

**Enhanced Detection Sensitivity to Negative  
Emotional Valence: The Role of Awareness,  
Attention, Anxiety, and Reward**

**Maha Nasrallah**



Institute of Cognitive Neuroscience,  
University College London, UK

Prepared under the supervision of Prof. Nilli Lavie

**Submitted for the degree of Doctor of Philosophy**

**University College London, September 2010**

## **Signed Declaration**

I, Maha Nasrallah, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

The studies presented in Chapter 2 of this thesis have been published with my colleague David Carmel and my supervisor, Nilli Lavie.

Nasrallah, M., Carmel, D., & Lavie, N. (2009). Murder, she wrote: Enhanced sensitivity to negative word valence. *Emotion, 9(5)*, 609-618.

## **Abstract**

The efficient detection of information of negative valence in the environment is crucial to survival (e.g. to elicit an avoidance response). However, previous research remains inconclusive regarding the question of whether detection is more sensitive to information of negative compared to positive valence. In the present thesis I used a signal detection approach applied to an emotional-evaluation word task (requiring the participants to classify a briefly presented masked word into emotional or non-emotional categories) to address this question. The results established conclusively enhanced detection sensitivity to negative valence compared to positive valence of verbal information, under both supraliminal and subliminal conditions (Chapter 2) while ruling out any alternative accounts in terms of word frequency, idiosyncratic differences in valence ratings and different levels of arousal. The extent to which the enhanced negative valence detection depends on availability of attention was addressed in Chapter 3. Using a dual-task paradigm, participants performed the emotional detection task together with a letter-search task of either low or high perceptual load. A negative valence detection advantage was found in the low load but not high load conditions. These results established that attentional resources are critical for the enhanced detection of negative valence. The role of individual differences in trait anxiety in the effects of attention on valence detection was examined in Chapter 4. The results demonstrated that high trait anxiety was associated with enhanced detection of negative valence even under high load, whereas individuals with low trait anxiety were less sensitive to negative valence across both levels of load. The

effects of monetary reward were addressed in Chapter 5. The results indicated that while reward enhanced detection sensitivity, the negative valence detection advantage remained unaffected. Overall the results establish conclusively a negative valence detection advantage that interacts with attention, trait anxiety, but not with reward.

## List of Figures and Tables

<b>Figure 1.1:</b> Mean SCRs to negative and neutral words in masked and unmasked presentation conditions (Silvert et al., 2004).....	19
<b>Figure 1.2:</b> Illustration of LeDoux's model.....	21
<b>Figure 1.3:</b> Example of trial sequence of task used in Zeelenberg et al. (2006)....	24
<b>Figure 1.4:</b> Example of dot-probe task used in Fox et al. (2001).....	28
<b>Figure 1.5:</b> Example of a modified version of the emotional Stroop task (White, 1996).....	30
<b>Figure 1.6:</b> Example of an RSVP task used in AB studies (Arnell, Killman, & Fijavz, 2007).....	33
<b>Figure 1.7:</b> Mean proportions of correct responses in study by Ogawa & Suzuki (2004) as a function of target 2 (T2) position .....	35
<b>Figure 1.8:</b> Average ERP waveforms to threat and neutral words in the word-relevant and colour-relevant tasks (Thomas et al., 2007).....	37
<b>Figure 1.9:</b> Mean interference scores for negative words in each group and exposure duration (Mogg et al., 1993).....	47
<b>Figure 1.10:</b> Example of experimental tasks used in Ansari & Derakshan (2010)	53
<b>Figure 1.11:</b> Amygdala activity to fearful versus neutral faces in Bishop et al. (2004).....	55
<b>Figure 1.12:</b> Trial sequence of paradigm used in Della Libera & Chelazzi (2006).....	60
<b>Figure 1.13:</b> Illustration of the sensory discrimination improvement as a function of reward (Pleger et al., 2008).....	62

<b>Figure 2.1:</b> Trial sequence in Experiment 1.....	70
<b>Table 2.1.</b> Experiment 1: Mean Percentages of Hits (False Alarms), Mean $d'$ and Beta scores, and Mean Confidence Ratings as a Function of Presentation Duration and Word Valence.....	72
<b>Table 2.2.</b> Experiment 2: Mean Percentages of Hits (False Alarms), Mean $d'$ and Beta scores, and Mean Confidence Ratings as a Function of Word Valence.....	75
<b>Figure 3.1:</b> Trial sequence in Experiment 4.....	98
<b>Figure 3.2:</b> Trial sequence in Experiment 4.....	99
<b>Table 3.1.</b> Experiment 4: Mean % Hit Rates, $d'$ and Beta scores as a Function of Load and Valence.....	102
<b>Table 3.2.</b> Experiment 5: Mean % Hit Rates, $d'$ and Beta scores as a Function of Load and Valence.....	109
<b>Table 3.3.</b> Experiment 6: Mean % Hit Rates, $d'$ , Beta scores, and Confidence ratings as a Function of Load and Valence.....	116
<b>Figure 4.1:</b> Trial sequence in Experiment 7.....	130
<b>Figure 4.2:</b> Trial sequence in Experiment 7.....	131
<b>Table 4.1.</b> Experiment 7: Mean % Hit Rates, $d'$ and Beta scores as a Function of Load and Valence.....	133
<b>Figure 4.3:</b> Correlation of Trait anxiety scores with the valence effect on $d'$ in the high load condition.....	138
<b>Table 4.2.</b> Experiment 7: Mean % Hit Rates, $d'$ and Beta scores as a Function of Load, Valence, and Anxiety Group.....	140
<b>Figure 4.4:</b> Interaction between Load and Valence on the $d'$ scores in the LTA group.....	144

<b>Figure 4.5:</b> Interaction between Load and Valence on the d' scores in the HTA group.....	144
<b>Figure 5.1:</b> Trial sequence in Experiment 8.....	156
<b>Table 5.1.</b> Experiment 8: Mean % Hit Rates, d' and Beta scores as a Function of Reward and Valence (averages across valences in bold).....	157
<b>Table 5.2.</b> Experiment 9: Mean % Hit Rates, d' and Beta scores as a Function of Reward, Valence, and Block Order (averages across valences in bold).....	161
<b>Table 5.3.</b> Experiment 9: Mean % Hit Rates, d' and Beta scores as a Function of Reward and Valence (averages across valences in bold).....	162

## Table of contents

<b>Abstract .....</b>	<b>3</b>
<b>List of Figures and Tables .....</b>	<b>5</b>
<b>Acknowledgements .....</b>	<b>11</b>
<b>Chapter 1: General Introduction .....</b>	<b>12</b>
1.1    Preface .....	13
1.2    Conscious vs. Unconscious processing advantage for negative words ....	17
1.2.1    Physiological studies .....	17
1.2.2    ‘Low road’ versus ‘high road’ .....	20
1.2.3    Identification and affective categorization of words .....	22
1.3    Emotional valence and attention .....	27
1.3.1    Research on spatial attention .....	27
1.3.2    Other selective attention tasks .....	28
1.3.3    The emotional Stroop task .....	29
1.3.4    Attentional blink and negative emotion .....	33
1.3.5    Neuroscientific evidence .....	36
1.4    Automatic vigilance to threat in anxiety .....	39
1.4.1    Evidence from spatial cueing paradigms .....	41
1.4.2    Findings from the emotional Stroop .....	45
1.4.3    Attentional Blink .....	49
1.4.4    Anxiety and attentional capacity .....	50
1.4.5    Neuroscientific evidence .....	54
1.5    Reward, attention, and perception .....	58
1.5.1    The effects of reward on visual attention .....	58

1.5.2	The effects of reward on perception and detection .....	61
1.6	Summary and aims of the present thesis .....	63
<b>Chapter 2: Enhanced Detection Sensitivity to Negative Emotional Valence:</b>		
<b>The Role of Awareness .....</b>		<b>67</b>
2.1	Introduction .....	68
2.2	Experiment 1 .....	68
2.3	Experiment 2 .....	74
2.4	Experiment 3 .....	78
2.5	Summary and conclusions .....	84
<b>Chapter 3: Enhanced detection of negative valence: The role of attention ...</b>		<b>90</b>
3.1	Introduction .....	91
3.2	Experiment 4 .....	96
3.3	Experiment 5 .....	107
3.4	Experiment 6 .....	113
3.5	Summary and conclusions .....	121
<b>Chapter 4: Emotion Detection and Attention: The Role of Individual Differences in Anxiety .....</b>		<b>124</b>
4.1	Introduction .....	125
4.2	Experiment 7 .....	129
4.3	Summary and conclusions .....	146
<b>Chapter 5: The Effect of Reward on Detection Sensitivity to Emotional Valence .....</b>		<b>151</b>
5.1	Introduction .....	152
5.2	Experiment 8 .....	154
5.3	Experiment 9 .....	159

5.4	Summary and conclusions .....	167
<b>Chapter 6: General Discussion .....</b>		<b>169</b>
6.1	Overview of findings .....	170
6.2	Implications for future research .....	183
6.3	Conclusions .....	188
<b>References .....</b>		<b>189</b>
<b>Appendix .....</b>		<b>205</b>

## Acknowledgements

My utmost gratitude goes firstly to my supervisor Nilli Lavie for her valuable guidance, endless patience and drive, and for enhancing the positive valence in the whole experience.

For all the significant input and continuous direction, I am most thankful to David Carmel.

I am extremely grateful to everyone in the lab, both those who have left and those who are still present, specifically James, Sophie, Todd, Sara, Nikos, Jake, Ana, Moritz, Nick, Yasemin, and Caroline (and many others) for all their generous help and all the much-needed ‘silly hours’!

My most heartfelt appreciation goes to my friends: Carine, Kristen, Leila, Maria, Iona, Ray, and Jessica, for their emotional support, inspiration, and for making the years I’ve spent in London the best they could ever be; and to my family, in particular my sisters Zeina, May, and Hala, and my brother Saad for their unconditional encouragement and for making me feel closer to home when most needed.

To Carl for his selfless faith in me throughout the years, thank you.

Last but definitely not least, I am most indebted to my mom and dad, for giving me both the ambition to thrive and the opportunities to fulfil all my aspirations.

Thank you.

**Chapter 1:**  
**General Introduction**

## **1.1 Preface**

Much literature has examined whether negative potentially threat-related stimuli have a processing advantage. Individuals appear to categorize stimuli as negative or positive on the basis of very little information (e.g. Murphy & Zajonc, 1993). A main function of this immediate evaluation of stimuli is to enable individuals to quickly attend to stimuli that might produce negative consequences on one's well-being. For evolutionary purposes, being able to quickly attend to threatening information is of high functional importance.

However, danger to one's survival is not the only form of threat. Negative social and psychological events (e.g. relationships, feedback, emotions) seem to have a greater impact on one's well-being than positive events (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001), and thus could also be considered psychologically threatening. Consequently, it would be important for individuals to be better at detecting negative over positive stimuli so that they would be better able to deal with (e.g. avoid where possible) their potential implications.

The hypothesis that negative stimuli would receive preferential processing over neutral or positive stimuli has been explored in research conveying emotional information through pictorial images of scenes (e.g. Koster, Crombez, Verschueren, & De Houwer, 2004; Most, Chun, Widders, & Zald, 2005); faces with emotional expressions (e.g. Bradley, Mogg, Falla, & Hamilton, 1998; Vuilleumier, Armony, Clarke, Husain, Driver, & Dolan, 2002; Vuilleumier, Armony, Driver, & Dolan, 2001) and words (e.g. Pratto & John, 1991; Kihara & Osaka, 2008). The present research focuses on the effects of negative emotional information conveyed with words. Although emotional scenes and faces can express rich emotional

information, it is often difficult to conclude that any processing advantage of one type of emotional stimuli (e.g. threat-related scenes conveying violent information) over another type (e.g. positive scenes conveying erotic information) is indeed due to the emotional valence of the stimuli rather than their different visual properties.

In contrast, stimuli such as words can be equated in terms of their visual appearance as well as their familiarity and intensity of emotional meaning conveyed. In addition, orthographic verbal stimuli convey meaningful emotional information pertaining to the complex social environment of human interaction we live in today, beyond immediate implications for survival.

To test the hypothesis that words conveying negative emotional information would have a detection advantage (over positive words), the effects of word valence on the accuracy and sensitivity of visual awareness were assessed in an emotional classification task for briefly-presented masked words. The results established a negative valence detection advantage. The interaction of the valence detection with attention was investigated in Chapter 3 to ask whether the enhanced detection of the negative valence can also be found in conditions of high perceptual load that exhaust all available attentional capacity in another task.

The relationship between individual differences in anxiety levels was addressed in Chapter 4 to test the hypothesis that the negative valence detection advantage might be higher in individuals with high anxiety compared to those with low anxiety. Finally, the effects of monetary reward on the valence detection task performance were also investigated (Chapter 5) to explore whether the enhanced sensitivity to negative valence is ‘hard-wired’ and as such not affected by reward. Alternatively, the negative valence detection advantage could merely reflect a

prioritization strategy and would thus be minimized or even eliminated when reward is given to any correct detection irrespective of its valence.

The existing literature on the processing of negative valence is reviewed next. The previous literature on negative versus positive word processing can be divided into two main strands: the first revolves around the potential processing advantage of negative words in visual awareness and mediating neural activity. In this domain, researchers have investigated whether unconscious negatively-valenced stimuli are more likely than neutral or positive stimuli to produce effects on neural activity as well as on behaviour, and whether negative stimuli are more readily accessible to conscious report than neutral or positive stimuli.

The second strand concerns the preferential effects of negative stimuli on attention. Work in this area has examined whether negative words are more likely to capture attention or interfere with a relevant task compared to positive or neutral words.

However, it is still not clear from previous research on the link between perception and valence whether, for example, the findings truly reflect an enhancement of perceptual sensitivity to negative valence or instead reflect biases in prioritization or response criterion. Furthermore, do the effects of negative valence on detection sensitivity require full conscious awareness as well as the availability of attentional resources? How do internal factors such as individual differences in anxiety or external factors such as differences in stimulus value influence people's sensitivities to emotional valence?<sup>1</sup>

As the review demonstrates, while negative words (compared to neutral or positive words) seem to show greater capture of attention, increased physiological

---

<sup>1</sup> Note that throughout the review, negative stimuli will be referred to as threatening only if they were specified as such in the corresponding paper.

responses, and greater identification in terms of accuracy, the question of whether negative words exhibit a true perceptual sensitivity advantage remains open. In addition, although research has been conducted showing an attentional bias towards threatening information, whether or not any detection sensitivity advantage of negative valence requires attentional resources has not been directly explored. Though much research has addressed the attentional bias to threat in anxiety, this research has not as yet addressed the effects of individual differences in trait anxiety on the perceptual sensitivity of negative (vs. positive) valence detection nor how trait anxiety affects the interaction of attentional load and the negative valence detection advantage. Finally, the review of recent research investigating the effects of reward on attention and perception, demonstrates that no previous study has thus far addressed the effects of reward on negative compared to positive emotional valence detection.

The review will begin by describing physiological and behavioural findings that reveal the conscious versus unconscious detection of emotional information. Next, the review will discuss the relevant research pertaining to the role of attention in the processing of emotional information from spatial cueing paradigms, to the Stroop task, and to neuroscientific evidence. An extension of these findings to the role of increased trait anxiety will be discussed, in addition to the relevant and recent theories of anxiety and cognitive processing. Finally, the role of reward in mediating perception and detection will be discussed, along with its implications on emotion processing.

