study 4 are in line with the predictions discussed with reference to Figure 51. The difference in normative ratings of arousal between high-arousal and low-arousal contents was more extreme for affective than for neutral picture categories, largely as an effect of the uneven distribution of emotional pictures in the two-dimensional space defined by valence and arousal (see Chapter 1, Figure 1). Following on from the logic given above, high-arousal positive and negative contents would be presumed to have a shorter latency to peak than neutral contents — neutral responses will have a medium onset and rise-time with no additional arousal component, while positive (longer onset, shorter rise-time) and negative (shorter onset, longer rise-time) will both have facilitation from an arousal component. These trends were apparent for the positive and threat

categories, but not for mutilation contents, which may be representative of a real difference between threat and mutilation contents, or simply a consequence of greater error in measurement arising from using blink latency to peak as a dependent variable. The ideal test for separate effects of arousal and valence would employ blink latency to onset.

SCR Magnitude

The problems with calculating late probe time SCR magnitudes and latencies have already been dealt with in the discussion of Study 2. Emotional pictures typically elicit an SCR; when the startle probe was presented several seconds after picture onset, a second SCR would generally be elicited before recovery of the initial response, creating problems in assessing the magnitude and latency parameters for this second response.

Dawson, Schell, and Filion (2000) also note the difficulty in calculating magnitude and latency characteristics for a second SCR superimposed on an initial response, and suggest using a computer generated algorithm to isolate the actual form of the second response. The following considerations only take into account early probe time data collected in the studies in this thesis.

Studies 2 and 3a found relatively consistent effects of emotional content on SCR magnitude. There were no indications of SCR modification by picture content for low-fear participants, defined as scoring at or below the median on the SNAQ measure of snake fear (Study 2), the MQ measure of blood and mutilation fear (Study 3a), or the FSS measure of fearfulness in multiple situations (both studies). The sole exception to this was for low FSS-score participants in Study 3a, who showed greater SCR magnitude for threat contents relative to neutral. High-fear participants in these two studies (defined by scores on any questionnaire) showed greater SCR magnitude during affective contents (both negative and positive) relative to neutral.

In Study 3b, early probe SCRs were only modified for high MQ-score participants, for the comparison between threat contents and neutral.

Modification of SCRs in Study 4 was not dependent on fear group (MQ score) or anxiety group (measured by the state and trait components of the STAI). There were different patterns of modification for low and high arousal picture contents: SCRs were enhanced for all affective contents in the high-arousal condition, whereas SCR enhancement in the low-arousal condition was observed for the two negative categories, but not for positive contents.

Study 5 found no significant effects for SCR modification for either simple or complex pictures, although the sample size was relatively small for this variable (n = 18). Like the SCR results of Study 3b, this represents a failure of the stimulus materials in engaging emotional processing.

Across Studies 2, 3a, and 3b, SCR enhancement was only observed for the above-median fear groups; in Study 4, SCR potentiation for positive contents was only apparent for the high-arousal condition. These results are consistent with two positions, (a) that the SCRs observed during the viewing of emotional pictures are related to the arousing nature of those pictures, and (b) sensitivity to these arousal dimensions is greater for highly-fearful participants relative to less fearful participants. The second point is suggested by the fact that differences in SCR modification between high and low fear-score groups were not specific to negative contents, so that low-fear participants did not show SCR potentiation for positive pictures, which were presumably as pleasant for them as for the high-fear participants. As SCR modification was only calculated on trials where a startle probe was presented immediately following picture onset, this may indicate that the startle probe is more likely to elicit SCRs in high-fear participants, and so possible combinatory effects of picture elicited SCR and probe SCR would mean more likelihood of these observed effects.

The effect of foreground arousal on SCR modification in Study 4, which did not differ on the basis of participant fear or anxiety, means that this difference between highly fearful and less fearful individuals may be primarily limited to less intense stimuli, and suggests that emotional modification of SCR magnitude by picture and/or probe is more likely to occur for highly-arousing pictures. The emphasis on researching early probe time responses in this thesis makes it almost impossible to unravel the separate effects of picture and probe on SCR magnitude. The

SCR data from pictures where startle probes occurred shortly after picture onset still provide some information on the arousal qualities of these probed pictures; it is just that these SCRs cannot be specifically attributed to either the probe or the picture content alone.

The relationship between SCR modification, emotional processing, and blink modification is covered in the section following discussion of SCR latency to peak.

SCR Latency to Peak

The SCR latency to peak results for late probe SCRs were probably also influenced by the superimposition of a second SCR onto an initial response, and so are not discussed here. For early probe time responses, the effects of emotional category on SCR latency to peak were not consistent across studies. In Study 2, animal threat content SCRs reached peak more quickly than positive SCRs. Study 3a found no significant differences between emotional categories. In Study 3b, mutilation content SCRs reached peak more quickly than positive contents, but threat and positive content SCRs were slower to reach peak than neutral.

In Study 4, SCRs for the low-arousal negative contents were slower than for neutral and positive contents; for high-arousal pictures, all three affective conditions' SCRs were slower to reach peak than neutral SCRs. Finally, in Study 5, complex spider picture SCRs were slower to reach their peak than complex positive picture SCRs.

As with blink latency to peak, SCR latency to peak is really a composite of two time components of the SCR, latency to onset and rise-time. These two components are supposedly highly related to the magnitude of an SCR, so that large magnitude SCRs should be associated with shorter onsets and rise-times (Dawson et al., 2000). This would suggest that the composite latency to peak measure should reflect the same information as latency to onset, given that faster response onset is associated with shorter rise-time, and so SCR latency to peak should be facilitated for those emotional categories with enhanced SCR magnitude relative to neutral. Across the studies, the significant SCR latency to peak results do not fit in with this hypothesis. The

modal observed effect was in fact the opposite, with longer latency to peak for those emotional categories where SCR magnitude was enhanced.

Whether this is indicative of actual differences in SCR latency to response onset from those reported elsewhere, or is a problem raised by the use of the latency to peak calculation, is unclear.

Startle modification at 300 ms

Startle blink modification only occurred in the presence of SCR enhancement. Those studies showing little or no emotional modification of startle (Studies 3b and 5) also failed to show any SCR enhancement at the early probe time. Early SCR potentiation was otherwise associated with startle blink modification. In Study 2, positive and human threat content SCRs were enhanced relative to neutral, and both of these categories were associated with blink magnitude modification in both probe time conditions. Animal threat content SCRs were not enhanced relative to neutral, and blinks were not potentiated for these contents among early probe time participants. Due to the between subjects design, it is not really valid to use the early condition participants' SCR data to draw conclusions regarding the late probe time participants' blink modification (these participants showed blink potentiation for animal threat contents). Differences between fear groups in this study were compromised by the uneven cell sizes in the design, and so will not be discussed further.

SCR modification in Study 3a was primarily observed for high-fear participants during threat, mutilation, and positive contents. These participants showed startle blink modification for these contents at the early and/or late probe times; blink modification for mutilation contents was limited to the late probe time. For low FSS-score participants in Study 3a, SCR modification was apparent for threat contents only, and only these pictures were associated with late probe-time startle potentiation for this group.

Startle modification did not occur in the absence of SCR potentiation. The sole exception to this

was for low-arousal positive contents in Study 4, for which no SCR enhancement was observed. Blink inhibition for these pictures was apparent at the late probe time, but not at the early probe time.

The dependency of blink modification on SCR enhancement is not apparent for the reversed relationship: Enhanced SCRs to a picture content did not always coincide with blink modification. In Study 3b, high MQ-score participants had enhanced SCR magnitudes for threat compared to positive responses, but showed no blink modification for threat pictures after several seconds of picture viewing. In Study 4, low-arousal mutilation contents were associated with SCR enhancement, but blinks were not potentiated during these contents at either probe time. This suggests that the outputs governing emotional modification of skin conductance and startle blink responding are either different, or are engaged at lower levels of arousal for SCR enhancement compared to blink modification.

Bradley and Lang (2001, cited in Codispoti et al., 2001) suggested that early startle modification is influenced by both attentional and emotional processes, the first of these inhibiting startle blink magnitude during viewing of motivationally relevant picture contents (i.e., positive and negative pictures), and the second modifying startle in line with the predictions of the response matching model. The net result will be the observed startle blink magnitude at early stages of picture viewing.

The studies in this thesis did not fit in with this theoretical position as stated, or with the results of studies from which that position was formulated. Studies 3b and 5, which showed no emotional modification of startle at either probe time, will not be discussed here. The experimental results for these studies appeared to be caused by a failure of the stimulus materials to elicit emotional processing (as indicated by the absence of late probe time startle modification) rather than failures of early modification specifically.

Early startle modification was more consistent with the predictions of the response matching model on its own: the experimental design of Studies 3a and 4 allowed the predictions of this

model to be tested separately for threat and mutilation content pictures. The results of Study 3a were in line with predictions based on Bradley, Cuthbert, and Lang (1993) and Globisch et al. (1999) — only high FSS-score participants showed early startle modification. When the data were analysed without this median split on the general fear questionnaire (i.e., in comparable experimental conditions to Bradley, Cuthbert, & Lang, 1993), early startle potentiation was still apparent for threat contents at 300 ms. Startle modification for mutilation contents was also restricted to these high fear participants, and was apparent only after several seconds of picture viewing. Combined with the limitation of mutilation-content startle potentiation to high-arousal pictures in Study 4, these data are part of a recent trend for observations of startle potentiation to be limited to specific negative emotional contents (as reviewed in the introduction to Study 3).