## **1.2 Conscious vs. Unconscious Processing Advantage for Negative Words**

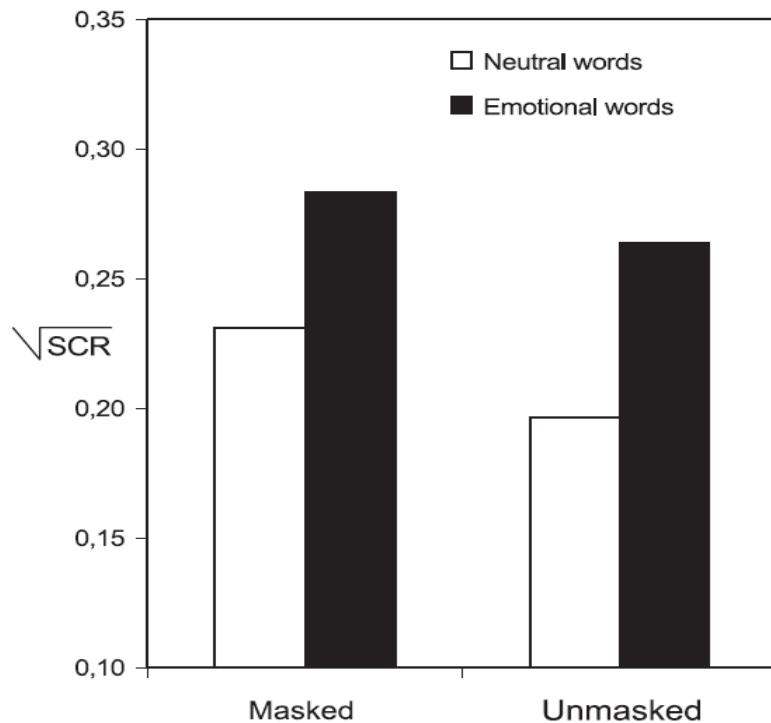
### *1.2.1 Physiological studies*

The question of whether emotional information can be processed unconsciously has triggered much physiological research (e.g. with faces: Whalen, Rauch, Etcoff, McInerney, Lee, & Jenike, 1998; in high trait anxiety: Etkin, Klemenhagen, Dudman, Rogan, Hen, Kandel, & Hirsch, 2004; in a patient with blindsight: Morris, DeGelder, Weiskrantz, & Dolan, 2001). While some of this research involved emotional face processing in clinical populations (e.g. with blindsight), my focus here is on the processing of emotional words in the normal population. Bernat, Bunce, & Shevrin (2001) recorded the participants' event-related potential (ERPs) recordings in response to passively viewing words presented either at a subliminal duration of 1 ms (although unmasked), or in another condition, at a supraliminal duration of 40 ms (unmasked). Unpleasant words produced a larger amplitude than the pleasant words in the left hemisphere (known to be involved in language processing) in both the subliminal and supraliminal conditions.

Although these findings might suggest both the preferential unconscious processing in addition to access to awareness for negative words, there are two caveats: Firstly, as the words were not masked, they were in fact available for visual processing for longer than their presentation duration due to the effects of visual persistence and iconic memory. Secondly, participants were asked to complete emotional ratings of the words every day over 28 days before the experiment. This is likely to have made the participants more primed towards the particular words used. However, although it may have sensitized the participants to

the specific words used, this priming should be similar for both the positive and negative words (as the words from both valences were rated prior to the experiment) and thus cannot explain the advantage found for the negative words over the positive words. In other words, the lack of masking and potential priming effects challenge the claim that the words were unconscious, but do not challenge the finding of the preferential processing of negative words.

More convincing evidence suggestive of the unconscious effect of negative words comes from a study conducted by Silvert, Delplanque, Bouwalerh, Verpoort, & Sequeira (2004). Silvert et al. (2004) presented the words for 150 ms followed by a mask (supraliminal condition), or at a brief presentation duration (12 ms – 41 ms) also masked. Presentation duration of the word in the subliminal condition was individually determined for each participant to satisfy the following criteria: 1) identification of the word was absent, 2) affective categorization of the word was at chance level (50%), 3) confidence ratings for correct and incorrect responses did not differ, and 4) the detection rates did not differ between negative and neutral words. Skin conductance responses (SCRs) were greater in response to negative words as compared to neutral words in general, as well as in the subliminal and supraliminal sessions when analyzed separately, reflecting similar reactions to aversive stimuli when the conscious identification of the stimulus is both present and absent (see Figure 1.1). It is not evident, however, whether the results show a general emotional response or if there is an advantage for negative words specifically, because there were no positive words to make such a comparison.



**Figure 1.1:** Mean SCRs to negative and neutral words in masked and unmasked presentation conditions (Silvert et al., 2004).

In a study that involved intracranial recordings of the amygdala of epileptic patients, Naccache, Gallaiard, Adam, Hasboun, Clemenceau, Baulac, Dehaene, & Cohen (2005) found compelling evidence for the advantage in unconscious perception of negative words over neutral words. The patients were required to make forced-choices for whether briefly-presented words (29 ms) were threatening or non-threatening. In the subliminal condition, the word was preceded and followed by a mask presented at a duration of 71 ms. In the visible condition, the post-mask was removed. Amygdala recordings revealed a large subliminal influence of emotional content in all patients as shown by a more positive response (however, in 5 of the 10 electrodes). The difference between negative and neutral words peaked at approximately 870 ms after word onset, which seems relatively

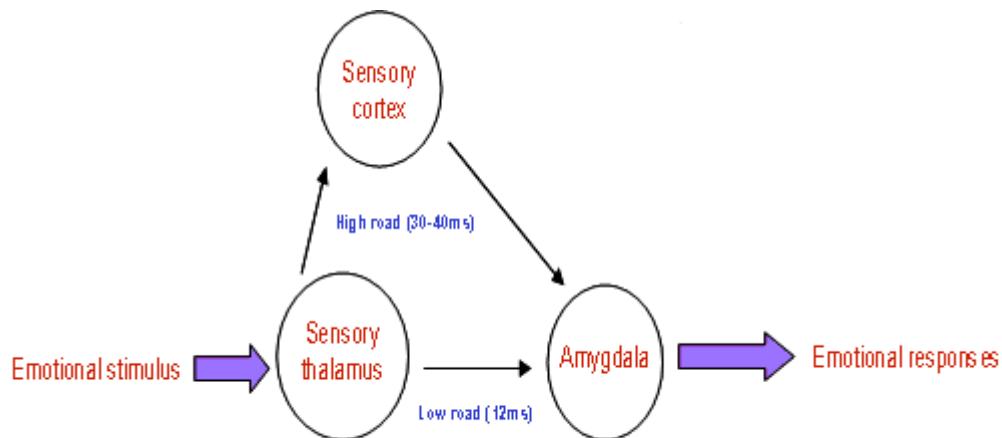
late, but still occurred much earlier than the motor response, and could be due to the necessary semantic processing stages before extraction of emotional meaning such as word recognition. It is important to note that both objective (null d') and subjective (no explicit recognition of any masked word) measures of consciousness showed that the participants were unaware of the words.

### *1.2.2 ‘Low road’ versus ‘high road’*

Taken together these results suggest that under conditions where conscious awareness of the words is absent, the emotional content of the words is still processed at some level (such as the amygdala) thus producing a physiological response. These findings are not surprising, especially if considered within the theoretical framework of the role of the amygdala in the processing of emotion in the brain put forward by LeDoux (1996). According to his work, there are two main pathways leading to the amygdala: the ‘high road’ or the ‘low road’. Emotional stimuli that go through the ‘high road’, in other words that are conscious, are first processed in the sensory thalamus, and from there are projected onto the sensory cortex for further, more detailed processing. Once the fine-tuned processing of the stimuli has occurred in the sensory cortex, the information is then sent to the amygdala, which then feedbacks into several other regions such as those responsible for autonomic regulation, resulting in an emotional response if the stimulus was an emotional one.

At times, however, the organism does not have enough information from the stimulus (i.e. lack of awareness of the stimulus) or enough time before potential harm can occur to process it in such detail, and therefore the processing of the stimulus goes through the ‘quick and dirty’ route (i.e. the low road). Following this

route, information about the stimulus is relayed into the sensory thalamus where it is only superficially evaluated, and from there it is immediately projected into the amygdala. This route takes around 12 ms as opposed to around 30 – 40 ms for the ‘high road’. If the stimulus is linked to or has an emotional component to it, the amygdala will then transmit the information to the relevant areas to produce an appropriate emotional response. A simplified model of the pathways involved in the processing of conscious and unconscious emotional stimuli is presented in Figure 1.2.



**Figure 1.2:** Illustration of LeDoux’s model.

Although prefrontal areas do mediate the amygdala response at a later stage, it appears that full conscious awareness of the stimuli is not necessary for their emotional content to be perceived and thus produce a corresponding response. Previous findings of related brain activity as well as an increased physiological response to unconsciously-presented emotional and more specifically negative stimuli can be explained by this model. One can also extend this model further to explain resulting behavioural differences between negative and neutral stimuli –

the subsequent cognitive and emotional responses to unconscious negative information may in turn influence performance in terms of response times and accuracies in detecting threatening stimuli.

Furthermore, cognitive-emotional interactions in the brain exist so that just as the amygdala receives input from the cortical sensory processing areas of the sensory modalities, so does it project back into those areas thus influencing the sensory processing occurring in these cortical regions (LeDoux, 2000). This amygdala regulation of the sensory cortex can consequently facilitate the processing of significant stimuli that signal danger even if those stimuli occur outside of the focus of attention.

To summarize, studies have established that negative words (compared to positive or neutral words) are preferentially processed even in the absence of awareness. Previous research in this area supports LeDoux's (1996) model that proposes a fast route for unconscious negative information into the amygdala as supported by findings of a larger amygdala response from intracranial recording. This results in the production of an emotional response (i.e. increased SCRs). Altogether these findings provide evidence of an unconscious processing of the negative information.

### *1.2.3 Identification and affective categorization of words*

Behavioural evidence of facilitated processing of unconsciously-presented negative words that complement nicely the neural evidence found for the unconscious processing of negative words observed in the Naccache et al. (2005) study was provided by Gaillard, Del Cul, Naccache, Vinckier, Cohen, & Dehaene

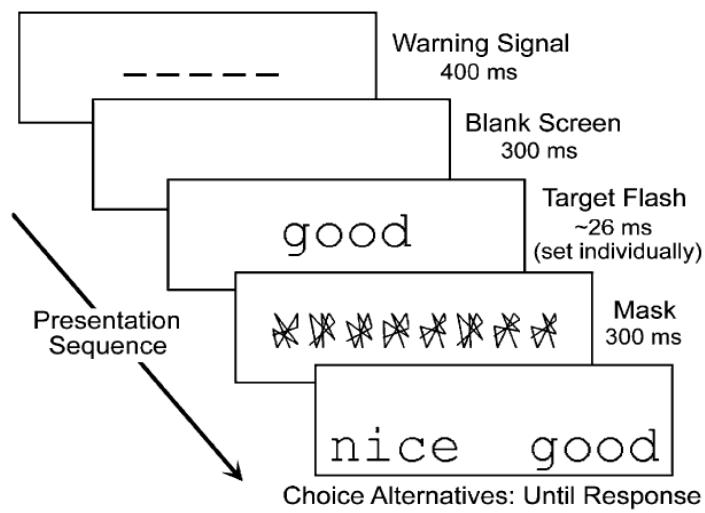
(2006). In their experiment, participants were presented with a masked negative or neutral word for 33 ms, but the stimulus-onset asynchrony (SOA) duration between the word and the subsequent backward mask varied between five conditions from low conscious perception to high conscious perception (SOA = 33 ms, 50 ms, 67 ms, 83 ms, or 100 ms respectively). The task was simply to attempt to name all the words and rate how visible each word was after each presentation.

Negative words were both more accurately identified and rated as more visible compared to neutral words. Indeed, the visibility ratings of the words were similar to that of previously seen words. Estimating the threshold for conscious access from both the subjective and objective data gave a mean threshold of around 33 ms. A final analysis of the experiment was made for error rates, and it was found that 32.5% of participants' errors were made for the negative words, as opposed to 67.5% for the neutral words. Interestingly, participants made significantly more emotional error responses when the word was actually emotional than when it was neutral, suggesting that some information about the word's semantic content was processed.

However, it is not clear whether the results obtained were due to the emotionality of the words in general or their negativity per se, seeing that, again, there were no positive words to explore this issue further. Moreover, the negative words could have consisted of a more cohesive category than the neutral words, which could have led to more inter-trial semantic priming in the negative case.

One study investigated the issue of perception of emotion in general using a forced-choice recognition task. Zeelenberg, Wagenmakers, & Rotteveel (2006) presented participants with a target word (either negative, neutral, or positive), followed by a backward mask, and then two words side by side, one of which was

the test word, and the other a foil. The presentation time of the target word was individually determined at the beginning of the experiment to produce 70% correct performance. This resulted in a mean target presentation time of 26 ms. The task was to indicate which of the two words was the previously-presented target word (see Figure 1.3).



**Figure 1.3:** Example of trial sequence of task used in Zeelenberg et al. (2006).

Results showed that participants correctly identified negative ( $M = 75\%$ ) and positive words ( $M = 75\%$ ) more often than neutral words ( $M = 70\%$ ), irrespective of foil valence (negative, neutral, or positive), with no significant difference between the identification rates of negative and positive words. These results indicate that there was enhanced processing of emotional stimuli. However, Zeelenberg et al. (2006) failed to find an advantage for negative over positive words. In addition, a potential problem in interpreting these results is that because

the target word was presented again immediately afterwards, backward priming may have occurred. Furthermore, the emotional words may have formed a more cohesive category than the neutral words, which may have affected the results.

An advantage for the detection of negative over positive words has been found in Dijksterhuis & Aarts (2003). In this study, they compared the presence/absence detection for negative versus positive words, presented for 13.3 ms masked, on 50% of the trials. The absent trials remained blank in the 13.3 ms window. Negative words had higher detection rates as well as (in another experiment) more accurate emotional classification compared to positive words.

The study by Dijksterhuis & Aarts (2003), however, is subjected to some criticism. The absence of neutral words as well as having negative and positive words intermixed within the same blocks did not allow for the assessment of separate false alarm (FA) rates for each word category. Therefore, analyses of sensitivity (signal detection) as well as of response criterion could not be performed (see also commentary in Laboue, 2004). It is not clear, therefore, whether the advantage found reflected merely a response bias. These are issues that will be addressed in the present thesis.

Snodgrass & Harring (2005) did measure the detection of emotional words in a task requiring participants to identify brief masked stimuli as words or random letter strings. Positive and negative words were presented in separate blocks. Somewhat surprisingly, results showed better sensitivity (measured by  $d'$  scores) to positive than to negative words. No analysis of whether this sensitivity difference was accompanied by a difference in response bias was reported.

The discrepancies between the results of the three studies mentioned above, despite their use of similar measures, may be due to their use of small word sets.

Dijksterhuis and Aarts (2003) used only fifteen words of each valence; Snodgrass and Harring (2005) used only fourteen and Zeelenberg et al., (2006) used only sixteen words in each condition. Such small sets are more open to sampling biases such as one of the word categories forming more cohesive categories.

Moreover, valence ratings in these studies were obtained either from separate pilot studies or published databases. Individual, idiosyncratic differences in valence attribution may therefore have either biased the results or reduced the experimental power to find an effect (e.g. in the case of Zeelenberg et al., 2006). Finally, arousal ratings of the words were not assessed in these studies. Thus differences in arousal between the valence categories used in the different studies may have thus accounted for the difference in the results.

In summary, in addition to research on the effects of word valence on awareness showing that emotional words seem to produce a larger physiological response, previous research has shown that emotional words are more accurately identified than neutral words. Furthermore, enhanced detection as shown by greater hit rates for negative words compared to positive words has also been demonstrated (although this may merely reflect a response bias as there was no assessment of detection sensitivity). Clearly, the question of whether negative information has a detection sensitivity advantage remains unclear. Testing this was the first aim of the present thesis.

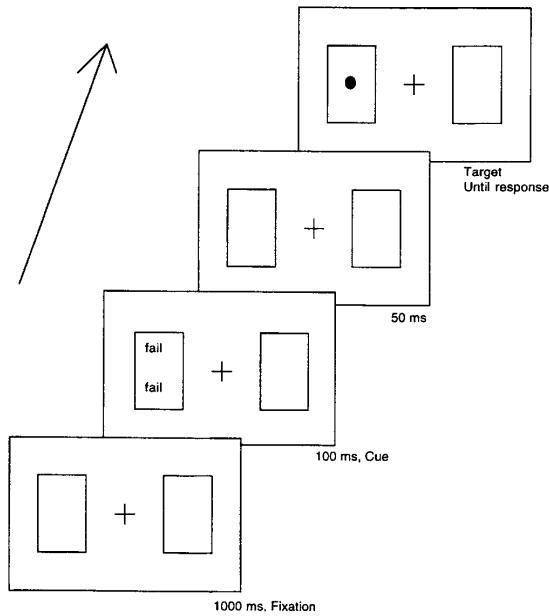
### **1.3 Emotional valence and attention**

Another aim of the present thesis was to address the role of attention in the detection sensitivity to emotional valence. Next I review studies that have investigated the preferential processing of negative information in attention.

#### *1.3.1 Research on spatial attention*

The enhanced capture of attention by negative words as well as their ability to engage focus of attention has been investigated by the attentional cueing paradigm. For example, in the dot probe task, participants are presented with a pair of stimuli, one of which is threatening, and the other neutral. Participants have to respond to a dot probe that is displayed after stimulus offset at one of the stimulus's locations. Generally, it is expected that participants will respond faster when their attention is focused on the location where the probe will appear, and slower when attention is engaged elsewhere. The latter is often termed disengagement cost. As my review shows, many studies report that negative emotional processing causes such a disengagement cost.

In a spatial cueing paradigm, Fox, Russo, Bowles, & Dutton (2001) presented participants with a threatening, neutral, or positive word as a cue at one of two locations (left or right box), followed by a target circle on one of the sides (Figure 1.4). Responses were slower following a threat word compared to a neutral or positive word when the target circle appeared on the opposite side of the word. These results suggest that it might be difficult to disengage attention from threatening information.



**Figure 1.4:** Example of the spatial cueing task used in Fox et al. (2001).

Many of the studies that have used probing paradigms in the study of attention to emotion have used non-word stimuli such as pictures or faces and are therefore less directly relevant to this thesis. Nevertheless, evidence for a difficulty in disengaging from threat has been shown in these studies (e.g. Koster et al., 2004; Koster, Crombez, Verschueren, & De Houwer, 2006).

### 1.3.2 Other selective attention tasks

Further support for the privileged processing of emotionally negative words comes from evidence of interference from negative words even when they are deliberately ignored. Many studies have shown this interference effect using only negative and neutral words (without comparing negative to positive words), and therefore one can only infer a general emotionality effect rather than a specific negative valence advantage over positive valence.

For example, Harris & Pashler (2004) investigated the issue of greater interference from negative unattended words using the digit-parity task. This task involved a brief (150 ms) and unmasked presentation of a word flanked by two digits. The participants had to indicate whether or not the digits were of the same parity (both odd, both even, or one of each) while ignoring the fixated word. Parity task response times (RTs) were longer both for negatively-charged words and for the participant's name (compared to random neutral words) when they were presented infrequently among other neutral words, but this interference effect rapidly diminished when these words were presented more often. In addition, the interference by negative words was smaller than that by the participant's name.

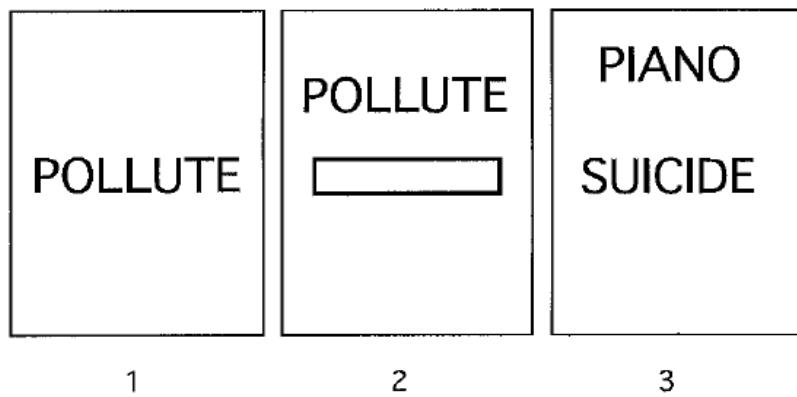
Selective attention to unattended negative compared to positive words has been shown in a different study using a lexical decision task (Calvo & Castillo, 2005). Participants were presented with a probe word that was either threat-related, positive, or neutral. The probe was preceded by a prime presented either to the right or left visual field that was identical or different to the probe. It was found that the processing of the probe was significantly facilitated (as shown by a reduction in lexical decision times) when the prime was threat-related, but not when it was positive or neutral. This finding reveals that threat words were more likely to capture attention in a parafoveal location and be semantically processed, thus leading to a priming effect.

### *1.3.3 The emotional Stroop task*

A widely-used paradigm to investigate the attentional bias to emotion is the emotional Stroop, whereby participants name the colour of an emotional or neutral word while ignoring the content of the word itself. Much research has investigated

the attentional bias to negative information using the emotional Stroop (e.g. in children: Perez-Edgar & Fox, 2003; and in individuals with high trait anger in response to angry versus neutral faces: van Honk, Tuiten, de Haan, Van den Hout, & Stam, 2001). For the sake of relevance, only studies that have been conducted on normal adults using verbal stimuli will be reviewed.

In one study using the emotional Stroop, greater interference (as shown by longer response latencies) from unpleasant words compared to neutral words was found with no difference between the response latencies of the pleasant and neutral words (White, 1996). However, this was only observed when the words were at fixation and not when they were spatially unattended (e.g. presented above fixation; see Figure 1.5). These findings suggest that negative valence does not necessarily capture spatial attention at a preattentive stage; rather the negative valence of words holds attention once the semantic properties are encoded. This conclusion is consistent with the disengagement cost found for negative information in the dot-probe paradigm.



**Figure 1.5:** Example of a modified version of the emotional Stroop task (White, 1996).

Interestingly, greater interference from negative compared to neutral words in the emotional Stroop task has been found even when the words were presented in Spanish-English bilingual speakers' second language (Sutton, Altarriba, Gianico, & Basnight-Brown, 2007). Though the bilinguals in this study were highly proficient, demonstrating equal interference effects in both their first and second language provides compelling evidence of the automatic activation of the emotional component in words.

As mentioned previously, only conclusions related to a general emotionality effect can be derived from studies that have compared negative versus neutral words. More relevant to this thesis are studies that have addressed the comparison between the negative and positive valence. For example, Gilboa-Schechtman, Revelle, & Gotlib, (2000) found Stroop-interference from negative words when participants participated in the negative mood-induction phase, whereas interference was found from positive words when participants were subjected to the positive mood-induction phase. Moreover, personally-relevant words produced greater interference than concern-irrelevant words. The results of this study therefore showed a mood-congruent attentional bias; the negative bias was only found when a negative mood was induced.

Borkenau & Mauer (2006), on the other hand, obtained the longest colour-naming latencies for pleasant words, medium response latencies from unpleasant words, and the shortest latencies for neutral words. However, hemispheric differences appeared such that unpleasant words produced longer response latencies compared to pleasant words when words were presented to the right hemisphere (or left visual field) whereas the latencies in response to the pleasant words were longer than unpleasant words when words were presented to the left

hemisphere (or right visual field). These findings suggest that, although no clear attentional bias to negative words was observed in terms of overall response latencies, a right hemisphere bias in the processing of negative words was found.

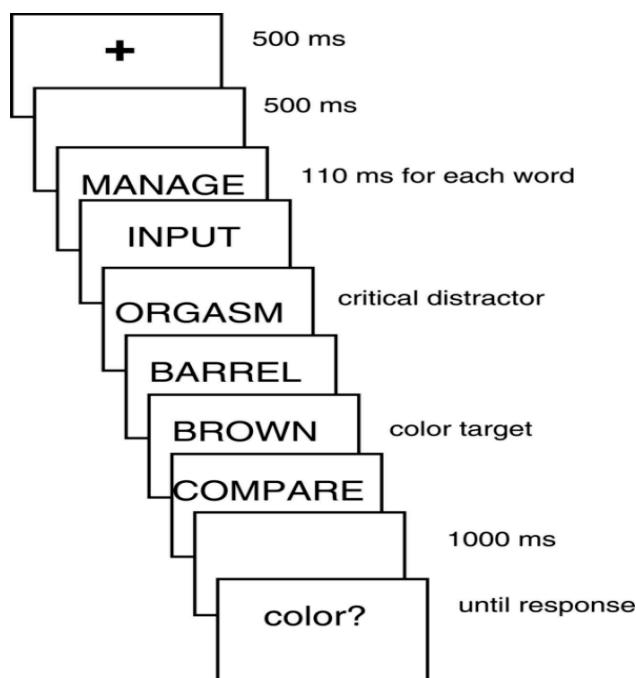
Contrary to the findings of Borkenau & Mauer (2006), McKenna & Sharma (1995) found that response latencies to name the colour of the word were slower to negative words, compared to positive and neutral words, with no RT difference between the positive and neutral words. Subsequent measures of implicit (with a stem-completion task) and explicit memory (with a recognition task) revealed that the advantage found for negative words was restricted to RT findings.

Further evidence of interference from negative words was also obtained in a study by Pratto & John (1991). In their study they presented participants with a word that was either a desirable (positive) or an undesirable (negative) trait and instructed them to name the colour of the word. Results showed slower responses to the undesirable traits compared to the desirable traits indicating an automatic vigilance to negative social information compared to positive information. In addition, this attentional bias to negative information increased subsequent memory for these traits as recall memory was enhanced for the undesirable traits as opposed to the desirable traits.

In summary, research on attention and emotion has shown that negative words appear to cue attention and make it difficult to shift attention away from them. In addition, despite a few failures from the emotional Stroop task in normal populations, previous research has provided evidence for greater interference from negative words even when deliberately ignored as shown by measures of response latencies.

#### 1.3.4 Attentional blink and negative emotion

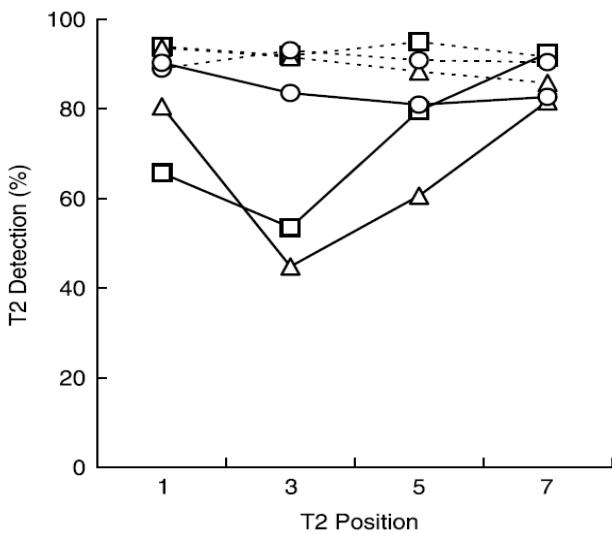
Another widely used paradigm used to study the attention-grabbing powers of emotional words is Attentional Blink (AB) paradigm (see Figure 1.6). In the AB task, participants are usually presented with stimuli in a rapid serial visual presentation (RSVP) where they are required to detect two targets in the stream. It is usually found that the detection of a second stimulus is impaired after reporting the first one successfully when the second target is presented only a short interval (less than 500 ms) after the first target – what is known as the attentional blink (AB; Kawahara, Di Lollo, & Enns, 2001; Raymond, Shapiro, & Arnell, 1992; Shapiro, Raymond, & Arnell, 1997).



**Figure 1.6:** Example of an RSVP task used in AB studies (Arnell, Killman, & Fijavz, 2007).

A reduced AB effect for negative words was observed, for example, in a study conducted by Anderson & Phelps (2001). When participants were required to identify the two green targets in an RSVP task, healthy participants were better able to identify the second target when it was a negative compared to a neutral word, in line with previous findings. But as positive words were not included in this study, the results only reflect a general emotional advantage over neutral words and not a negative advantage specifically. The remainder of this section will therefore focus mainly on comparisons between negative and positive words.

Ogawa & Suzuki (2004) provided further evidence for the preferential processing of negative stimuli using the AB paradigm. In their paradigm, they presented Chinese ideographs to Chinese participants and found that detection of presence or absence of the second target (defined by its colour) in the stream was impaired for both positive and neutral target ideographs presented shortly after the first target (i.e. within the ‘blink’), but no impairment in detection was found for negative ideograph targets (see Figure 1.7), suggesting that negative verbal information is more likely to capture attention and be available for conscious report than positive or neutral information. Furthermore, the lowest false alarm (FA) rates were found for the negative targets, suggesting that the higher detection rates could not be attributed to a response bias. In addition, a negative first target led to an AB for all valence types of the second target (neutral, positive, and negative) indicating that negative information engages attention for a longer period of time than positive or neutral information, thus leading to a reduced ability to process subsequent information presented shortly afterwards.



**Figure 1.7:** Mean proportions of correct responses in study by Ogawa & Suzuki (2004) as a function of target 2 (T2) position. Dotted line with square: Neutral-control; solid line with square neutral-experimental; dotted line with triangle positive-control; solid line with triangle positive-experimental; dotted line with circle negative-control; solid line with circle negative-experimental.

Kihara & Osaka (2008) compared the processing of negative and positive words in an RSVP task and found further support for a reduced AB for negative words but not for positive or neutral words. Furthermore, negative words were not only less affected by an AB, but they were also found to grab attentional resources thus interfering with the identification of a neutral subsequent target. An enhanced AB effect to a negative second target was also found when the first target was a negative word, suggesting that the conscious detection of negative information requires the availability of attentional resources.