The pattern of results from Studies 2, 3a, and 4 suggest an additional formulation to the response matching model regarding negative emotional processing:

1. The hierarchy of startle blink magnitude for negative contents (e.g., Bradley, Codispoti, Cuthbert, & Lang, 2001) represents a continuum of startle modification, calculated over the population as a whole, ranging across pollution (associated with the smallest blink magnitudes), loss, illness, contamination, accidents, mutilation, animal attack, and human attack contents (associated with the greatest blink magnitudes).

2. The basic mechanisms of startle modification do not differ between high and low fear participants, but these mechanisms are influenced by individual sensitivity to negative stimuli.

3. Modification of startle by negative contents (threat and mutilation stimuli) is also influenced by the intensity of the stimuli. There appears to be a wider effective intensity range for threatening stimuli than for mutilation stimuli.

4. Early startle modification is more sensitive to these processes than late startle modification.

This hypothesis does not suggest different causal mechanisms for early and late startle modifi-

cation, but that early startle modification is more sensitive to the same emotional qualities that alter late startle blinks — intensity and participant fearfulness.

Study 4 still did not reveal the factors mediating the specificity of emotional content and arousal. The main alternative to drawing conclusions implicating emotional content as the causal influence behind early startle modification relates to attentional factors. Study 2 showed early blink modification for some threat contents; Study 3a showed early blink potentiation for threat contents but for high general-fear participants only. Neither of these studies explicitly manipulated or directed the participants attention prior to picture onset: Participants were simply asked to view the pictures for their entire duration. In Study 4, picture onset was signalled for 500 ms prior to picture presentation by a white cross in the centre of the computer screen. Blink modification at the early probe time occurred for threat pictures and for highly-arousing mutilation pictures. The difference in results between Study 3a (potentiation for high fear participants only) and Study 4 (potentiation not specific to a fear or anxiety group) could reflect the operation of what might be termed "attentional capture". In Study 4, attention was directed to the pictures from onset, whereas in Study 3a no such manipulation was used. The limitation of early blink potentiation in Study 3a to (a) threat contents and (b) high-fear participants could indicate that these individuals are faster than low-fear individuals at orienting to unpleasant/threatening material when their attention is directed elsewhere. When attention is fixed (Study 4), these between fear-group differences cease to be evident.

These results suggest that the difference between high and low fear participants may be one of directing attention to stimuli rather than different speeds of processing leading to startle modification. This attentional explanation could also apply to the difference between threat and mutilation contents, so that threat contents are better at capturing attention than are mutilation contents, allowing early blink modification for threat contents when attention is not fixed (Studies 2 and 3a) and early blink potentiation for other negative contents when attention is fixed on the display prior to picture presentation. Fixing the participant's gaze on the display may mean that processing by 300 ms occurs to the same extent as at longer picture-to-probe latencies, so that early blink modification would occur for those pictures that would potentiate startle at later

stages of picture processing.

The consistency of startle modification across probe time for both types of mutilation stimuli in Study 4 suggest that attentional or complexity factors are not responsible for the lack of modification for low-arousal contents. If these were influencing startle blink magnitude, we would expect to see no modification at the early probe time, but modification at probe times after several seconds of viewing. One relatively direct mediating factor of the blink modification discrepancy between low and high arousal mutilation contents could be the fear-evoking characteristics of these stimuli, such that only those mutilation contents that elicit fear will potentiate startle. This presumes that the high-arousal mutilation category had a higher proportion of such pictures than did the low-arousal category. This would need to be tested more explicitly, by contrasting mutilation content pictures that are associated with high and low degrees of fear, as reported by participants. A second, more indirect test of this aspect could look at the relationship between amygdala activation, self-report of stimulus fearfulness, and startle potentiation. It is possible that only fear evoking stimuli will activate the amygdala, leading to startle potentiation, and comparing amygdalar activation between negative content pictures that potentiate startle and those that do not may shed further light on emotional specificity of startle modification. It may transpire that the amygdala is necessary for early startle modification, but other mechanisms (such as those involved with anxiety) modify startle at later stages of picture viewing.

These competing hypotheses are somewhat beyond the scope of this thesis, and represent the next step in ascertaining the mechanisms of early startle modification. This thesis showed that startle blink potentiation for negative picture contents can occur in unselected samples at 300 ms probe times, and highlighted emotional specificity and content intensity as two factors that influence early startle modification. The following section deals with the experimental design and some technical details regarding the recording of blink responses that are pertinent to the results of these experiments, and the final section describes some avenues of research that should clarify the role of possible mediating factors involved in early startle modification by negative emotional pictures.

Experimental Design and Technical Issues

The disadvantages of the between-subjects design for probe time in Study 2 has been discussed at length in this General Discussion. This limited the validity of conclusions comparing early and late viewing time responses to the startle probe. The complexity manipulation in Study 5 was also suboptimal, primarily in that it restricted the types of pictures that could reasonably be used in the experiment. Collecting ratings for the pictures used in Studies 3b and 5 would have added validity to the conclusions that the picture contents were generally not emotionally engaging, although the SCR results provided an indication that this was the case.

The methods for allocating pictures to probe times and positions in the presentation orders were also not as randomised as they could ideally have been. Picture combination effects were tested to see if startle modification differed by the particular pictures on which probes were presented, and emotional modification of blink magnitude never differed on the basis of this dimension.

One further aspect of the experimental design that requires some defence is in the collection of questionnaire data following the completion of the startle modification procedure, with the implication that this procedure could influence participants' self-reported fear or anxiety levels. The decision to collect these data following the main experiment was made primarily with concerns in the opposite direction: That asking participants about their fear and anxiety levels prior to beginning the study would lead to heightened expectations of unpleasant stimuli and/or outcomes, and so influence the startle modification data. As the fear questionnaires addressed secondary hypotheses in this thesis, the questionnaires were presented at the completion of the startle modification procedure. It is possible that this procedure led to participants overestimating their levels of fearfulness, and so inflating scores on the questionnaires. The median-split analyses used to investigate these factors should rule out such an occurrence. A more likely possibility, which cannot be resolved here, is that the questionnaire data are less accurate measures than they could have been if responses were collected prior to the main experiment. As discussed above, this was not done in order to avoid influencing the startle modification data.

The advantages of the experimental procedures used reside primarily in the technical details regarding the filtering and rectification of the blink EMG signal. To start with, blink responses are smaller at early probe times than after several seconds of picture viewing, on average over picture contents. Limiting the range of frequencies recorded in the signal (especially restricting the lower frequencies) can significantly reduce the power of that signal. Setting an EMG signal high-pass filter to 90 Hz (so that frequency components below 90 Hz are removed) can remove up to 50% of the signal power (Berg & Balaban, 1999) — several studies have used this setting for studies on early blink modification (e.g., Bradley, Cuthbert, & Lang, 1993; Codispoti et al., 2001; Globisch et al., 1999; Levenston et al., 2000). The high-pass filter used in this study, set to exclude frequencies below 15 Hz (as noted in the method to Study 2, this should have been 28 Hz), may be more suitable for testing early blink modification as smaller signals should be more accurately identified.

Globisch et al. (1999) still detected blink modification in their high-fear participants with 90 Hz high-pass filtering, and so the above explanation does not suffice in explaining null results for early startle modification, unless early blink responding for these participants was particularly large (and so not likely to be distorted by the reduction in signal power). There is no evidence to suggest this was this case.

A second factor that influences the size of responses is the time constant used in rectifying and integrating the EMG signal. This thesis used a relatively short time-constant of 10 ms; Globisch et al. (1999) used a magnitude calculation that was computationally similar to a 60 ms time-constant; Levenston et al. (2000) used an 80 ms time-constant, and both Bradley, Cuthbert, and Lang (1993) and Codispoti et al. (2001) used 123 ms time-constants. The problem here is that using longer time-constants to rectify the blink EMG signal attenuates the power of this signal compared to using a shorter time-constant, and again makes the detection of small responses less likely (Blumenthal, 1994). The use of a shorter time constant for blink EMG signals may be a very important factor in the detection of blink modulation in the early stages of picture viewing.

These considerations highlight the advantage of filtering and/or integrating the raw signal off-line (after recording), as this allows both greater flexibility in the deployment of these settings as well as the ability to compare response patterns between competing methodologies (e.g., 10 ms versus 123 ms time-constant).

Future Directions of Research on Early Startle Blink Modification

To further test the characteristics underlying early modification of the startle response, subsequent studies could begin by testing whether the fear-evoking nature of mutilation pictures is mediating the arousal effect on blink magnitude for these pictures observed in Study 4. Two other areas of research present themselves fairly immediately.