It seems that semantic processing of the words is required for the negative words to capture attention (Huang, Baddeley, & Young, 2008). In their study, participants viewed an RSVP task that included a distractor word (neutral or

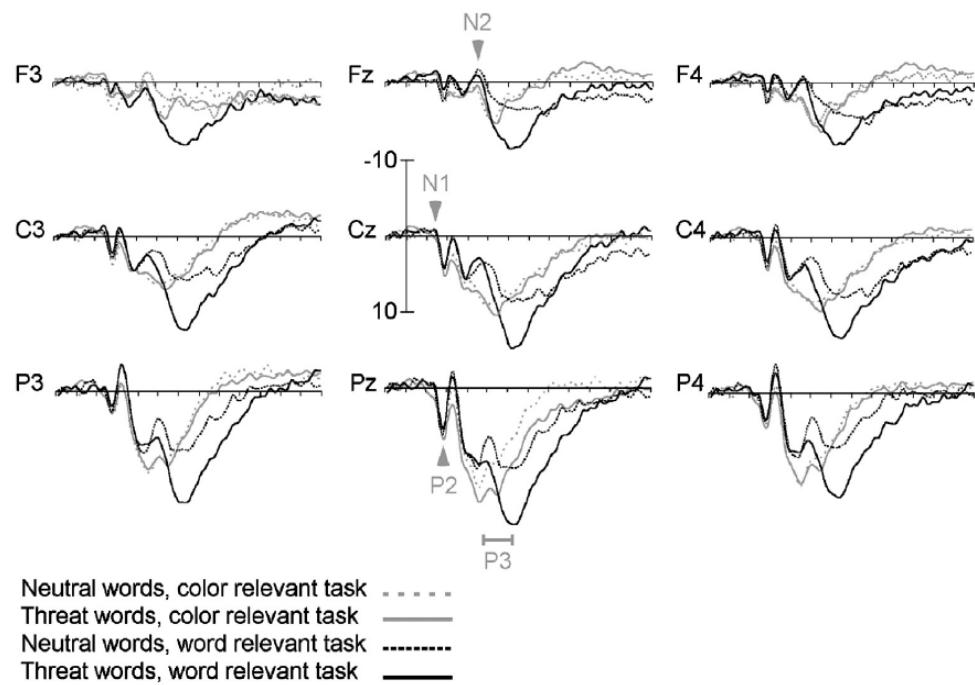
negative) followed by a target word (type of fruit). Emotionality of the distractor word impaired the detection of the target when participants were required to process the words semantically (i.e. identify the fruit). When superficial (identification of the uppercase word) or grammatical (identification of word that rhymes with ‘pear’) processing of the words were required, negative words were not found to result in an enhanced AB effect.

Overall, evidence from AB studies reveals that negative words, when semantically processed, can escape the attentional blink indicating that negative information may be perceived under conditions where high demands are placed on attention. Further evidence of the processing of emotion even when unattended comes from neuroscientific evidence reviewed below.

### *1.3.5 Neuroscientific evidence*

Negative information has been shown to enjoy preferential access to processing resources (as indicated by its ability to escape the attentional blink). The amygdala has been shown to be necessary for the reduced AB effect for negative emotion to emerge. In the study by Anderson & Phelps (2001) which showed a reduced AB effect for negative words compared to neutral words in an RSVP task, a patient with bilateral damage to the amygdala did not show an advantage in the processing of aversive words as usually shown by a reduced AB (but showed normal AB results from early relative to later temporal lags). Further comparisons with patients with right or left lesions to the amygdala revealed that the enhanced perception of negatively valenced words depends mainly on the left amygdala. Thus the amygdala appears to play a crucial role in the processing of emotion.

Although no behavioural evidence of differences in RTs between threat and non-threat words was found in their study, Thomas, Johnstone, & Gonsalvez (2007) provided evidence from event-related potentials (ERP) for the preferential processing of negative words. Greater ERP amplitudes were found in response to threat words (compared to non-threat words) in the emotional Stroop task (see Figure 1.8). Threat words were also associated with greater right than left hemisphere amplitude as well as greater amplitude compared to neutral words in the right hemisphere. These findings provide direct evidence that threat was differentially processed even when it fails to affect RT.



**Figure 1.8:** Average ERP waveforms to threat and neutral words in the word-relevant and colour-relevant tasks (Thomas et al., 2007).

Implications for a relationship between emotion and brain activity can be drawn from the findings of the studies mentioned earlier. But as only negative and neutral words were used without any comparisons with positive words, one cannot conclude whether the neuroscientific evidence found in response to negative words in the emotional Stroop task by Thomas et al., (2007) and in the lesion study by Anderson & Phelps (2001) reflect a negative valence advantage per se or a general emotional advantage.

In a recent ERP study that did present participants with negative, positive, and neutral words, Franken, Gootjes, & van Strien (2009) found an early, differential brain response to emotional words, namely the early posterior negativity (EPN) component – a component that has been shown to be modulated by emotional pictorial stimuli. The EPN response was present for both pleasant and unpleasant words. However, this finding did not affect the Stroop interference. Instead, the Stroop interference was associated with a later component (the late positive potential (LPP)) that reflects sustained emotional attention, as unpleasant words yielded a larger LPP compared to neutral words. In contrast, pleasant words showed no significant difference in LPP in comparison with neutral words. These results concur with the conclusion that negative emotion effects on Stroop may reflect a slow disengagement process (rather than an automatic bias).

In summary, neuroscientific evidence revealed a significant role of the amygdala in the enhanced perception of emotion as well the differential processing of negative words even when they are unattended (as shown by greater ERP amplitudes in response to negative words compared to neutral words as well as larger later ERP components involved sustained attention for negative words).

## **1.4 Automatic vigilance to threat in anxiety**

Research on the perception and detection of emotion reviewed thus far has been established in the general population with no analysis of potential effects of individual differences in the processing of emotion. Individual differences in the way people attend to emotional stimuli, such as anxiety, have in fact been found (Yiend, 2010). The role of anxiety in the detection of emotional valence is addressed in Chapter 4.

Anxiety is a psychological and physiological state characterized by several somatic, emotional, cognitive, and behavioural symptoms. Some of the physiological responses in anxiety are increased heart rate, deeper breathing, perspiration, and the secretion of adrenalin, among many others. Anxiety is also accompanied by emotional and cognitive symptoms such as having a sense of dread, restlessness and irritability, as well as the anticipation and exaggeration of danger and future-oriented worrisome thoughts. Behavioural responses to anxiety and potential danger are escape, avoidance, freezing, or aggression (Nolen-Hoeksema, 2004).

These components typically result in anxiety being an unpleasant state. Although it is crucial for one's survival to be able to efficiently detect danger, anxious individuals possess a hypervigilant threat detection system and seem to exaggerate the frequency and severity of potentially threatening situations (Eysenck, 1992).

Studies investigating the issue of a hypervigilance to threat in anxiety have been conducted over many years. It is a well-established finding that individuals

with clinical or high trait anxiety show an attentional bias towards threatening information (for a review see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007), even in children and adolescents (Dalglish, Moradi, Taghavi, Neshat-Doost, & Yule, 2001). The present thesis focuses on effects of non-clinical anxiety on the processing of emotional information for two main reasons: one, clinical populations may show specific effects related to the disorder (such as phobia-specific effects) and therefore might not be generalizable to all populations; second, clinical populations may have a lower general functioning (i.e. greater difficulty performing the task) which therefore may affect the results in general. In the sake of relevance to the present thesis, I review only the studies that have been conducted on non-clinical populations investigating the role of anxiety in the preferential processing of negative information.

Most of these studies concerned the interaction between anxiety and attention to emotional information. Only one study so far has directly addressed the effect of anxiety on emotional detection per se (Manguno-Mire, Constans, & Geer, 2005). The task in their study was to classify words as either ‘safe’ or ‘dangerous’. The words were presented for either 14 ms and masked or for unlimited duration (until a response was made) and not masked. Responses were considered correct when negative words were classified as ‘dangerous’, and positive and neutral words as ‘safe’. The results showed that in the masked condition anxious participants had higher hit rates for threat words and non-anxious subjects had higher hit rates for neutral and positive words. In the non-masked (unlimited exposure) condition no differences were found.

In order to assess whether this difference was due to anxious participants’ enhanced ability to detect threat or to a response bias, a signal detection analysis

was performed. Two detection sensitivity measures for the negative words were calculated – one for the detection of negative targets versus neutral distractors and another for the detection of negative targets versus positive distractors. Results showed that while the sensitivity measures to the negative words did not differ between the anxiety groups, high anxious individuals possessed a response bias to the detection of negative words (in other words to interpret ambiguous stimuli as threatening) compared to low anxious individuals. They concluded that individuals with high anxiety have a lower response criterion for categorizing unconscious stimuli as threatening rather than an increased ability to detect negative valence.

I consider this study further in Chapter 4. For now I note that their results are confined to ‘safe’ versus ‘dangerous’ detection, whereas the present thesis considered a wider range of emotional connotations. Next I review the previous research on selective attention and processing of negative emotional information in anxiety.

#### *1.4.1 Evidence from spatial cueing paradigms*

Evidence exists suggesting that the attentional bias in anxiety reflects problems with disengaging from threatening material. This is reflected by faster responses to detecting a probe appearing in the same location of a threatening stimulus in the dot probe paradigm (MacLeod & Mathews, 1988). Many studies that have investigated this attentional bias in anxiety with probing paradigms have not used verbal stimuli, but instead have used faces (e.g. Bradley, Mogg, & Millar, 2000; Mogg, Millar, & Bradley, 2000) or pictures (e.g. Yiend & Mathews, 2001). Although some will be described briefly in the next section as they indicate differences in anxiety on the processing of emotion, it is important to note that any

conclusion from studies using pictures or faces cannot be directly applied to the processing of words.

In line with previous findings supporting an attentional bias to threat, Koster et al. (2004), for example, found that responses were faster when probes appeared at the location of previously-presented threatening pictures. This was found in all individuals, but the attentional bias increased with higher anxiety. In another pictorial dot-probe study using high-threat, moderate-threat, and neutral pictures, Koster et al. (2006) found that not only did individuals with high-trait anxiety (HTA) have increased attentional bias scores to all threatening information in general, but they also oriented significantly more to moderate threat pictures than low-trait anxiety (LTA) participants. LTA participants indicated some orientation towards high threat pictures, and significant avoidance to moderate threat. Considering the significance of being able to attend to extremely threatening information, it is not surprising to find that even individuals with low anxiety orient towards high threat.

Mogg, McNamara, Powys, Rawlinson, Seiffer, & Bradley (2000) also found that the low anxious group showed significantly greater vigilance for the high threat compared to the low threat pictures. In addition, their findings suggested an effect of threat value of the stimuli in terms of greater vigilance to high compared to mild threat that was found across all participants (both high and low trait anxiety groups).

Increased vigilance towards threatening faces has also been found in high anxiety compared to low anxiety (Bradley, Mogg, Falla, & Hamilton, 1998). In a dot-probe of threatening, happy, or neutral faces that were presented for one of two durations (500ms or 1250ms), the high trait anxious participants showed a greater

attentional orienting bias towards threatening faces and increased avoidance of happy faces than the low anxious participants. The degree of attentional orienting bias was correlated with trait anxiety measures, whereas no relation between avoidance of happy faces and trait anxiety was found once measures of depression were partialled out, implying that avoidance of happy faces might be linked to the presence of dysphoria rather than to anxiety. The attentional bias to threatening faces in high anxiety was more robust in the shorter compared to the longer duration, suggesting that the increased vigilance towards threat in anxiety seems to operate mainly at the initial stages of processing. Though this study compared negative versus positive stimuli, one cannot conclude with certainty whether these findings obtained in response to faces would extend to verbal processing.

Dot-probe studies using word stimuli have been conducted and have found further support both for the suggestion of an increased vigilance towards negative information and for the suggestion of a difficulty in disengaging from negative words. For example, MacLeod, Mathews, & Tata (1986) provided evidence for the first suggestion showing a shift of attention towards threat words versus neutral words in anxious participants compared to controls. In their probing paradigm, one word was presented above and one below the centre. Participants had to name the upper word and then respond to the dot-probe as quickly as possible. Results showed that anxious individuals were faster to respond to the dot when it appeared in the place of a threat word compared to a neutral word, whereas controls showed a pattern of shifting attention away from such stimuli as revealed by faster responses to the dot when the threat word was in the opposite location.

The findings from a similar dot-probe study by Salemink, Van den Hout, & Kindt (2007) supported the disengagement cost hypothesis. Their results showed

that high anxious participants were slower in responding to the probe when the probes appeared at the location of the previously-presented neutral word when the word was accompanied by a threatening compared to a neutral word. However, given that only negative and neutral words were presented in these two studies, the conclusions remain linked to emotional valence in general.

The attentional bias in anxiety to negative versus positive valence in words was investigated by Fox et al. (2001). As described earlier in the General Introduction, participants in general were slower following a threat word compared to a neutral or positive word when the target circle appeared on the opposite side of the word. When the word was presented at fixation followed by a target letter either above or below it, only high state-anxious participants as opposed to low state-anxious participants revealed longer RTs to naming the letter when the word was threatening compared to when it was neutral or positive.

To summarize, research from spatial cueing paradigms have shown that high anxiety (compared to low anxiety) is associated with an increased vigilance towards threatening pictures and faces. Evidence for greater engagement of attention as well as faster shift of attention towards negative words in high versus low anxiety has also been provided within dot-probe studies. Some of these conclusions have been drawn from paradigms where the participants attended to the stimuli. The next section will address research on individual differences in anxiety levels in the processing of negative words when their content is ignored.

#### *1.4.2 Findings from the emotional Stroop*

A large body of research using the emotional Stroop task has shown pronounced interference from negative words in highly-anxious and clinical populations (e.g. those with Post-Traumatic Stress Disorder; for a review see Williams, Mathews, & MacLeod, 1996), as well as individuals with anxiety-sensitivity (the tendency to fear and catastrophize anxiety-related sensations; Koven, Heller, Banich, & Miller, 2003). Responses to threat versus non-threat words (both positive and neutral) were also found to be longer for anxious participants with Generalized Anxiety compared to controls, with no differences between the positive and neutral words (Mathews, Mogg, Kentish, & Eysenck, 1995). This cognitive bias appears to show disorder-specific characteristics, for example while individuals with Generalized Anxiety Disorder (GAD) showed greater slowing of responses to all emotional words, Social Phobics (SP) showed greater interference to SP-related words specifically (Becker, Rinck, Margraf, & Roth, 2001).

More relevant to this thesis are findings related to the automatic processing of negative words in individuals with high trait-anxiety. Studies that have focused on non-clinical differences in anxiety will be reviewed next.

Richards, French, Johnson, Naparstek, & Williams (1992) found that it took longer for participants with high trait anxiety to name the colour of anxiety-related words compared to happiness-related words. In addition, trait anxiety was positively correlated with the anxiety-related difference index (the difference in RT between anxiety-related words and matched neutral words).

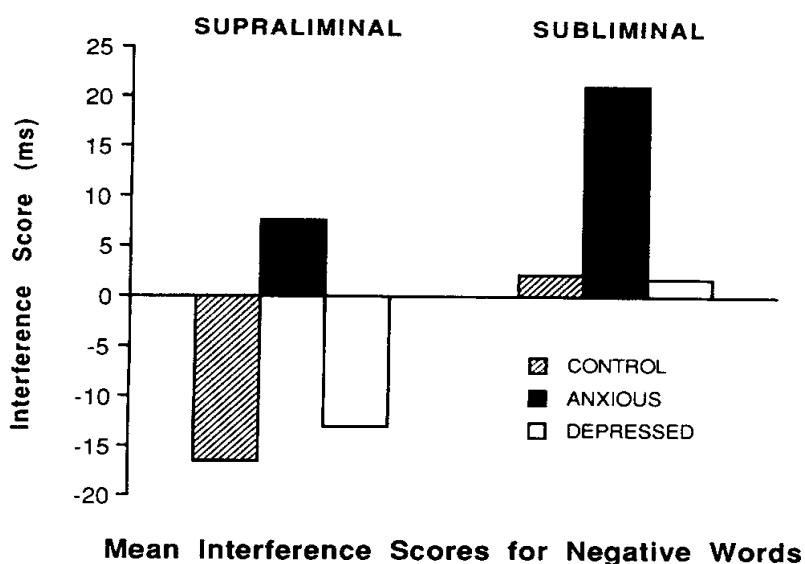
Similarly, significant differences in colour-naming response times were found between threat words (physical and social) and positive words for anxious individuals whereas no such differences emerged for controls (Mathews &

MacLeod, 1985). Interestingly, all participants showed interference from social threat words, whereas only those more concerned with physical worries showed equal disruption from physical threat words indicating an effect of concern-relevance of the words on Stroop interference.