It may be that differences between negative picture categories in early startle potentiation simply reflect the amount of visual information to be processed in a picture, so that the lack of potentiation for some mutilation content pictures (Studies 3a and 4) is indicative of the higher complexity of these pictures compared to threat contents. This seems unlikely, as a fear system (such as that proposed in the introduction to Study 2) should be capable of detecting danger in the presence of distracting information. At very short picture-to-probe onset latencies, this may still have an effect. Varying the foreground pictures' complexity should be one way of answering this question. The complexity manipulation in Study 5 seemed largely ineffective, as well as being unsuitable for certain types of pictures (i.e., those not recognisable in silhouette form). A reasonable alternative may be the presentation of a target stimulus (e.g., snake, dead body) in a display consisting of several additional emotionally neutral stimuli. Comparing blink responses between those displays that contain a negative target, those composed entirely of neutral stimuli, and displays containing only the target stimulus, could be a good step towards answering the question of whether picture complexity influences early startle modification.

Attentional factors could be tested in a similar design to the multiple-image display proposed above as a complexity manipulation. Attention could be directed to a given point in a display

matrix, following which a target stimulus is presented either at the indicated point or at another position. This manipulation could be varied so that displays either included the target stimulus only, or the target stimulus plus distractor stimuli. It should be clear that questions about picture complexity and questions about attentional fixation are investigating the same issues of participant vigilance for negative stimuli, and whether identification of emotional information can occur quickly in the presence of distracting information.

If these studies were to include participant fearfulness in their experimental design, then screening of questionnaire scores from a large sample of potential participants combined with proactive recruitment of high and low fear participants would give a more powerful design for testing these differences.

Summary of General Discussion

This thesis used startle reflex modification to assess emotional processing of picture content at very short latencies. Two questions raised at the start of this General Discussion were whether early modification of startle was specific to highly-fearful individuals, and whether this could be limited to certain categories of negative stimuli. The results indicated that emotional modification of the startle reflex can take place within 300 ms of picture onset.

To summarise:

1. Early blink modification was observed in unselected samples for threat stimuli (Studies 2, 3a, and 4).

2. Early modification for mutilation stimuli was limited to high-arousal contents, and only when picture onset was signalled (Study 4).

3. There was limited evidence that only high fear participants showed early startle potentiation when picture onset was not signalled (Study 3a).

4. Two of the studies showed either no emotional modification of startle (Study 3b) or very limited evidence of startle modification (Study 5). The emotional pictures used in these studies were most likely unsuccessful at eliciting emotional processing, rather than being indicative of differences in startle modification as such.

These results show that the emotional content of picture stimuli can be identified within 300 ms of picture onset; attentional explanations were offered as to why the observed effects differed between experiments where picture onset was signalled and experiments where no warning were given of picture presentation. The results of Studies 2, 3a, and 4 indicate that processing of the emotional content of pictures, as indexed by the startle reflex, can occur within 300 ms of picture onset.

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Appendix A

Self-Assessment Manikin Display Screen

Figure A1 presents the SAM display screen used to collect participant ratings of the emotional dimensions for pictures in Study 1. In the computer programme, the SAM characters were pink with yellow hair, and the superimposed 'explosion' depicted on the arousal dimension was white. The top row represents the valence dimension, from very pleasant (far left, score of 9) to very unpleasant (far right, score of 1). The second row represents the arousal dimension, from highly arousing (far left, score of 9) through to calm (far right, score of 1). The bottom row represents the dominance dimension, from dominated/not in control (far left, score of 1) to dominant/in control (far right, score of 9). Once a picture had been displayed for six seconds, participants selected a single box on each dimension. For valence and arousal, the five boxes from left to right returned values when selected of 9, 7, 5, 3, and 1. For dominance, the five boxes from left to right returned values when selected of 1, 3, 5, 7, and 9.

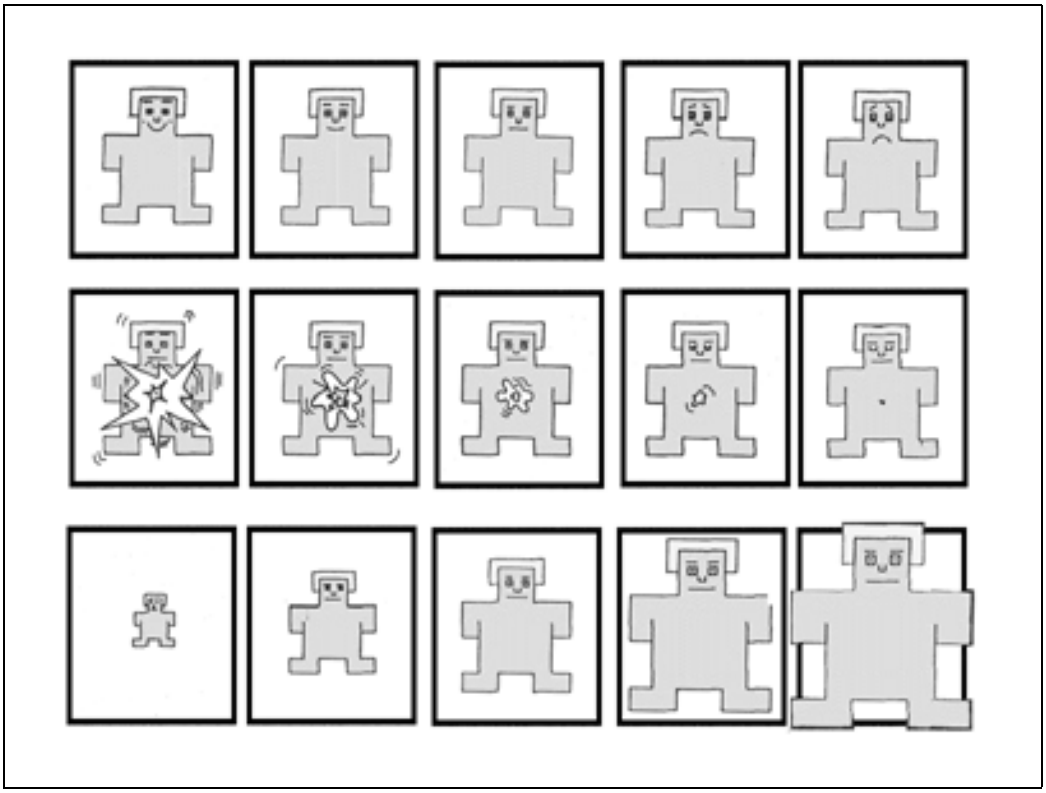

Figure A1. Display screen for SAM picture ratings, used to collect ratings in Study 1. The top row is for valence ratings, the middle row for arousal ratings, and the bottom row for dominance ratings.

Appendix B

SNAQ, SPQ, and MQ Questionnaires

Each questionnaire was preceded by the following instruction: “Please circle TRUE if the item is true, or mostly true of you. Circle FALSE if the item is false or mostly false of you.”. The items for each questionnaire are presented below. For items that were modified for New Zealand participants, the original phrasing is given in square brackets at the appropriate point. Each participants’ score represents the number of items circled as ‘TRUE’; some items were reverse scored, so that ‘FALSE’ responses counted towards the total. These items are marked with a dagger.

SNAQ Inventory

1. I avoid going to parks or on camping trips because there may be snakes about.
2. I would feel some anxiety holding a toy snake in my hand.
3. If a picture of a snake appears on the screen during a motion picture, I turn my head away.
4. I dislike looking at pictures of snakes in a magazine.
5. Although it may not be so, I think of snakes as slimy.
6. I enjoy watching snakes at the zoo. †
7. I am terrified by the thought of touching a harmless snake.
8. If someone says that there are snakes anywhere about, I become alert and on edge.
9. I would not go swimming at the beach if snakes had ever been reported in the area.
10. I would feel uncomfortable wearing a snakeskin belt.
11. When I see a snake, I feel tense and restless.
12. I enjoy reading articles about snakes and other reptiles. †
13. I feel sick when I see a snake.
14. Snakes are sometimes useful.
15. I shudder when I think of snakes.
16. I don’t mind being near a non-poisonous snake if there is someone there in whom I have confidence. †
17. Some snakes are attractive to look at. †
18. I don’t believe anyone could hold a snake without some fear.
19. The way snakes move is repulsive.
20. It wouldn’t bother me to touch a dead snake with a long stick. †
21. If I came upon a snake in the woods I would probably run.
22. I’m more afraid of snakes than any other animal.
23. I would not want to travel to Australia [“down south”] or in tropical countries, because of the greater prevalence of snakes.
24. I wouldn’t take a course like biology if I thought you might have to dissect a snake.
25. I have no fear of non-poisonous snakes. †
26. Not only am I afraid of snakes, but worms and most reptiles make me feel anxious.

27. Snakes are very graceful animals. †
28. I think that I'm no more afraid of snakes than the average person. †
29. I would prefer not to finish a story if something about snakes was introduced into the plot.
30. Even if I was late for a very important appointment, the thought of snakes would stop me from taking a shortcut through an open field.

SPQ Inventory

1. I avoid going to parks or on camping trips because there may be spiders there.
2. I would feel some anxiety holding a toy spider in my hand.
3. If a picture of a spider crawling on a person appears on the screen during a motion picture, I turn my head away.
4. I dislike looking at pictures of spiders in a magazine.
5. If there is a spider on the ceiling over my bed, I cannot go to sleep unless someone kills it for me.
6. I enjoy watching spiders build webs. †
7. I am terrified by the thought of touching a harmless spider.
8. If someone says that there are spider anywhere about, I become alert and on edge.
9. I would not go down to the garage [basement] to get something if I thought there might be spiders there.
10. I would feel uncomfortable if a spider crawled out my shoe as I took it out of the closet to put it on.
11. When I see a spider, I feel tense and restless.
12. I enjoy reading articles about spiders. †
13. I feel sick when I see a spider.
14. Spiders are sometimes useful. †
15. I shudder when I think of spiders.
16. I don't mind being near a harmless spider if there is someone there in whom I have confidence. †
17. Some spiders are very attractive to look at. †
18. I don't believe anyone could hold a spider without some fear.
19. The way spiders move is repulsive.
20. It wouldn't bother me to touch a dead spider with a long stick. †
21. If I came upon a spider while cleaning the attic I would probably run.
22. I'm more afraid of spiders than any other animal.
23. I would not want to travel to Australia [Mexico or Central America] because of the greater prevalence of poisonous spiders.
24. I am cautious when buying fruit because bananas may attract spiders.
25. I have no fear of non-poisonous spiders. †
26. I wouldn't take a course in biology if I thought I might have to handle live spiders
27. Spider webs are very artistic. †
28. I think that I'm not more afraid of spiders than the average person. †
29. I would prefer not to finish a story if something about spiders was introduced into the plot.
30. Even if I was late for a very important appointment, the thought of spiders would stop me from taking a shortcut through an underpass.
31. Not only am I afraid of spiders but millipedes and caterpillars make me feel anxious.

MQ Inventory

1. I could not remove the hook from a fish that was caught.
2. I would feel some revulsion looking at a preserved brain in a bottle.
3. If a badly injured person appears on TV, I turn my head away.
4. I dislike looking at pictures of accidents or injuries in magazines.
5. I do not mind visiting a hospital and seeing ill or injured persons. †
6. Medical odors make me tense and uncomfortable.
7. I would not go hunting because I could not stand the sight of a dead animal.
8. Watching a butcher at work would make me anxious.
9. A career as a doctor or nurse is very attractive to me. †
10. I would feel faint if I saw someone with a wound in the eye.
11. Watching people use sharp power tools makes me nervous.
12. The prospect of getting an injection or seeing someone else get one bothers me quite a bit.
13. I feel sick or faint at the sight of blood.
14. I enjoy reading articles about modern medical techniques. †
15. Injuries, accidents, blood, etc., bother me more than anything else.
16. Under no circumstances would I accept an invitation to watch a surgical operation.
17. When I see an accident I feel tense.
18. It would not bother me to see a bad cut as long as it had been cleaned and stitched. †
19. Using very sharp knives makes me nervous.
20. Not only do cuts and wounds upset me, but the sight of people with amputated limbs, large scars, or plastic surgery also bothers me.
21. If instruments were available, it would be interesting to see the action of the internal organs in a living body. †
22. I am frightened at the idea of someone drawing a blood sample from me.
23. I don’t believe anyone could help a person with a bloody wound without feeling at least a little upset.
24. I am terrified by the idea of having surgery.
25. I am frightened by the thought that I might some day have to help a person badly hurt in a car wreck.
26. I shudder when I think of accidentally cutting myself.
27. The sight of dried blood is repulsive.
28. Blood and gore upset me no more than the average person. †
29. The sight of an open wound nauseates me.
30. I could never swab out a wound.

Appendix C

Items from the FSS-II-R Questionnaire

The instructions for this questionnaire were as follows: “Please read through the following list of items and situations, and circle the word that best describes the amount of fear that you feel towards that object or situation. Please circle *one word only* per description.”

The possible fear words for each item and their score were: None (1), Very little (2), A little (3), Some (4), Much (5), Very much (6), and Terror (7). The fear items/situations were:

Sharp objects	Illness or injury to loved ones
Being a passenger in a car	Driving a car
Dead bodies	Mental illness
Suffocating	Closed places
Being a passenger in an airplane	Boating
Worms	Spiders
Rats and mice	Thunderstorms
Hypodermic needles	Snakes
Sharks	Cemeteries
Roller coasters	Seeing a fight
Being alone	Death of a loved one
Death	Dark places
Being in a fight	Strange dogs
Fire	Deep water
Blood	Sight of weapons
Heights	Stinging insects
Swimming alone	Untimely or early death
Illness	Car accidents
Electric shock	Strangers
Domestic animals	

Appendix D

IAPS Picture Valence and Arousal Ratings from Study 1

The following are the means and standard errors for all pictures rated by participants in Study 1. The IAPS number and descriptions are as stated in the IAPS manual (Lang et al., 1999b). The 'Category' column details which of the three basic affective categories the picture was placed in for analysis in Study 1. The detail in square brackets indicates the specific negative category these pictures were placed in. [Sn] represents snake pictures, [Sp] spider pictures, [An] non-snake/spider unpleasant animals, [T] non-animal threat pictures, and [M/D] mutilation or disgust pictures.

Table D1: Means (and Standard Errors) for Valence and Arousal Ratings of IAPS Pictures in Study 1.

IAPS Number	Description	Valence	Arousal	Category
1019	Snake	3.41 (.26)	5.09 (.3)	Negative [Sn]
1022	Snake	3.68 (.26)	4.95 (.33)	Negative [Sn]
1030	Snake	4.77 (.26)	3.36 (.3)	Negative [Sn]
1040	Snake	3.55 (.22)	4.82 (.31)	Negative [Sn]
1050	Snake	3.37 (.31)	5.37 (.32)	Negative [Sn]
1051	Snake	3.88 (.32)	4.81 (.3)	Negative [Sn]
1052	Snake	3.84 (.23)	4.67 (.32)	Negative [Sn]
1070	Snake	4.12 (.28)	4.12 (.31)	Negative [Sn]
1080	Snake	4.49 (.26)	3.70 (.29)	Negative [Sn]
1090	Snake	4.30 (.28)	3.84 (.32)	Negative [Sn]
1101	Snake	4.35 (.28)	4.21 (.31)	Negative [Sn]
1110	Snake	4.59 (.25)	4.23 (.3)	Negative [Sn]
1111	Snake	3.77 (.25)	4.68 (.32)	Negative [Sn]
1112	Snake	3.82 (.29)	5.27 (.35)	Negative [Sn]
1113	Snake	3.82 (.24)	4.55 (.34)	Negative [Sn]
1120	Snake	3.28 (.29)	5.19 (.3)	Negative [Sn]

Table D1: continued.

IAPS Number	Description	Valence	Arousal	Category
1121	Lizard	6.23 (.26)	3.05 (.26)	Positive
1200	Spider	3.98 (.32)	4.35 (.39)	Negative [Sp]
1201	Spider	3.93 (.26)	4.44 (.32)	Negative [Sp]
1220	Spider	3.65 (.24)	4.44 (.34)	Negative [Sp]
1230	Spider	4.72 (.27)	3.98 (.35)	Negative [Sp]
1240	Spider	4.68 (.31)	3.77 (.3)	Negative [Sp]
1270	Cockroach	4.00 (.23)	3.68 (.25)	Negative [An]
1274	Cockroach	3.95 (.24)	3.91 (.29)	Negative [An]
1275	Cockroach	4.23 (.25)	3.68 (.28)	Negative [An]
1280	Rat	2.86 (.21)	4.64 (.33)	Negative [An]
1300	Pit Bull	2.68 (.22)	5.82 (.28)	Negative [An]
1301	Dog	3.74 (.27)	4.30 (.33)	Negative [An]
1302	Dog	4.07 (.27)	4.44 (.33)	Negative [An]
1303	Dog	4.00 (.25)	4.41 (.33)	Negative [An]
1313	Frog	5.77 (.22)	3.27 (.26)	Positive
1321	Bear	4.91 (.35)	4.07 (.3)	Negative [An]
1460	Kitten	8.18 (.2)	3.36 (.33)	Positive
1610	Rabbit	7.05 (.25)	2.59 (.26)	Positive
1620	Springbok	7.65 (.22)	2.16 (.25)	Positive
1670	Cow	6.67 (.24)	1.79 (.21)	Positive
1710	Puppies	8.72 (.11)	3.65 (.4)	Positive
1720	Lion	6.81 (.26)	3.28 (.25)	Positive
1721	Lion	8.14 (.15)	3.41 (.33)	Positive
1750	Bunnies	8.09 (.17)	2.95 (.33)	Positive
1910	Grouper	6.09 (.25)	2.45 (.25)	Positive
1920	Porpoise	7.91 (.22)	3.32 (.37)	Positive

Table D1: continued.