Further evidence from the Emotional Stroop task revealed that individuals with high trait anxiety showed increased colour naming latencies for threat words (such as exam-related negative words) relative to non-threat words (that also included exam-related positive words) under unconscious conditions where the word was replaced by a mask after 20 ms. In addition, an opposite effect was found for low trait anxiety participants, demonstrating an increased ability to avoid threatening information. Under conscious conditions (i.e. word was presented until response), increased state anxiety was associated with faster responses to threatening words related to exams for both high and low anxiety subjects, and with increased interference from threatening compared to unthreatening exam-unrelated material. High and low trait anxiety seem also to work in an opposite manner at a preconscious level, with high anxiety being associated with greater disruption from threatening information and the latter being associated with avoidance of threatening information (MacLeod & Rutherford, 1992). It is not clear, however, whether these findings would extend to general emotional information.

Another colour-naming task tested these effects with words that, although were relevant to the participants' concerns, encompassed more general emotional connotations. Anxious, depressed, and control participants were presented with anxiety-related, depression-related, positive, or neutral words on a background patch of colour and were required to name the colour of the background (Mogg,

Bradley, Williams, & Mathews, 1993). Words were presented either subliminally (for 1 ms followed by backward masked after 14ms), or supraliminally (until response with no mask). Awareness checks including a lexical decision task and a detection task confirmed that participants were unaware of the stimuli in the subliminal condition as shown by chance-level performance. Results showed increased colour naming latencies for negative words in anxious participants compared to depressed and control participants under both exposure conditions (see Figure 1.9), supporting the idea of a bias for negative information in anxiety.



**Figure 1.9:** Mean interference scores for negative words in each group and exposure duration (Mogg et al., 1993).

Similar interference from threatening compared to neutral words for participants with high anxiety (in contrast with the low anxious participants) was found in both the traditional and a separated troop task (Fox, 1993). Given that the separated Stroop involved presenting the words above or below the colour patch,

these findings suggest that individuals with high trait anxiety show increased distraction by unattended negative information outside the focus of attention. Interestingly, high anxious participants also showed greater distraction by colour words whereas the low anxious participants did not, suggesting that individuals with high anxiety might have a general difficulty maintaining attentional focus and ignoring irrelevant distractors.

Further evidence of greater distraction by unattended negative words comes from a study by Mathews, May, Mogg, & Eysenck (1990). In a visual search task, participants were required to search for the words ‘left’ or ‘right’ as fast as possible. The location of the word was cued by fixation crosses in some trials and the target word was accompanied by a distractor word that was either physically-threatening (e.g. crippled), socially-threatening (e.g. ashamed), positive (e.g. generous), or neutral (e.g. horizon). No significant differences were found between the positive and neutral words and so both types of words were combined into one ‘non-threatening’ category. Similarly, responses to the physically-threatening and socially-threatening were combined into one ‘threatening’ category. Results showed that anxious and recovered participants were slower than controls when they were required to search for the target word among threatening distractors. Interestingly, only anxious individuals were slower than controls in response to the target word when it was accompanied by a distractor word of any type, possibly reflecting a general distractibility in anxiety disorders as also suggested by the findings in the study by Fox (1993).

#### *1.4.3 Attentional blink*

Negative information has also been shown to have preferential access to processing resources in an AB study (Fox, Russo, & Georgiou, 2005). Participants were required to categorize a first picture T1 that was either mushrooms or flowers and a second target T2 that was either a happy or fearful face embedded in an RSVP stream of neutral faces. Two main findings were revealed: firstly, an AB effect occurred for the fearful faces even for the high state and trait anxiety group, producing further evidence that the processing of emotion is not automatic. Secondly, although still present, the degree of the AB to the fearful faces was attenuated for the high anxiety group, supporting the suggestion that anxiety is related to a hypervigilance of the fear-detection system.

The study by Fox et al. (2005) suggests that threatening stimuli are better detected than positive or neutral stimuli. However, given that their results are based on the processing of facial expressions which may differ from those of verbal information, they are not directly relevant to the present thesis.

In summary, one study has claimed that individuals with high trait anxiety possess a response bias to interpreting information as threatening rather than an enhanced detection sensitivity to negative words. Other research has demonstrated greater interference from negative words in colour-naming tasks (i.e. the emotional Stroop), a slowing of responses by negative distractors in individuals with high compared to low anxiety, and a reduced AB for fearful faces. Given that previous research has indicated that the processing of emotional information may be less modulated by attention in individuals with high anxiety levels, the effects of anxiety on attention in general will be reviewed next.

#### *1.4.4 Anxiety and attentional capacity*

As some of the previously-mentioned studies indicated (e.g. Fox, 1993; Mathews et al., 1990), impaired attentional control in anxiety seems to extend to general processing and is not restricted to emotional processing per se. Considerable evidence for decreased cognitive performance in anxiety indeed has been provided (for a review see Eysenck, 1992). A recent and promising theory is the Attentional Control theory (Eysenck, Derakshan, Santos, & Calvo, 2007), which is developed from the Processing Efficiency theory (Eysenck & Calvo, 1992).

According to the Processing Efficiency theory, elevated anxiety does not predict decreased performance per se, rather reduced processing efficiency in terms of enhanced effort to perform the task adequately. It is assumed that anxious individuals are pre-occupied by task-irrelevant thoughts and worries that use up attentional resources, thus leaving fewer resources available for the processing of the current task. The crucial point is that these worrisome thoughts motivate such individuals to minimize the potential adverse effects of their intrusive thoughts on performance by utilizing additional processing resources. Processing efficiency is thus affected to a greater extent than performance effectiveness. Specifically, anxiety is assumed to primarily affect the central executive and to also have a small negative effect on the functioning of the phonological loop (involved in the rehearsal of verbal material). This assumption leads to the prediction that anxious individuals will show impaired performance in dual-task situations that place high demands on the central executive.

Research has supported this assumption (Eysenck, Payne, & Derakshan, 2005). In this study, participants with either high or low anxiety performed the Corsi Blocks Test (a highly complex visuo-spatial task) as a primary task while performing a secondary task that involved the central executive (counting backwards from a two-digit number), the phonological loop (repeating the letters A, B, C, and D, out loud continuously), or the visuo-spatial sketchpad (tapping out a ‘z’ pattern on a tapping pad with their right index finger). When the secondary task involved the central executive, high anxious participants performed the primary task worse than the low anxious participants. Adverse effects of anxiety on performance of the secondary task were also observed when the task required the central executive. These findings imply that anxiety is related to a reduced capacity of the central executive.

The Attentional Control theory (Eysenck et al., 2007) suggests more specific effects of anxiety on control capacity. In the Attentional Control theory, anxiety affects performance through its adverse effects on a key function of the central executive – attentional control. Attentional control is defined as having two distinguishable processes: top-down goal driven or controlled processes, and bottom-up stimulus driven processes. According to the Attentional Control theory, anxiety disrupts the balance between those two systems by increasing the influence of bottom-up stimulus driven processes over those for efficient goal driven top-down control.

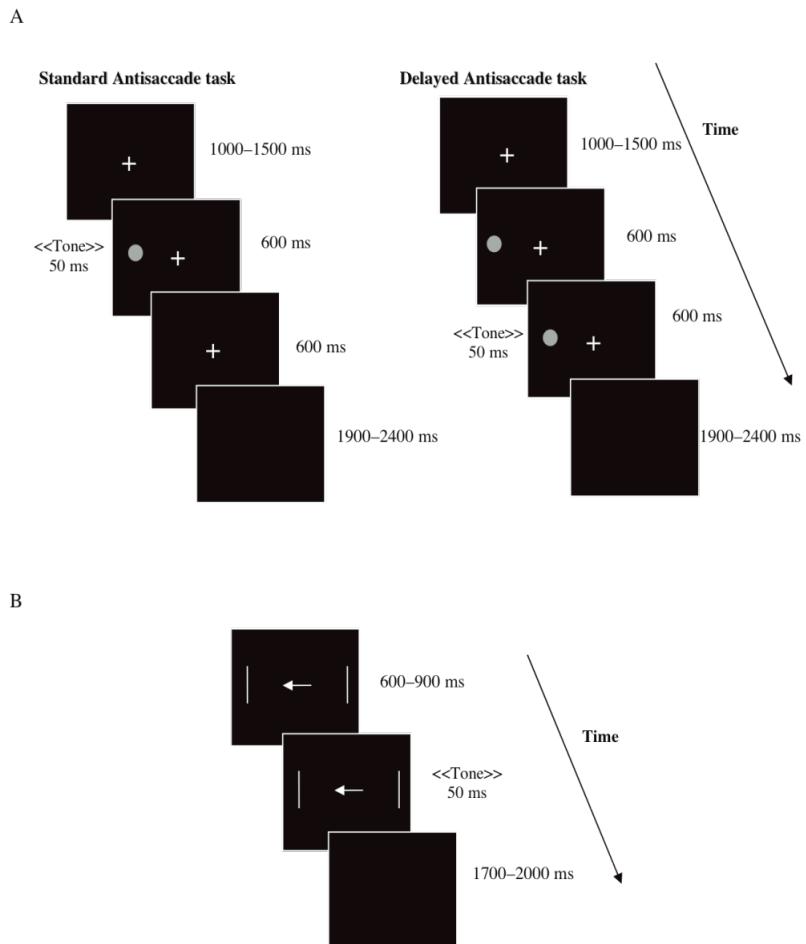
Functions that depend on the availability of working memory resources for efficient performance such as shifting and inhibition have been shown to be adversely affected by high anxiety (Derakshan & Eysenck, 2009). In one study examining the effect of anxiety on task-switching (Ansari, Derakshan, & Richards,

2008), participants performed antisaccade and prosaccade tasks in either a single-task (separate blocks of antisaccade and prosaccade trials) or a mixed-task design (both tasks presented within the same block). In an antisaccade task, attentional control is exercised in order to suppress a reflexive saccade towards an abrupt stimulus and generate a volitional saccade to its mirror position, whereas in the prosaccade task, participants are required to look at the abrupt cue.

Individuals are generally slower in making a correct saccade away from the stimulus in the antisaccade trials compared to the prosaccade trials where there is no competition between reflexive saccades and volitional responses. In the mixed-task, participants are required to switch between antisaccade and prosaccade tasks and an improvement in antisaccade performance (i.e. reduction in antisaccade latencies) is generally found in the switching trials compared to repeat trials. Results of this study showed that high anxious participants showed no such improvement, contrary to low anxious participants who became significantly faster on antisaccade trials in the mixed-task blocks compared to the single-task block. In relation to the Attentional Control theory, these findings suggest that high anxious individuals have a reduced top-down attentional control for efficient shifting of attentional resources for the new task, implying a diminished working memory capacity.

In addition to task-switching, high anxiety seems to also be linked to poor inhibitory functions. Introducing a delay before each of the antisaccade and prosaccade tasks showed that while the inhibition effect in the Delayed antisaccade and Delayed prosaccade tasks was present in both the high and low anxious groups, it was significantly greater in the high anxious group (Ansari & Derakshan, 2010;

see Figure 1.10 for trial displays). These findings suggest that inhibitory control and not volitional action generation is affected in anxiety.



**Figure 1.10:** Example of experimental tasks used in Ansari & Derakshan (2010).

In summary, anxiety appears to be characterized by a reduced attentional capacity and processing efficiency as well as impaired attentional control. This has been implicated in tasks that involve executive control (e.g. in the case of distraction) and dual-task coordination. I note however that this reduced capacity is not manifested in all attentional tasks. Notice for example that the Fox et al. (2005)

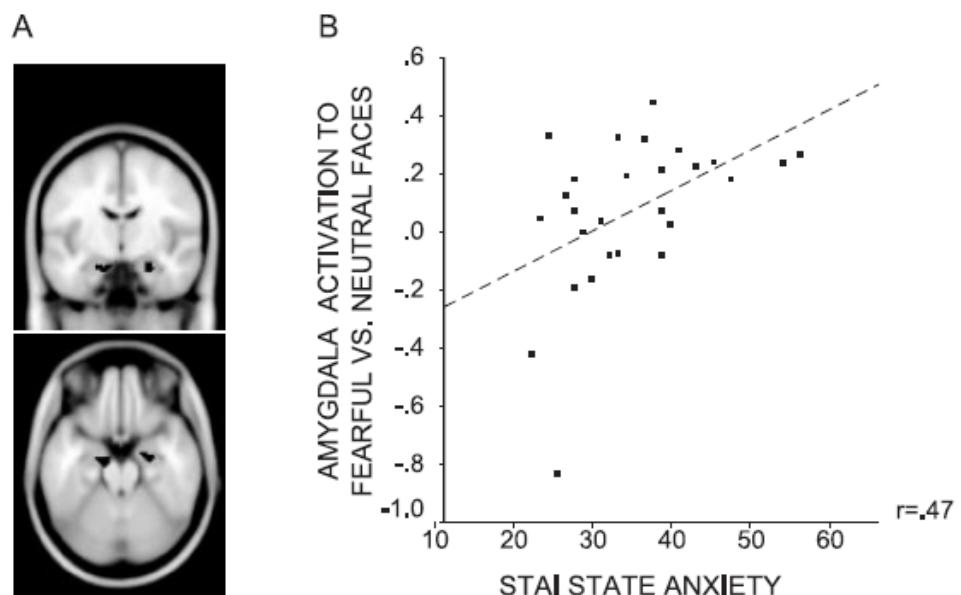
study did not show a greater AB cost associated with anxiety. This point is discussed further in Chapter 4.

#### *1.4.5 Neuroscientific evidence*

Neuroscientific evidence provides support for the idea that individuals with high levels of anxiety have a general reduced attentional control in response to non-emotional distractors. Bishop (2009) found that participants' trait anxiety level was inversely associated with activity in prefrontal areas involved in attentional control, specifically in the Dorsolateral Prefrontal Cortex (DLPFC), in response to incongruent (distractor letter N with target X or vice versa) versus congruent (distractor and target letters were the same) trials under low perceptual load conditions. More specifically, low trait anxiety was associated with increased DLPFC activity in the low load conditions. It seems, therefore, that the effect of anxiety on cognitive performance (i.e. reduced attentional capacity) is modulated by the level of perceptual load.

As reviewed previously, highly anxious individuals have been shown to have a hypervigilant threat detection system as well as reduced top-down control to negative information specifically (e.g. Fox et al., 2005). In line with these previous studies, neuroimaging studies have shown that state anxiety involves a reduced effect of attention on the increased amygdala activity in response to fearful facial expressions (Bishop, Duncan, & Lawrence, 2004). In their study, participants were presented with two pictures of houses and two pictures of fearful or neutral facial expressions and were required to attend to either set indicating whether the pictures were the same or different. Across participants, there was a significant right amygdala response to fearful compared to neutral faces. Furthermore, state anxiety

was related to left amygdala activation in response to fearful versus neutral faces (Figure 1.11). When the faces were attended, both low and high state anxious individuals showed increased amygdala activity in response to fearful versus neutral faces. Crucially, high state anxious participants showed less attentional modulation of the amygdala response to fearful versus neutral faces as shown by a selective amygdala response to unattended fearful faces in the high but not low state anxious participants.



**Figure 1.11:** Amygdala activity to fearful versus neutral faces in Bishop et al. (2004).

Electrophysiological evidence has also been obtained providing further support for the idea of an early attentional bias in anxiety (Fox, Derakshan, & Shoker, 2008). Participants with either high or low trait anxiety were presented with a pair of angry-neutral or happy-neutral facial expressions for 150 ms

followed by a target after either a short target onset asynchrony (TAO; 150 ms) or a long TAO (600 ms). Participants were required to indicate when the orientation of the target matched that of the thicker arm of the fixation cross. The N2pc (an ERP component that consists of an early response originating in the parietal cortex and a later response originating in the occipitotemporal regions) has been shown to be elicited by task-irrelevant fearful faces (see also Eimer & Kiss, 2007). Interestingly, only high trait anxious but not low trait anxious participants demonstrated a significantly enhanced N2pc in response to angry faces, supporting the idea that high anxiety is related to an attentional capture by threat. No N2pc response was found for happy faces for either of the anxiety groups.

However, it is possible that the results found in the studies by Bishop et al. (2004) and Fox et al. (2008) only extend to conditions where attentional load is low as the tasks performed did not exhaust attentional resources. The effect of perceptual load in relation to threatening stimuli has also been investigated in anxiety (Bishop, Jenkins, & Lawrence, 2007). Perceptual load was manipulated in a letter-search task that was superimposed on either a fearful or a neutral facial expression. Results showed that perceptual load modulated the amygdala response to the fearful faces (measured with fMRI) across all participants irrespective of their anxiety levels. High state anxious participants showed a selective amygdala response to fearful faces under low load whereas participants with both high and low state anxiety did not show any significant increase in the amygdala response to fearful versus neutral faces under high perceptual load. No differences in amygdala responses in either of the load conditions were found in relation to differences in trait anxiety.

Significant interactions with trait anxiety were found in the prefrontal areas. In the low perceptual load conditions, low trait anxiety was associated with increases in activity to fearful faces in all three regions of the Ventrolateral Prefrontal Cortex (VLPFC), the DLPFC, and the rostral Anterior Cingulate Cortex (ACC), whereas no such increase was observed for participants with high trait anxiety. Under conditions of high perceptual load, on the other hand, no significant increase in activity was observed for either anxiety group.

Two main implications can be drawn from these findings: Firstly, the modulation of the prefrontal areas that are primarily involved with controlled processing by anxiety supports the view that elevated trait anxiety is associated with impoverished attentional control and an inability to prevent the processing of irrelevant distractors. Secondly, and contrary to the idea that anxiety should influence threat evaluation at a preattentive stage, these results suggest that, in line with Lavie's (1995) perceptual load model, individual differences in processing will only emerge under conditions of low perceptual load. With respect to the present thesis, these findings suggest that no modulation by anxiety will be found in response to negative word valence under conditions of high perceptual load. This hypothesis is discussed further in Chapter 4.

To sum up, neuroscientific evidence showed increased related brain activity in response to threat for individuals with high compared to low anxiety. This was typically obtained for emotional information presented in pictures. The implications for emotion processing in words (as tested in the present thesis) are therefore somewhat indirect. Previous research also suggests that individual

differences in anxiety will only emerge under conditions of low but not high perceptual load.

## **1.5 Reward, attention, and perception**

The literature reviewed so far has described how factors such as allocation of attention, levels of awareness, and anxiety states mediate the perception of certain stimuli, specifically, of negative valence. Another factor that seems to influence the processing of information is the stimulus reward motivational value. This factor is investigated in Chapter 5 of this thesis. Though no study so far has addressed this question with regards to the detection of emotion in particular, research has been conducted on the effects of reward on perception in general (reviewed next).

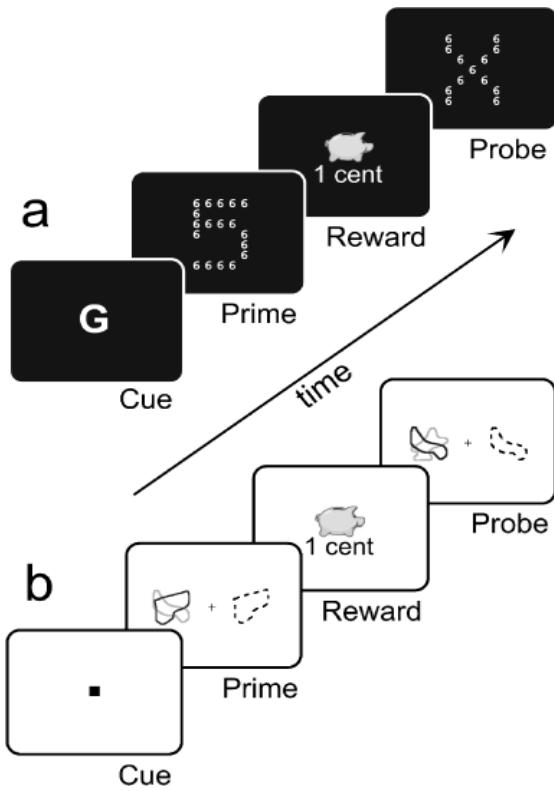
### *1.5.1 The effects of reward on visual attention*

One study has investigated the effects of reward on visual selective attention by means of a negative priming (NP) paradigm (Della Libera & Chelazzi, 2006). In NP paradigms, participants are typically presented with a prime followed shortly afterwards by a probe – a perceptual judgment is required for both. The prime usually consists of a task-relevant target and a distractor that can potentially interfere with the main task and should thus be ignored. Visual selective attention is therefore required to suppress the processing of the distractor and favour target processing. The probe display also typically involves a target and a distractor.

When the distractor in the prime display matches the target in the probe display is when NP occurs (reflected by lower accuracies and longer RTs).

In this study, participants were required to identify the number presented at either the global or local level for both the prime and probe displays. Primes were global numbers composed of local numbers that were congruent in half the trials, whereas probes were global Xs made of local numbers or global numbers made of local Xs. An example of the trial sequence and stimuli involved in the task is displayed in Figure 1.12. Participants were given a cue before the prime display indicating which level (G for global or L for local) to attend to and were required to indicate the number shown at the cued level. In another task, participants performed a same/different judgment between one of two differently coloured shapes presented to the left visual field and another shape presented to the right (both prime and probe displays contained a target and a distractor). Correct responses were rewarded by displaying the monetary reward amount (either high or low value) before the probe display.

Results showed firstly that responses were faster after low rewards compared to high rewards. Crucially, a modulation of the NP effect by reward was also found. Specifically, a robust NP was observed when the prime was followed by a high reward, but this effect was eliminated under low reward conditions (that sometimes showed an opposite facilitation (positive priming-like) effect). These findings suggest that visual selective attention can be adjusted according to external feedback. Specifically, while the robust inhibitory effects applied to the distractor were consistent following highly rewarded trials, these effects were lifted when associated with low reward (indicating less successful performance).



**Figure 1.12:** Trial sequence of paradigm used in Della Libera & Chelazzi (2006).

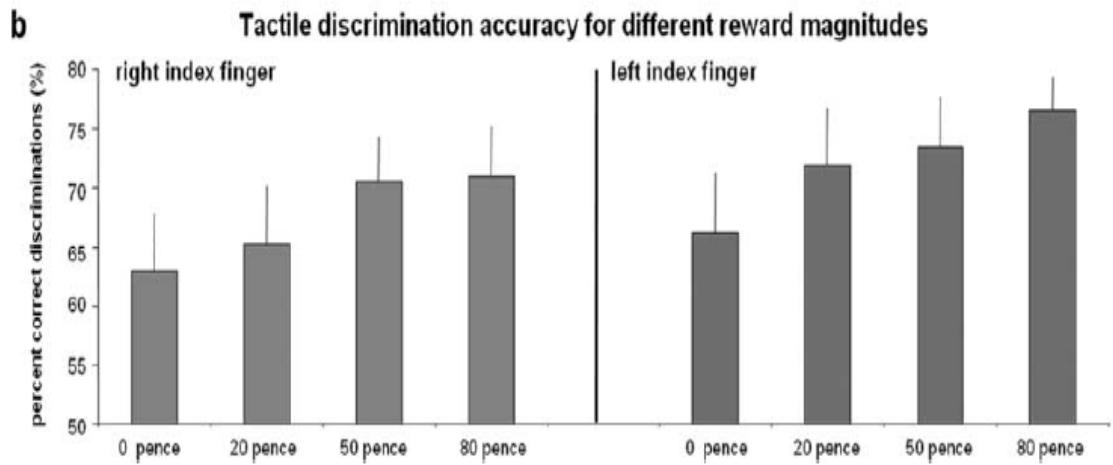
Additional behavioural evidence of an effect of reward on visual attention comes from a visual search paradigm in an EEG study (Kiss, Driver, & Eimer, 2009). The paradigm involved searching for a coloured target singleton (either red among gray or green among gray) within the display and judging the location of a notch (at the top or bottom) in the singleton target. The critical manipulation was that some participants were rewarded (with more bonus points resulting in higher payment) for correct fast performance for red targets than for green targets while others were rewarded for green targets. Results showed that responses were faster to high-reward targets compared to low-reward targets. Moreover, performance

was more efficient for high-reward than for low-reward targets as indicated by combining RTs and error rates into the parameter of inverse efficiency.

In short, modulating effects of reward on attention in terms of faster and more accurate processing have been established. More relevant to the present thesis is the potential effect of reward on detection and sensory process (reviewed next).

### *1.5.2 The effects of reward on perception and detection*

Reward has also been shown to speed up responses in the detection of novelty (Bunzeck, Doeller, Fuentemilla, Dolan, & Duzel, 2009). More relevant to the present concern with effects of reward on perception is the effect of reward on sensory function; reward has been shown to facilitate somatosensory decision-making and modulate responses in the primary somatosensory cortex (Pleger, Blankenburg, Ruff, Driver, & Dolan, 2008). Participants discriminated the relative frequency of two successive electrical stimulations applied to their index finger and signal which of the two frequencies was higher. Four reward levels were used and the potential monetary reward value was indicated to the participants. Participants were also informed via visual feedback six to eight seconds after the presentation of the somatosensory stimuli whether or not they have been rewarded. Interestingly, accuracy of the somatosensory judgments improved as reward value increased (see Figure 1.13). Moreover, receiving a reward on a preceding trial led to better performance on the next trial and had a larger influence as reward value received increased.



**Figure 1.13:** Illustration of the sensory discrimination improvement as a function of reward (Pleger et al., 2008).

Reward has also been found to improve performance on an orientation discrimination task (Baldassi & Simoncini, 2009). The experimental paradigm began with a cue line indicating the axis of a peripheral stimulus that yielded a higher probability of reward. Next the stimuli of the dual task were presented; in the attention task participants were required to count a foveal disk that was flashed several times (100 ms duration each time) and the attentional load was varied by adjusting the contrast of the disk. A peripheral target was displayed during presentation of one of the disks and its orientation was either coinciding or orthogonal to the cue line. Participants had a 90% chance (high reward) of earning credit (for obtaining a Scratch & Win ticket) when they correctly reported the orientation of the target tilt if it coincided with the cue, or had a 10% chance (low reward) if the orientation of the target was orthogonal to the cue. Orientation discrimination thresholds were measured and revealed that average thresholds were lower for reward versus no reward conditions and decreased substantially

according to low or high reward trials. This was found regardless of attentional load indicating that reward may act independently but similarly to attention by modulating the activity of early sensory stages such as V1.

The effects of reward on detection of a target have also been investigated in a cued forced-choice localization task (Engelmann & Pessoa, 2007). In this task, participants were required to indicate the location of a peripherally cued target (a house or face either to the right or left of fixation). They were encouraged to report the location of the target as quickly and as accurately as possible and to win as much money as possible. A significant effect of incentive was found as detection sensitivity ( $d'$ ) of the target increased linearly with incentive value, indicating that reward improves detection sensitivity. An enhancing effect of incentive on  $d'$  values in response to targets was found in another similar cued target localization study (Engelmann, Damaraju, Padmala, & Pessoa, 2009).

## **1.6 Summary and aims of the present thesis**

My review has demonstrated that negative words capture and engage attention, as shown by attentional cueing and AB paradigms. Evidence of interference from negative words with one's ability to maintain attention on a specific task has been somewhat mixed in normal populations, but has been consistently shown in anxious populations.

With respect to research on the effects of word valence on awareness, emotional words seem to produce a larger physiological response than neutral words. Enhanced identification for negative words has also been demonstrated (as shown by naming) as well as detection (as shown by greater hit rates). No study so

far has shown an advantage in sensitivity to the detection of the valence of negative words compared to positive words. The first aim of this thesis was therefore to establish an enhanced sensitivity to negative compared to positive valence by means of a signal detection measure of sensitivity ( $d'$ ). This effect was investigated under both supraliminal and subliminal conditions as well as conditions of low versus high perceptual load (Chapter 3), while controlling for differences between the subjective valence and arousal ratings of the negative and positive words.

Differences in anxiety in the processing of threat have been extensively researched and have consistently reported an attentional bias to threat in high anxiety compared to low anxiety as well as a selective related brain activity and electrophysiological response to threat in high anxiety states in contrast with low anxiety states. High anxiety seems to be characterized with a reduced attentional capacity and poor executive control compared to low anxiety. Although the processing of negative information seems to be less modulated by attention in high anxiety, individual differences in cognitive processing have been shown to be eliminated by high perceptual load. Another aim of this thesis was therefore to investigate individual differences in anxiety levels in relation to the negative valence detection advantage as well as the effects of load on valence detection.

Reward has been shown to modulate visual attention as reflected by increased NP effects as well as more efficient and faster detection of rewarded stimuli. Reward also enhances sensory detection and improves performance on subsequent trials, revealing a potential enhancement in sensitivity of the sensory function in response to reward. Though previous research on reward seems to indicate a facilitation of perception with the administration of reward, no study thus far has examined the effects of reward on the detection of emotional valence.

Therefore, the final aim of this thesis was to examine the effects of reward on the detection of emotional valence as well as on the negative valence advantage.

### *General method*

To achieve the aim of establishing a negative valence detection advantage, the general task followed in all the chapters of the present thesis was to report on each trial whether a briefly presented word was emotional or neutral. Note that the task did not require word detection *per se*; words were presented on all trials. Rather, in order to report whether the word was emotional or neutral, participants had to detect its emotional valence. Thus this task will be referred to throughout the thesis as valence detection (as opposed to word detection).

In the present thesis, I sought to establish a negative valence advantage using a method that is not subject to the criticisms that have been made towards previous studies. A signal detection analysis approach was used to allow for assessing whether any valence-detection advantage reflects enhanced sensitivity to negative versus positive valence, rather than a mere response bias.

In order to allow for a signal detection and sensitivity assessment for both positive and negative words, each valence was presented with neutral words in the same block. Each block of trials comprised presentations of neutral words and one type of emotional word (either positive or negative). In this way, separate FA rates (misclassifying neutral words as negative or as positive) could be calculated for each of the word valences. Therefore, in Experiments 1 and 2 as well as all experiments in Chapters 3, 4, and 5, a signal-detection approach was employed and both sensitivity ( $d'$  scores) and response bias (beta scores) to negative and positive words were measured.