IAPS Number	Description	Valence	Arousal	Category
1930	Shark	2.91 (.28)	6.18 (.28)	Negative [An]
1931	Shark	3.98 (.23)	5.14 (.33)	Negative [An]
2030	Woman	6.67 (.27)	2.07 (.26)	Positive
2040	Baby	8.07 (.2)	2.95 (.28)	Positive
2050	Baby	7.68 (.22)	3.09 (.31)	Positive
2160	Father	7.64 (.23)	3.23 (.31)	Positive
2200	Neutral Face	5.50 (.19)	2.45 (.25)	Neutral
2210	Neutral Face	4.68 (.17)	2.77 (.25)	Neutral
2220	Male face	4.86 (.25)	3.09 (.27)	Neutral
2250	Neutral baby	6.45 (.29)	2.77 (.29)	Neutral
2276	Girl	2.55 (.2)	3.73 (.3)	Neutral
2530	Couple	7.93 (.18)	2.40 (.26)	Positive
2540	Mother	7.79 (.21)	2.81 (.3)	Positive
2650	Boy	7.23 (.19)	1.79 (.22)	Neutral
2692	Bomb	3.73 (.22)	4.23 (.37)	Negative [T]
2840	Chess	5.27 (.21)	1.86 (.2)	Neutral
3000	Mutilation	1.27 (.1)	7.50 (.3)	Negative [M/D]
3010	Mutilation	1.45 (.2)	6.86 (.29)	Negative [M/D]
3100	Mutilation	1.45 (.14)	6.82 (.32)	Negative [M/D]
3140	Mutilation	1.68 (.18)	6.50 (.3)	Negative [M/D]
3150	Mutilation	2.12 (.19)	6.16 (.38)	Negative [M/D]
3170	Mutilation	1.65 (.22)	6.49 (.37)	Negative [M/D]
3280	Dental exam	3.50 (.22)	4.23 (.31)	Negative [M/D]
4180	Erotic female	5.95 (.26)	3.41 (.37)	Positive
4210	Erotic female	5.00 (.41)	4.12 (.41)	Positive
4235	Erotic female	5.41 (.34)	3.73 (.34)	Positive

Table D1: continued.

IAPS Number	Description	Valence	Arousal	Category
4240	Erotic female	5.00 (.35)	3.59 (.35)	Positive
4250	Attractive female	6.72 (.25)	2.53 (.29)	Positive
4290	Erotic female	4.21 (.38)	3.98 (.4)	Positive
4470	Erotic male	5.00 (.33)	3.51 (.33)	Positive
4500	Attractive man	5.98 (.28)	2.49 (.24)	Positive
4510	Attractive man	5.86 (.25)	2.77 (.25)	Positive
4520	Erotic male	6.50 (.26)	3.50 (.34)	Positive
4550	Erotic male	5.32 (.32)	3.95 (.3)	Positive
4611	Erotic couple	6.64 (.25)	4.23 (.33)	Positive
4653	Erotic couple	6.95 (.24)	3.47 (.32)	Positive
4660	Erotic couple	6.63 (.25)	3.42 (.32)	Positive
5200	Flowers	7.74 (.21)	2.02 (.24)	Neutral
5520	Mushroom	5.70 (.22)	1.65 (.21)	Neutral
5530	Mushroom	5.56 (.23)	1.51 (.18)	Neutral
5731	Flowers	7.00 (.23)	1.79 (.2)	Neutral
5740	Plant	5.86 (.19)	1.64 (.19)	Neutral
5760	Nature	7.95 (.19)	2.91 (.31)	Neutral
5820	Mountains	6.86 (.33)	3.23 (.35)	Neutral
5830	Sunset	8.05 (.19)	3.50 (.36)	Positive
5875	Bicyclist	6.63 (.23)	2.02 (.24)	Positive
5900	Desert	6.72 (.26)	2.58 (.33)	Neutral
5982	Sky	7.51 (.25)	3.23 (.31)	Neutral
6000	Prison	3.64 (.22)	4.09 (.32)	Negative [T]
6020	Electric chair	3.14 (.24)	4.49 (.33)	Negative [T]
6150	Outlet	5.27 (.15)	1.68 (.21)	Neutral
6190	Aimed gun	3.60 (.25)	4.53 (.32)	Negative [T]

Table D1: continued.

IAPS Number	Description	Valence	Arousal	Category
6200	Aimed gun	3.98 (.21)	3.84 (.31)	Negative [T]
6210	Aimed gun	4.02 (.24)	3.84 (.28)	Negative [T]
6230	Aimed gun	2.86 (.18)	5.50 (.34)	Negative [T]
6243	Aimed gun	3.23 (.25)	4.86 (.33)	Negative [T]
6244	Aimed gun	2.86 (.23)	5.36 (.34)	Negative [T]
6250	Aimed gun	3.23 (.22)	5.23 (.29)	Negative [T]
6260	Aimed gun	3.09 (.24)	5.93 (.32)	Negative [T]
6300	Knife	2.86 (.21)	5.37 (.33)	Negative [T]
6410	Aimed gun	4.26 (.23)	3.28 (.28)	Negative [T]
6930	Missiles	4.91 (.21)	2.40 (.26)	Negative [T]
7000	Rolling pin	5.14 (.16)	1.50 (.21)	Neutral
7002	Towel	5.32 (.14)	1.50 (.2)	Neutral
7006	Bowl	5.09 (.11)	1.23 (.12)	Neutral
7010	Basket	5.18 (.11)	1.45 (.17)	Neutral
7020	Fan	5.56 (.22)	1.37 (.17)	Neutral
7030	Iron	5.19 (.13)	1.60 (.17)	Neutral
7050	Hair dryer	5.42 (.17)	1.28 (.14)	Neutral
7060	Trash can	5.09 (.18)	1.42 (.18)	Neutral
7080	Fork	5.32 (.14)	1.45 (.18)	Neutral
7090	Book	5.32 (.13)	1.59 (.2)	Neutral
7100	Fire hydrant	5.14 (.14)	1.36 (.15)	Neutral
7110	Hammer	4.91 (.13)	2.05 (.24)	Neutral
7130	Truck	5.47 (.2)	1.74 (.22)	Neutral
7150	Umbrella	5.56 (.23)	1.47 (.22)	Neutral
7170	Light bulb	5.56 (.2)	1.42 (.16)	Neutral
7182	Checkerboard	5.56 (.24)	3.00 (.27)	Neutral

Table D1: continued.

IAPS Number	Description	Valence	Arousal	Category
7190	Clock	5.41 (.17)	1.68 (.21)	Neutral
7200	Brownie	7.05 (.24)	2.44 (.3)	Positive
7207	Beads	5.41 (.24)	2.18 (.25)	Neutral
7211	Clock	5.27 (.14)	1.64 (.23)	Neutral
7224	File cabinets	5.00 (.11)	1.59 (.21)	Neutral
7230	Turkey	7.23 (.26)	2.53 (.33)	Positive
7270	Ice cream	7.65 (.21)	2.77 (.31)	Positive
7325	Watermelon	8.12 (.18)	2.49 (.29)	Positive
7350	Pizza	7.05 (.26)	3.05 (.29)	Positive
7491	Building	5.33 (.2)	1.84 (.21)	Neutral
7495	Store	5.93 (.21)	2.02 (.27)	Neutral
7500	Building	5.23 (.17)	1.70 (.25)	Neutral
7503	Card dealer	5.70 (.19)	2.12 (.28)	Neutral
7560	Freeway	4.73 (.22)	2.73 (.32)	Neutral
7580	Desert	8.14 (.18)	3.36 (.36)	Positive
7590	Traffic	4.95 (.2)	2.77 (.27)	Neutral
7600	Dragon	6.55 (.23)	3.36 (.29)	Positive
7620	Jet	6.53 (.27)	2.53 (.31)	Neutral
7830	Agate	5.23 (.17)	1.88 (.21)	Neutral
7900	Violin	6.16 (.2)	1.47 (.16)	Neutral
7920	Car crash	5.09 (.28)	2.35 (.25)	Neutral
7950	Tissue	5.23 (.15)	1.32 (.14)	Neutral
8030	Skier	7.09 (.25)	6.09 (.32)	Positive
8080	Sailing	6.95 (.24)	4.32 (.31)	Positive
8120	Athlete	7.18 (.21)	2.59 (.25)	Positive
8200	Water skier	7.84 (.18)	3.93 (.35)	Positive

Table D1: continued.

IAPS Number	Description	Valence	Arousal	Category
8350	Tennis player	7.56 (.2)	3.14 (.33)	Positive
8370	Rafting	7.88 (.21)	4.72 (.32)	Positive
8500	Gold	7.14 (.27)	3.51 (.38)	Positive
9007	Needles	2.77 (.2)	4.86 (.33)	Negative [M/D]
9008	Needle	3.41 (.29)	3.59 (.29)	Negative [M/D]
9140	Cow	2.64 (.18)	4.45 (.29)	Negative [M/D]
9180	Dead seal	2.91 (.28)	3.93 (.28)	Negative [M/D]
9400	Soldier	2.02 (.19)	5.19 (.34)	Negative [M/D]
9571	Dead cat	1.74 (.15)	5.47 (.32)	Negative [M/D]
9582	Dental exam	3.60 (.24)	4.21 (.33)	Negative [M/D]
9584	Dental exam	3.79 (.2)	3.60 (.3)	Negative [M/D]
9592	Injection	4.21 (.2)	3.70 (.3)	Negative [M/D]
9594	Injection	4.49 (.19)	3.42 (.28)	Negative [M/D]
9630	Nuclear bomb	3.41 (.38)	5.18 (.33)	Negative [T]

Appendix E

Pictures used in Study 2

The pictures used in Study 2 are listed in Table E1. The following IAPS pictures were also included as 'Filler' pictures: 3000 (Mutilation), 3150 (Mutilation), 9180 (Dead Seal), 9400 (Dead Soldier). Startle probes were never presented during 'Filler' negative contents.