Moreover, to achieve a robust and general method of the detection of emotional valence, a larger set of words (88 negative, 88 positive, and 176 neutral words) than previously used was employed in the present thesis. Finally, none of previous studies assessing the detection of negative versus positive words controlled for whether the intensities of the participants' subjective pleasantness ratings differed between the negative and positive words. Therefore, in addition to controlling for the lexical frequency of the words, differences in the idiosyncratic valence ratings of the negative and positive words were corrected for in all of the experiments of the present thesis. The role of arousal was also addressed in all but the first two experiments.

**Chapter 2:**

**Enhanced Detection Sensitivity to Negative Emotional**

**Valence: The Role of Awareness**

## **2.1 Introduction**

The purpose of Chapter 2 was to test the hypothesis that the detection of the emotional valence would result in enhanced accuracy and sensitivity for negative words (vs. neutral) compared to positive words (vs. neutral). On the basis of the research reviewed in the General Introduction that has shown a general processing advantage for negative emotional valence (e.g. Pratto & John, 1992; Kihara & Osaka, 2008; Fox et al., 2001), I predicted that this advantage will be expressed in detection sensitivity measures.

## **2.2 Experiment 1**

### **Method**

#### *Participants*

Twenty-seven participants (mean age 26, range 18-44; 20 females), recruited from UCL's online subject pool, took part in Experiment 1 and were paid £5 for their participation. All participants in all three experiments were native English speakers and had normal or corrected-to-normal vision.

#### *Stimuli and Procedure*

88 negative, 88 positive, and 176 neutral words (Appendix) were selected from the Handbook of Semantic Word Norms (Toglia & Battig, 1978). Words were chosen such that on a scale of 1 (most negative) to 7 (most positive) ratings were lower than 2.5 for negative words ( $M = 2.24$ ,  $SD = 0.18$ ); higher than 5.5 for positive words ( $M = 5.75$ ,  $SD = 0.2$ ); and mid-range for neutral words ( $M = 4$ ,  $SD = 0.11$ , range= 3.82-4.19). Word length ranged between 3-8 letters. Mean word

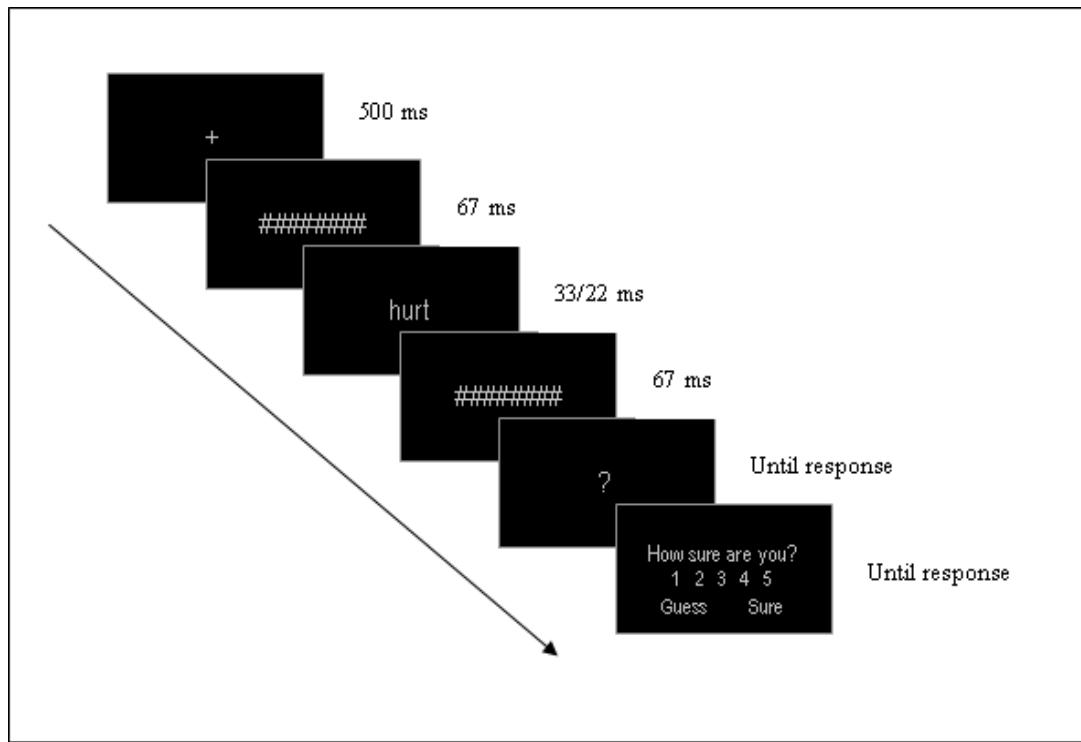
lengths were 5.43 (SD = 1.39), 5.31 (SD = 1.51), and 5.15 (SD = 1.27) letters for negative, positive and neutral words, respectively.

The experiment took place in a dimly-lit room. E-Prime 1 (Psychological Software Tools) was used to run the experiment on a PC with a 15" CRT screen (90 Hz refresh rate). A chin rest was used to maintain a viewing distance of 60 cm. Each trial began with a fixation cross, presented for 500 ms. A mask (eight hash characters) was then presented for 67 ms, followed immediately by a word, presented for either 22 ms or 33 ms (in different blocks). The word was replaced by another mask, again presented for 67 ms (Figure 2.1). All stimuli were presented in the centre of the screen in light grey (target word = 3.45 cd/m<sup>2</sup>, mask = 5.58 cd/m<sup>2</sup>) on a black background (0.014 cd/m<sup>2</sup>). The words were presented in lower-case Arial Narrow font. Word length ranged between 0.67° and 3.15° and height ranged between 0.47° and 0.86°.

Valence and word exposure duration were blocked. Participants were informed of the type of block prior to each block, and were requested to press one key if a word had emotional connotations (positive or negative, depending on the block), and another to report a neutral word. Following each response, participants were asked to rate their confidence by pressing one of the 1 (pure guess) to 5 (absolutely sure) keys. Each block consisted of 44 trials, (22 emotional and 22 neutral words, presented in random order). Each word was presented once during the experiment. The assignation of neutral words to negative or positive blocks was counterbalanced across participants.

Participants completed four practice blocks of 12 trials each (different words were used in the practice and experiment). This was followed by eight experimental blocks (four each for positive and negative valence; for each valence

there were two blocks with 33 ms and two with 22 ms presentation durations). Block order was counterbalanced across participants for both valence and exposure duration. Half of the words in each category (positive, negative and neutral) were used in each of the duration conditions; the combinations of word-list pairings (which neutral words were presented with which positive or negative words, for each duration) were also counterbalanced.



**Figure 2.1: Trial sequence in Experiment 1.** Trial onset was indicated by a fixation cross. The presentation of a word (in this example, a negative one) was preceded and followed by masks. Participants then indicated by key presses first whether the word had been emotional or neutral, and then how confident they were of that response.

Upon completion of the experiment participants provided subjective valence ratings for the words used in the experiment using a 1 (very negative) to 7 (very positive) scale. These ratings were used to ensure that the valence of each emotional word category was comparable, by equating their average distance from the extreme. For each individual, whenever the mean for one category was closer to the extreme than the mean for the other category, the most extreme words from that category and least extreme words from the other category were removed from any further analysis, until the mean valence ratings of the word categories were at an equal distance from the relevant extreme and standard deviations were similar. This resulted in the removal of six (33 ms) and seven (22 ms) negative words, and seven (33 ms) and six (22 ms) positive words on average per participant. The remaining word lists had mean ratings of 2.19 for the negative words ( $SD = .87$ ), and 5.76 for the positive words ( $SD = .84$ ). No neutral words were excluded as their mean ratings did not significantly differ from 4 ( $M = 3.93$ ,  $SD = .29$ ).

## Results

The results of Experiment 1 are summarized in Table 2.1.

**Table 2.1.** Experiment 1: Mean Percentages of Hits (False Alarms), Mean  $d'$  and Beta scores, and Mean Confidence Ratings as a Function of Presentation Duration and Word Valence

Duration				
	22 ms	33 ms		
	Negative	Positive	Negative	Positive
Hit % (FA)	64 (21)	50 (20)	77 (14)	59 (12)
$d'$	1.37	1.08	2.18	1.68
Beta	2.11	2.76	2.24	4.36
Confidence	3.06	2.95	3.93	3.97

Correct categorizations were defined as hits, and used to calculate accuracy rates for each valence. The hit and false alarm (categorizing a neutral word as emotional) rates were used to calculate  $d'$  and beta scores. Detection sensitivity,  $d'$ , is calculated by subtracting the z-score of the FAs from the z-score of the hits:  $d' = (z(\text{Hits}) - z(\text{FA}))$ . Beta, a measure of response criterion, is also derived from the hits and FAs to assess response bias, through the following equation:  $\text{In}(\beta) = \frac{1}{2}[z(\text{Hits})^2 - z(\text{FA})^2]$ . A beta greater than 1 is considered conservative whereas a beta lower than 1 is considered liberal. Percentage accuracy (hit) rates, and  $d'$  and beta scores were entered into 2 (valence: positive or negative) by 2 (duration: 22 or 33 ms) repeated-measures ANOVAs. These analyses revealed a main effect of

duration both for hit rates ( $F(1,26) = 10.17$ ,  $MSE = 351.21$ ,  $p = .004$ ) and  $d'$  scores ( $F(1,26) = 50.15$ ,  $MSE = .263$ ,  $p < .001$ ): Both accuracy and sensitivity were better under the 33 ms exposure than the 22 ms conditions. Importantly, there was also a main effect of valence for both hit rates ( $F(1,26) = 27.75$ ,  $MSE = 248.51$ ,  $p < .001$ ) and  $d'$  scores ( $F(1,26) = 9.04$ ,  $MSE = .465$ ,  $p = .006$ ), indicating that valence detection and sensitivity were better for negative than for positive valence. This result supports the hypothesis of an emotional categorization advantage (or better detection of emotional valence) for negative words. The effect of valence did not interact with duration ( $F(1,26) = 1.37$ ,  $MSE = 95.66$ ,  $p = .252$  for the hits;  $F(1,26) = 1.34$ ,  $MSE = .221$ ,  $p = .257$  for the  $d'$  scores).

Response criterion tended to be higher in the longer duration (although this effect did not reach significance;  $F(1,26) = 3.35$ ,  $MSE = 5.96$ ,  $p = .079$ ) and lower for negative compared to positive judgments ( $F(1,26) = 9.02$ ,  $MSE = 5.94$ ,  $p = .006$ ). As Table 2.1 shows, the effect of valence on criterion was larger for the 33 ms than the 22 ms duration. Indeed, it was significant in the 33 ms duration ( $t(26) = 3.08$ ,  $SEM = .69$ ,  $p = .005$ ), but not in the 22 ms duration ( $t(26) = 1.3$ ,  $SEM = .5$ ,  $p = .202$ ). The interaction of duration and valence, however, only reached marginal significance ( $F(1,26) = 3.77$ ,  $MSE = 3.88$ ,  $p = .063$ ). While the detection sensitivity of the negative valence was accompanied by a less conservative bias, this does not challenge the negative valence sensitivity advantage given that the two measures of  $d'$  and beta are independent of each other. In addition, one must not disregard the fact that participants still showed a conservative bias in detecting the negative valence regardless of the difference found, as shown by beta scores that are greater than 1 (see Table 2.1).

### *Confidence Ratings*

Overall confidence ratings were significantly lower in the 22 ms conditions ( $M = 2.83$ ) than in the 33 ms conditions ( $M = 3.75$ ; Wilcoxon Signed Rank Test,  $Z = 4.43$ ,  $p < .001$ ). However, even at the 22 ms duration the mean confidence ratings were nowhere near the ‘pure guess’ score of 1. A closer inspection of the confidence rating data indicated that participants rated their responses as a pure guess (i.e. a response of “1”) on 33% of trials in the 22 ms condition, and on only 12% of trials in the 33 ms condition. Thus, viewing conditions were not reliably subliminal under either exposure duration.

## **2.3 Experiment 2**

The results of the confidence ratings in Experiment 1 revealed that the shorter presentation duration used did not result in potentially subliminal effects. This experiment attempted to investigate whether the advantage for negative valence detection would occur under subliminal presentation conditions, by degrading stimulus visibility. To this end, the words were presented for 22 ms and their luminance was reduced.

### **Method**

#### *Participants*

Twenty-three new participants (mean age 21, range 18-27; 17 females) participated in Experiment 2 and were paid £5 for their participation.

#### *Stimuli and Procedure*

The stimuli and procedure of Experiment 2 were similar to those of Experiment 1 with the exceptions that the words were all presented for 22 ms and their luminance was reduced to 1.29 cd/m<sup>2</sup>. Participants completed two practice blocks of 24 trials each prior to the experimental blocks.

Individual valence ratings were also collected in this experiment, and the same procedure used in Experiment 1 to equate extremeness of valence was followed again here. This resulted in the removal of ten negative and seven positive words on average per participant. The remaining word list ratings were 2.05 (SD = .65) for the negative words, and 5.95 (SD = .65) for the positive words. No neutral words were excluded since their mean rating was 4 (SD = .2).

## Results

The results of Experiment 2 are summarized in Table 2.2.

**Table 2.2.** Experiment 2: Mean Percentages of Hits (False Alarms), Mean d' and Beta scores, and Mean Confidence Ratings as a Function of Word Valence

	Word Valence	
	Negative	Positive
Hit % (FA)	52 (45)	47 (46)
d'	.18	.03
Beta	1	1
Confidence	1.62	1.54

Both accuracy (hit) rates and valence detection sensitivity (d' scores) were again higher for negative than for positive words ( $t(22) = 2.43$ , SEM = 2.04,  $p =$

.024 for hits;  $t(22) = 2.2$ , SEM = .07,  $p = .039$  for  $d'$  scores). In addition, sensitivity to negative valence was higher than chance ( $d'$  scores were significantly higher than zero;  $t(22) = 3.87$ , SEM = .048,  $p = .001$ ), but sensitivity to positive words did not differ significantly from zero ( $t < 1$ ).

These findings are not surprising if considered within the framework of LeDoux's (1996) model, which describes that negative information can be unconsciously processed and reaches the amygdala through a quick route (the 'low road'). This information then produces an emotional response that provides the individual with a 'feeling' indicating potential threat without full awareness of the source of information. This intuitive feeling is one plausible mediator of unconscious processing, namely what influenced participants' responses when they were merely guessing. In addition, given that the amygdala projects back to the sensory cortex, it is likely that the sensory signal is enhanced as a result. Thus the negative words may have been detected even when processed subliminally.

Critically, the enhanced accuracy and sensitivity for negative (compared to positive) words was not accompanied by a difference in response bias. Beta scores were identical for negative and positive words (Table 2.2).

### *Confidence Ratings*

Confidence ratings were low overall (Table 2.2), and indicate that participants felt they were guessing on nearly all trials. Wilcoxon signed-rank tests showed no differences between the overall confidence ratings for neutral ( $M = 1.55$ ) versus negative ( $Z = 1.14$ ,  $p = .254$ ) and neutral versus positive ( $Z = 1.3$ ,  $p = .194$ ) words. Participants did, however, report slightly but significantly higher confidence for negative compared to positive words ( $Z = 2.96$ ,  $p = .003$ ).