Table E1: Picture set used in Study 2.

Positive		Neutral		Animal Threat		Human Threat	
1460	Kitten	2200	Neutral Face	1050	Snake	2692	Bomb
1710	Puppies	2210	Neutral Face	1051	Snake	6020	Electric chair
1720	Lion	2840	Chess	1052	Snake	6190	Aimed gun
1920	Porpoise	5520	Mushroom	1120	Snake	6230	Aimed gun
2040	Baby	5530	Mushroom	1300	Pit Bull	6244	Aimed gun
2530	Couple	5740	Plant	1301	Dog	6260	Aimed gun
5982	Sky	6150	Outlet	1930	Shark	6250	Aimed gun
7200	Brownie	7000	Rolling pin	1931	Shark	6300	Knife
7270	Ice cream	7002	Towel				
7350	Pizza	7006	Bowl				
7580	Desert	7050	Hair dryer				
7600	Dragon	7130	Truck				
8030	Skier	7182	Checkerboard				
8200	Water skier	7190	Clock				
8350	Tennis player	7207	Beads				
8370	Rafting	7224	File cabinets				
4210/2160	Nude	7503	Card dealer				
4235/4520	Nude	7590	Traffic				
4240/4550	Nude	7830	Agate				
4611	Erotic Couple	7950	Tissue				

Note. For nude pictures, the first picture number noted was used for male participants, and the second for female participants.

Appendix F

Pictures used in Studies 3a and 3b

The pictures used in Study 3a and Study 3b are listed in Table F1. Table F2 presents a list of 'Filler' pictures used in both Studies 3a and 3b. Startle probes were not presented on these pictures in either study.

Table F1: Picture set used in Studies 3a and 3b.

Positive		Neutral		Mutilation		Threat	
Study 3a							
1460	Kitten	2840	Chess	3140	Mutilation	1300	Pit Bull
2040	Baby	5740	Plant	3150	Mutilation	1301	Dog
2530	Couple	7006	Bowl	3170	Mutilation	6244	Aimed gun
4210/4520	Nude	7182	Checkerboard	9008	Needle	6250	Aimed gun
7350	Pizza	7503	Card dealer	9140	Cow	6260	Aimed gun
8030	Skier	7830	Agate	9400	Soldier	6300	Knife
Study 3b							
1710	Puppies	5520	Mushroom	3000	Mutilation	1321	Bear
1920	Porpoise	6150	Outlet	3010	Mutilation	1930	Shark
2540	Mother	7050	Hair dryer	3051	Mutilation *	6190	Aimed gun
4235/4550	Nude	7207	Beads	9433	Dead man *	6230	Aimed gun
7270	Ice cream	7590	Traffic	9500	Porpoises *	6243	Aimed gun
8200	Water skier	7950	Tissue	9571	Dead cat	6510	Attack *

Note. For nude pictures, the first picture number noted was used for male participants, and the second for female participants. Asterisks indicate that the picture was not rated in Study 1, and so IAPS standardised ratings for these pictures were used in calculating mean valence and arousal ratings reported in Table 13.

Table F2: ‘Filler’ Pictures used in Studies 3a and 3b.

2200	Neutral Face	1460	Kitten
2210	Neutral Face	1720	Lion
5530	Mushroom	4611	Erotic Couple
7000	Rolling Pin	7200	Brownie
7002	Towel	7580	Desert
7130	Truck	7600	Dragon
7190	Clock	8350	Tennis player
7224	Filing cabinet	8370	Rafting
4240	Nude (Male Participants)	2160	Father (Female Participants)

Appendix G

Pictures used in Study 4

Table G1 lists the IAPS pictures used in Study 4, and divides them into Emotional Categories and Arousal conditions.

Table G1: High and Low Arousal Pictures Used in Study 4, Divided by Emotional Category.

	Arousal Condition			
	High		Low	
Threat	1050	Snake	1301	Dog
	1300	Pit Bull	6020	Electric Chair
	6230	Aimed Gun	6190	Aimed Gun
	6250	Aimed Gun	6243	Aimed Gun
	6260	Aimed Gun	6244	Aimed Gun
	6300	Knife	6410	Aimed Gun
Mutilation	3000	Mutilation	3051	Mutilation
	3030	Mutilation	3550	Injury
	3071	Mutilation	9140	Cow
	3150	Mutilation	9400	Soldier
	3400	Severed hand	9433	Dead man
	9250	War victim	9571	Cat
Neutral	2220	Male Face	5530	Mushroom
	2230	Sad face	6150	Outlet
	7190	Clock	7130	Truck
	7620	Jet	7500	Building
	7820	Agate	7550	Office
	7830	Agate	9070	Boy
Positive	4180/4290	Nude	1710	Puppies
	4500/4510	Nude	2160	Father
	4660	Erotic Couple	7200	Brownie
	8030	Skier	7230	Turkey
	8080	Sailing	7270	Ice Cream
	8200	Water skier	8500	Gold

Note. For nude pictures, the first picture number noted was used for male participants, and the second for female participants.

Appendix H

Pictures and Silhouettes [Simple Pictures] used in Study 5

Table H1 lists the pictures that were included in the 'complex' picture conditions for the positive, neutral, and spider categories. An asterisk denotes those colour pictures that were created for this study by the author, and are available on request. Numbers in square brackets indicates that an IAPS photograph was used as a background to a non-IAPS foreground item. A brief description is provided for these pictures. Table H2 lists the IAPS photographs used as filler pictures in this study.

Table H1: Complex Condition Pictures Used in Study 5.

Condition	IAPS Number	Description
Spiders	1200	
	1201	
	1220	
	1230	
	1240	
	Spider *	Small spider on leaf
Neutral	5520	
	7110	
	7211	
	7004	
	7035	
	7150	
Positive	5010	
	Flower *	White flowers on leaf background
	Flower *	Pink and yellow flower
	[7705] *	Apple on background of toolbox [IAPS]
	[7237] *	Bananas on abstract background [IAPS]
	[7182] *	Candy on abstract background [IAPS]

Table H2: IAPS Filler Pictures Used in Study 5.

Positive		Neutral		Negative	
1440	Seal	2200	Neutral face	1930	Shark
2540	Mother	5250	Nature	6020	Electric chair
7270	Ice cream	7050	Hair dryer	6230	Aimed gun
8021	Skier	7500	Building	9001	Cemetery

The following pages include the ‘simple’ condition pictures used in Study 5. These pictures were presented as white foregrounds on black background to match more closely in overall brightness to the ‘complex’ condition pictures, but are presented here as negative images (i.e., black foreground on white background) to facilitate viewing and printing.

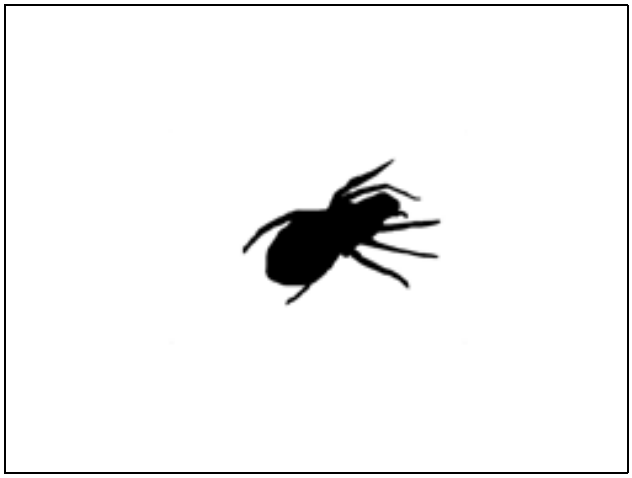

Figure H1. Spider silhouette used in Study 5

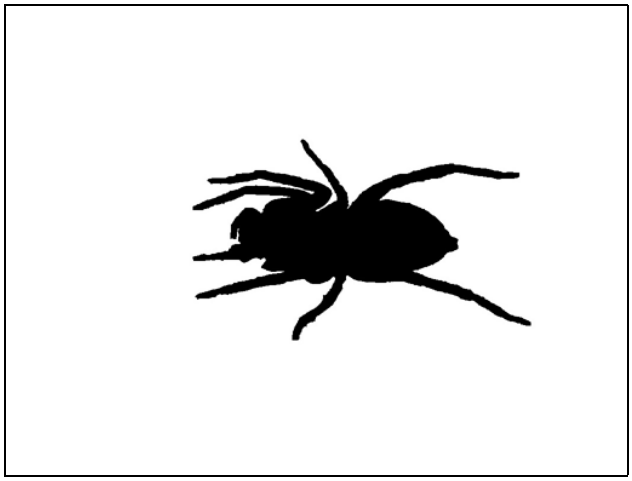

Figure H2. Spider silhouette used in Study 5

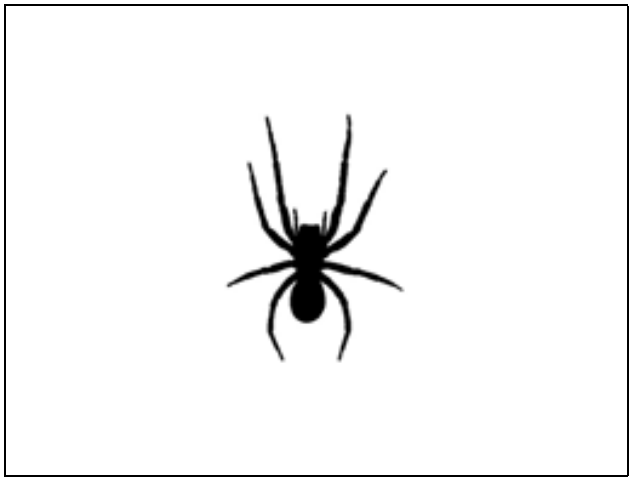

Figure H3. Spider silhouette used in Study 5

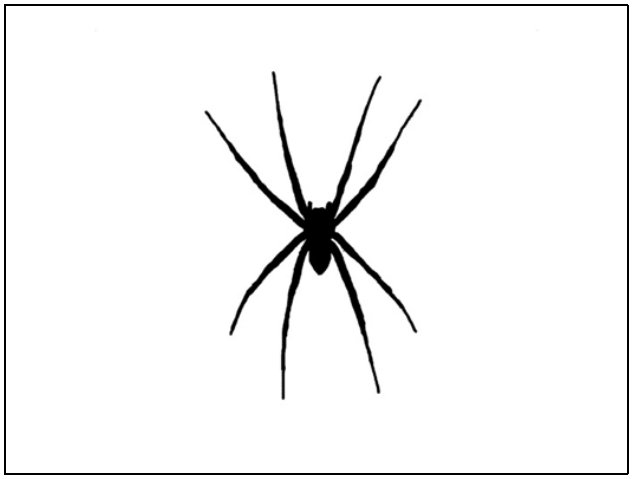

Figure H4. Spider silhouette used in Study 5

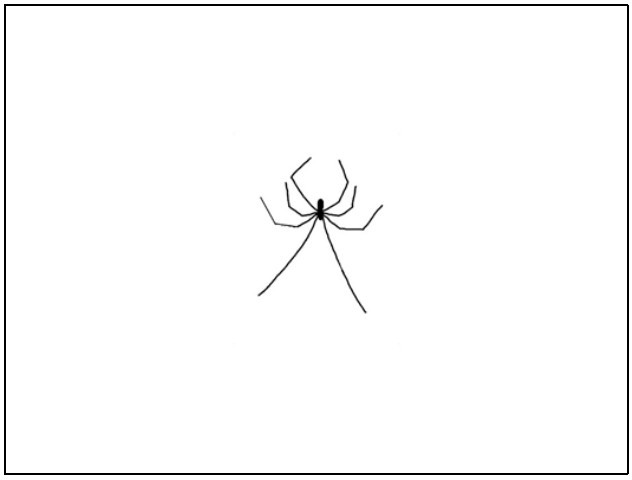

Figure H5. Spider silhouette used in Study 5

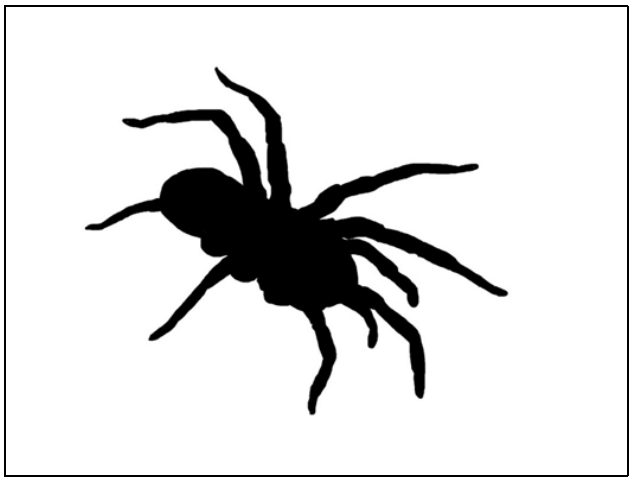

Figure H6. Spider silhouette used in Study 5

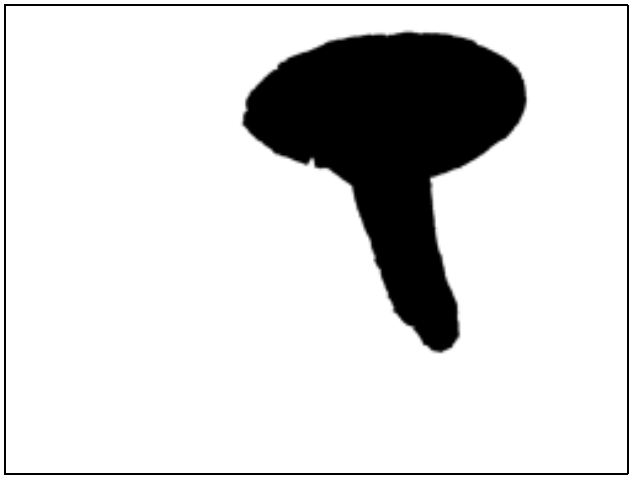

Figure H7. Neutral condition silhouette used in Study 5, adapted from IAPS picture 5500

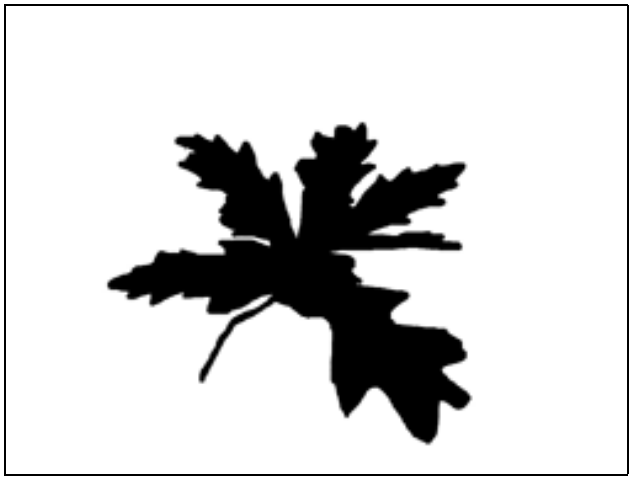

Figure H8. Neutral condition silhouette used in Study 5, adapted from IAPS picture 5740

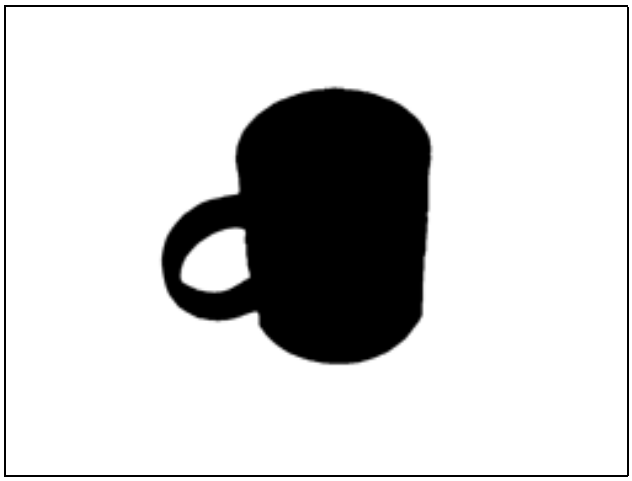

Figure H9. Neutral condition silhouette used in Study 5, adapted from IAPS picture 7009

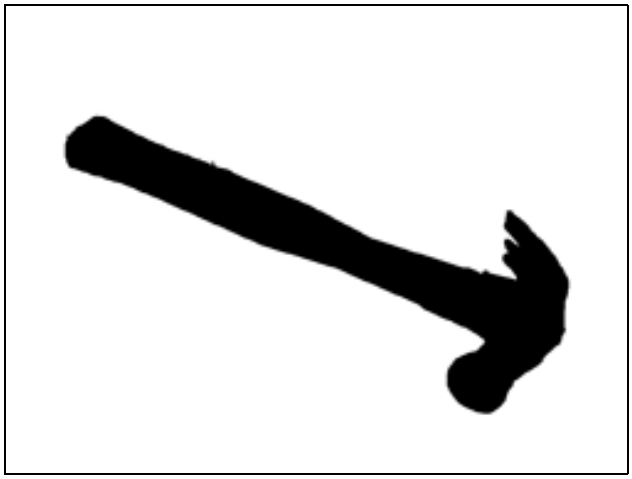

Figure H10. Neutral condition silhouette used in Study 5, adapted from IAPS picture 7034

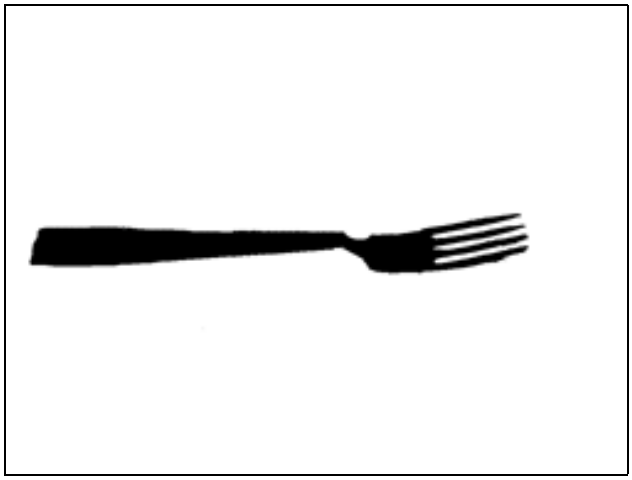

Figure H11. Neutral condition silhouette used in Study 5, adapted from IAPS picture 7080

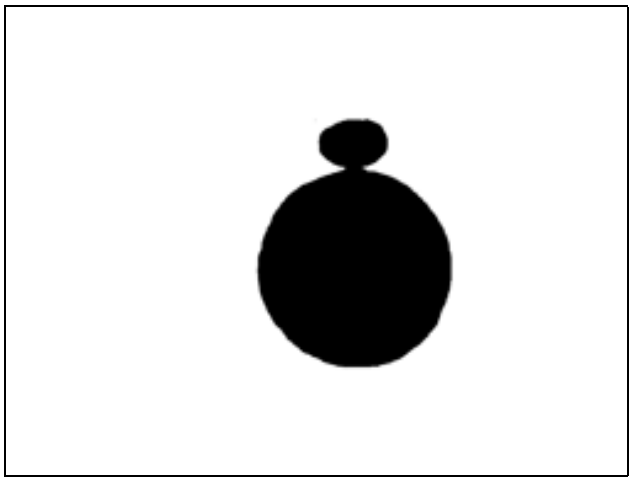

Figure H12. Neutral condition silhouette used in Study 5, adapted from IAPS picture 7190

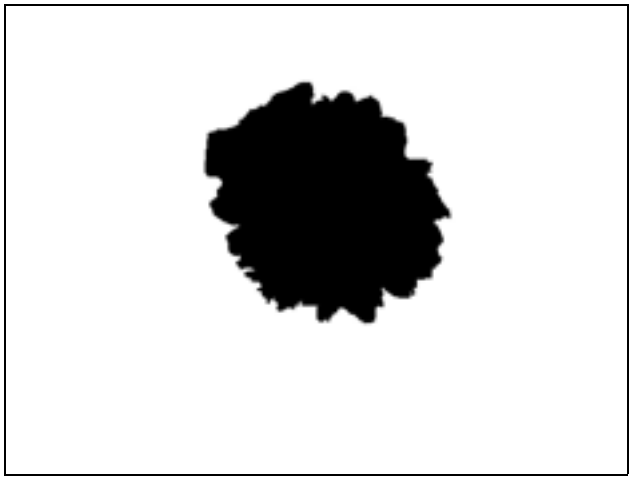

Figure H13. Positive condition silhouette used in Study 5, adapted from IAPS picture 5001

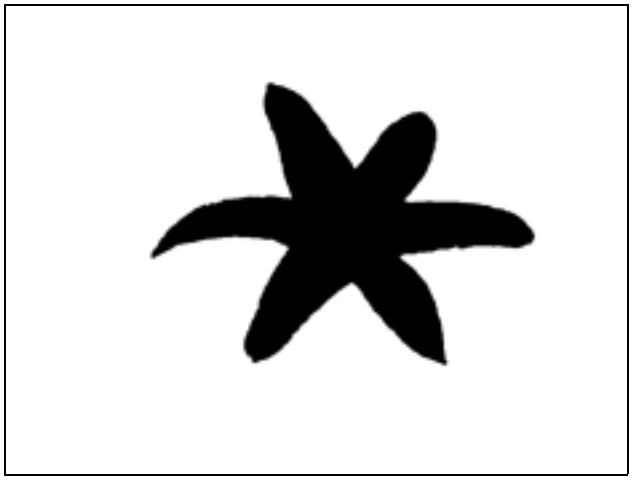

Figure H14. Positive condition silhouette used in Study 5, adapted from IAPS picture 5030

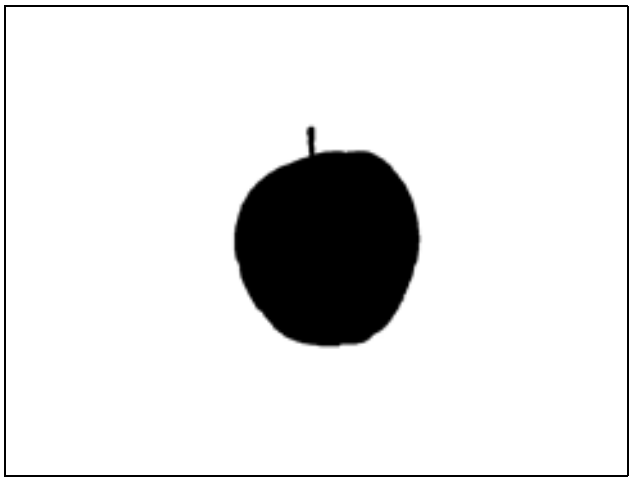

Figure H15. Positive condition silhouette used in Study 5

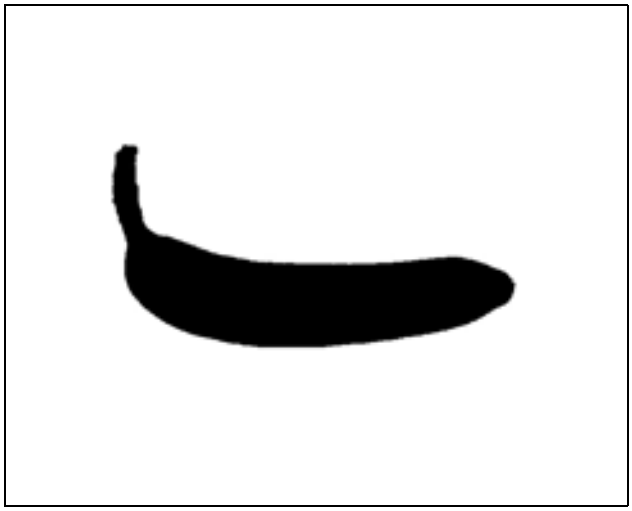

Figure H16. Positive condition silhouette used in Study 5

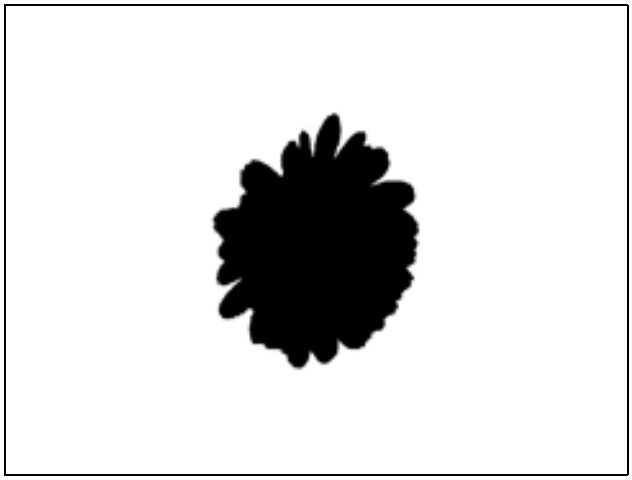

Figure H17. Positive condition silhouette used in Study 5

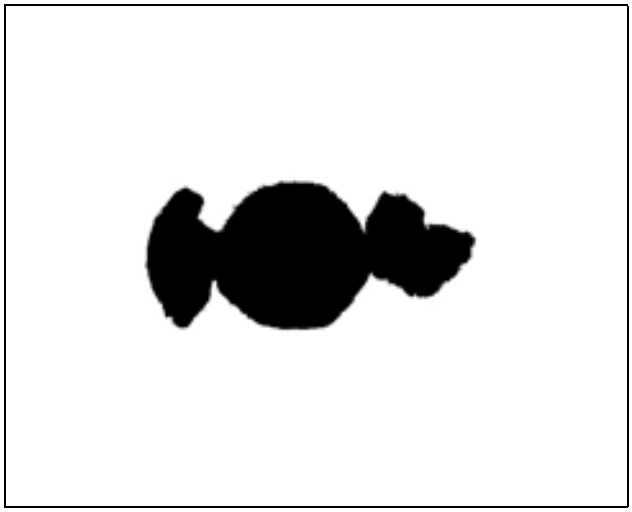

Figure H18. Positive condition silhouette used in Study 5