To rule out the possibility that the enhanced hit rates and sensitivity were due to a differential residual awareness between negative and positive words, sensitivity only for responses with a confidence rating of 1 ('pure guess') was compared. Indeed, this comparison still showed an advantage in sensitivity to the negative (vs. positive) valence (mean  $d'$  scores were .14 for negative words and -.07 for positive words;  $t(22) = 2.21$ , SEM = .09,  $p = .038$  for the difference). Moreover, the  $d'$  scores of the 'pure guess' negative words remained significantly above the zero chance level ( $t(22) = 2.14$ , SEM = .06,  $p = .043$ ), unlike the  $d'$  scores of the positive words ( $t < 1$ ). The response criterion remained 1 for both valence categories.

Finally, a way of assessing participants' awareness of the words is by examining whether or not participants were more confident on correct responses compared to incorrect responses. It follows that if participants were aware of what they saw on any given trial, this should be reflected in their confidence level, and therefore higher confidence would be expected, on average, when they perform correctly than when they do not. If participants were unaware of the words and were guessing, they would be expected to show not only low overall confidence ratings, but also similar confidence for the correct and the incorrect trials (indicating that they were still guessing on correct trials and any success they had was by chance). For all word types there was no difference between confidence ratings reported on correct and incorrect trials (negative:  $M$  correct = 1.75,  $M$  incorrect = 1.54;  $Z = 1.61$ ,  $p = .107$ ; positive:  $M$  correct = 1.64,  $M$  incorrect = 1.48;  $Z = 1.62$ ,  $p = .104$ ; neutral:  $M$  correct = 1.59,  $M$  incorrect = 1.55;  $Z = .51$ ,  $p = .614$ ).

It should be acknowledged that confidence ratings are not a foolproof way to assess awareness or its complete absence; self-reported confidence may be low for reasons unrelated to awareness (e.g. Pleyers, Corneille, Luminet & Yzerbyt, 2007). Thus, one cannot rule out the possibility that some residual awareness remained under conditions of very brief presentation and self-reported guessing. Even with this caveat, however, the main result of this experiment is that a valence detection advantage for negative words was still evident under conditions in which participants reported they were guessing, and did not show a difference in confidence between correct and incorrect trials. Subliminal perception, construed in this limited sense, can therefore influence affective categorization despite the absence of subjective awareness.

## **2.4 Experiment 3**

The interference effects of negative valence found in various experimental paradigms described in the General Introduction may, at least under some conditions, be due to arousal rather than valence (Zald, 2003). A recent study (Aquino & Arnell, 2007), for example, found that only highly-arousing sexual taboo words, but not less arousing threatening words or non-arousing neutral words, produced longer RTs in a version of the emotional Stroop task that required making number parity judgments while ignoring an irrelevant word. These findings are reminiscent of the ‘perceptual defense’ effects whereby taboo words produce longer RTs (e.g., McGinnies, 1949) and may result from greater attentional engagement as well as the recruitment of additional processes such as executive control by highly-arousing words.

Arnell, Killman & Fijavs (2007) investigated the role of arousal in an RSVP task. When the valence and arousal of distractor words appearing before the target (and therefore serving as an equivalent of the first target in the AB paradigm) were manipulated, only highly-arousing sexual-taboo (but not negative, positive, threatening or neutral) words caused reduced identification of targets (color names) that followed shortly after them.

In another RSVP task that required participants to detect the colour of the first target word (T1) followed by the colour name of the second target word (T2), Mathewson, Arnell, & Mansfield (2008) found a significant reduction in T2 detection when T1 was a sexual/taboo word compared to when it was a negative, positive, or neutral word (no other comparisons between the T1 types were significant). Moreover, taboo words were recognized more often than all other word types and the memory for these words mediated the relationship between the arousal ratings of the emotional words and the subsequent detection of T2.

Anderson (2005) also found that although both pleasant and unpleasant words resulted in a reduced AB for T2 compared to neutral T2, arousal rather than valence was the most predictive dimension of the AB reduction. These findings suggest a mediating role of arousal in the attention to and encoding of the words.

Considering the potential mediating role of arousal, Experiment 3 was conducted to examine whether any processing advantage for negative words would still be apparent independently of arousal. As in the previous experiments, participants were requested to classify the words into emotional or neutral. The effects of arousal were controlled for in two ways: First, it is possible that presenting positive and negative words in different blocks in the previous experiments caused a difference in the average level of arousal throughout blocks

containing different valences. Therefore, in Experiment 3 a mixed-block design was used in which positive, negative and neutral words were presented within the same blocks. Second, to control for any specific effects potentially induced within a block by the more arousing words, participants' individual arousal ratings of each word (in addition to their valence ratings, as in the previous experiments) were collected and the word categories for each participant were matched for both attributes.

## **Method**

### *Participants*

Eight new volunteers (5 females, mean age 27, range 22-34) were recruited from the UCL online subject pool and paid £7 for participation.

### *Stimuli and Procedure*

The stimuli, procedure and experimental parameters were similar to Experiment 1, except words were presented for 22 ms in all blocks and all word categories (negative, positive, and neutral) were intermixed within each block. Participants were required to press a button on the keyboard if the word presented was neutral, or another button if the word was emotional (the same response was used for negative and positive words both to preserve the response characteristics of the previous experiments, and because the main interest in this experiment is whether the presence of emotional valence itself was better detected for negative than for positive words). Following this response, they were again required to rate their confidence level on a scale of 1 to 5, as in Experiments 1 and 2.

Participants first completed a practice block consisting of 36 trials (12 of each word type; these words were not used again in the experiment). This was followed by four blocks of 88 trials, each consisting of 22 negative-word, 22 positive-word, and 44 neutral-word trials.

Following completion of the categorization task, participants were asked to provide subjective valence ratings for the words used, as in Experiments 1 and 2. Some words were then excluded from the negative and positive word lists in order to equate the two categories for extremeness of valence ratings. This resulted in the removal of an average of 10 negative and 9 positive words per participant.

Following the valence rating blocks, participants were asked to rate how arousing they found each of the words used in the experiment. The words were again presented in random order, in four blocks of 88 trials preceded by one practice block (using new words) of 12 trials. Each trial began with a word presented in light grey over a black background until the participant pressed the Space bar, after which the Self-Assessment Mannequin (a widely-used rating scale with pictures displaying the relative emotion; Lang, 1980) was displayed on screen for the participants to use as a rating scale. The scale ranged from 1 (very calm) to 9 (very aroused), with 5 being neither calm nor aroused. Once participants pressed the corresponding number, the next trial began.

After equating the word-sets for valence, only three out of the eight participants rated the negative words as higher in arousal than the positive words, on average, making it unlikely that an advantage for negative words would be due to higher arousal caused by such words. However, to ensure that the word-sets were matched for arousal as well as valence, additional words were excluded from the negative and positive word lists for all participants until the mean arousal

ratings for these word categories were equal. This resulted in the exclusion of a further 31 negative and 31 positive words, on average, in addition to the words excluded to match valence (note that even after excluding these words, the average numbers of words were still 47 and 48 for negative and positive words, respectively – about three times the number of words used in the previous studies of Dijksterhuis & Aarts, 2003; Snodgrass & Harring, 2005; and Zeelenberg et al, 2006). After matching the word categories for both valence and arousal the final mean valence ratings were 2.54 (SD = .81) and 5.41 (SD = .78) for negative and positive words, respectively. No neutral words had to be excluded as their mean valence ratings did not differ significantly from 4 (M = 3.95, SD = .32). The mean arousal ratings across all participants were 4.7 (SD = 1.11), 4.7 (SD = 1.09), and 3.49 (SD = 1.21) for the negative, positive, and neutral words respectively.

## Results

The intermixed-block design employed in this experiment precluded the calculation of d' scores (since false alarms – misclassifying a neutral word as emotional – could not be assigned to a specific valence). Therefore, the dependent measure used in this experiment was percentage accuracy (hit rates). Importantly, even after matching the two categories for valence and arousal, the mean hit rate for categorizing negative words as emotional (66%) was significantly higher than for positive words (50%;  $t(7) = 2.86$ , SEM = .058,  $p = .024$ ). Interestingly, participants were significantly more accurate in categorizing the neutral words (77%) compared to both positive ( $t(7) = 3.73$ , SEM = .074,  $p = .007$ ) and negative words ( $t(7) = 2.46$ , SEM = .045,  $p = .044$ ). The higher hit rates for neutral than for emotional words most likely indicate that participants adopted a conservative

criterion for reporting emotional valence, which resulted in a high hit rate for neutral words. The fact that negative words had a higher hit rate than positive ones indicates negative valence was more likely to overcome this strict criterion.

### *Confidence Ratings*

Wilcoxon signed-rank tests revealed that confidence ratings did not differ significantly between the negative ( $M = 3.3$ ) and the neutral ( $M = 3.05$ ) words, or between the positive ( $M = 3.08$ ) and the neutral words (both  $p$  values  $> .1$ ). However, the difference between the confidence ratings of the negative and positive words was significant ( $Z = 2.03$ ,  $p = .042$ ). Participants were therefore slightly more confident when reporting negative valence.

It should be noted that presentation conditions in Experiment 3 were not designed to be subliminal; therefore, the conclusion that the valence-detection advantage for negative words is evident when controlling for arousal is limited to consciously-perceived words. Attempting to assess whether the conclusion can be generalized to words that participants reported no subjective awareness of, only trials with a confidence rating of 1 (“guess”) were examined. The power of this analysis, however, was severely curtailed by the small number of guess trials: one participant had no such trials; the remaining 7 participants had an average of 9 negative ( $SD = 3.4$ ) and 12 positive ( $SD = 4.98$ ) guess trials. There was a trend toward better valence detection for negative than positive words ( $M = 26\%$  and  $20\%$ , respectively), though unsurprisingly this trend did not reach statistical significance ( $t(6) < 1$ , *ns*).

### *Lexical frequency*

The Celex database (Baayen, Piepenbrock, & Gulikers, 1995) was used to assess the lexical frequency of the words used in this experiment. The positive words were found to have a higher average frequency ( $M = 1529$  per million) than the negative words ( $M = 720$  per million), ruling out the possibility that the negative-word advantage found in all three experiments could have been due to such words being more familiar. To rule out an alternative account in terms of potential effects of uniqueness (i.e. the frequencies of the neutral words being closer to those of the positive than of the negative words) the neutral and positive words with the highest frequencies were removed, so that the remaining words had similar frequencies to the negative words (Neutral words:  $M = 729$ ,  $SD = 1062$ ; Positive words:  $M = 724$ ,  $SD = 646$ ). This did not alter the direction of the results for either Experiment 1, 2, or 3, or their significance in Experiments 1 and 2. The significance of the negative-positive and negative-neutral hit-rate differences in Experiment 3 was somewhat reduced ( $p = .055$  and  $p = .057$ , respectively).

## **2.5 Summary and conclusions**

An advantage in detecting the emotional valence of negative (compared to positive) words was found in the present chapter. In an emotional categorization task that required participants to decide whether a briefly-presented word was neutral or emotional, better accuracy (hit rates) as well as higher sensitivity (measured with criterion-free  $d'$  scores) for negative (compared to positive) words were found. The present chapter extended this result to conditions under which

participants reported they were guessing and therefore showed no subjective awareness of the words' valence.

The negative-word advantage was found despite positive and negative words being equated for extremeness of emotional valence and arousal (as assessed by the participants' post-experiment ratings), and despite comparing the negative words with positive words of the same or even higher lexical frequency. Except for the supraliminal presentation condition (33 ms) of Experiment 1 where the response criterion was more conservative for the positive compared to the negative valence, the negative detection advantage was not accompanied by differences in response criterion between the negative and positive valence. Note, however, that the response criterion has always been found to be conservative (greater than 1) for the negative valence including the 33 ms duration condition. Furthermore, this difference in response criterion does not challenge the negative valence detection advantage given that the two measures of  $d'$  scores and beta are independent of one another. Thus the present findings are the first to show a clear detection sensitivity advantage for the negative valence per se compared to the positive valence under both supraliminal and subliminal conditions.

The negative valence detection advantage found here extends the previous findings that showed a general emotional advantage for naming negative versus neutral words (Gaillard et al., 2006) and for detecting both negative and positive words compared to neutral words in a recognition task (Zeelenberg et al., 2007) to finding a negative detection advantage. This conclusion is consistent with previous findings that have shown a detection advantage for negative compared to positive words (Dijksterhuis & Aarts, 2003). However, as discussed previously (in the General Introduction), this advantage was demonstrated on accuracy rates with no

measures of detection sensitivity or response bias. The present chapter established this negative advantage for the first time on detection sensitivity measures.

The findings of the present chapter are inconsistent with previous research that found a detection sensitivity advantage of positive words over negative words (Snodgrass & Harring, 2005). No measures of response bias were reported, however, in this study. This discrepancy may be due to their use of a small set of words as small word sets are more prone to sampling biases (e.g. one of them could form more a cohesive category so that inter-category priming effects are more likely and could facilitate detection). In addition, Snodgrass & Harring (2005) (like all the other previous studies) have not corrected for differences in idiosyncratic ratings. Despite basing their corrections on established databases or on independent ratings from other pools of participants, it remains possible that the participants in the actual experiments may have evaluated the positive words as closer to the positive end than compared to the negative words.

The results of the present chapter also suggest that less information is needed for the negative valence to be detected compared to the positive valence. The  $d'$  scores of the positive words did not differ significantly from chance when the processing of the words was unconscious in contrast with the detection of the negative valence that was significantly higher than chance. This suggestion is in line with the implication found in the study by Gaillard et al. (2006) of a potentially lower threshold of conscious detection for negative words.

The present chapter also verified that an advantage for detecting emotional valence in negative (compared to positive) words is evident even when differences in the arousal induced by negative and positive words are ruled out as an alternative account (Experiment 3): Higher accuracy was still found for negative

words when controlling for individual participants' valence intensity and arousal ratings, differences in lexical frequency, and despite negative and positive words appearing in the same blocks, ruling out both differences in individual words' arousal ratings and differences in the overall levels of arousal in different blocks as alternative accounts for the negative valence detection advantage. Note that although some of the previous research has failed to find a negative processing advantage when differences in arousal between the negative and positive valence were corrected for (e.g. Aquino & Arnell, 2007; Arnell et al., 2007), the paradigm used in the present thesis was sufficiently sensitive to reveal the negative valence detection advantage despite correcting for differences in arousal between the negative and positive valence.

The intermixed block design of Experiment 3 also allows for the ruling out of another potential alternative account for the effects of negative valence. When valence was blocked (as in Experiments 1 and 2) one might suggest that the enhanced accuracy and sensitivity found for negative valence was in fact the result of emotionally-neutral words being better categorized as such when the choice was between them and negative, rather than positive, words. If neutral words were more distinct from negative than from positive words, this implies that in the context of negative words they were perceived as being further away from that category – i.e., more positive; in contrast, in the context of positive words they were not perceived as more negative (or if they were, this difference was not as extreme as the difference in a negative-word context).

This, however, cannot explain the negative valence advantage found in Experiment 3, in which neutral words were intermixed with positive and negative words in the same block. Furthermore, any general (non-context driven) bias

toward perceiving neutral words as more positive (and for such words to therefore stand out more amongst negative than positive words) may have also been manifested in the subjective valence ratings that the participants provided at the end of the experiment. Across all three experiments, however, all the participants consistently rated all of the neutral words as neutral (rather than as somewhat more positive). The exclusion procedure followed, based on the individual subjective valence ratings, also ensured that neither the positive nor negative valence categories used in our analysis was closer to the neutral category.

The present findings may have implications for understanding the neural mechanisms of emotion perception. An ongoing debate (Pessoa, 2005) concerns the questions of whether emotional stimuli are processed automatically, and whether their processing may not even require awareness. Whereas some neuroimaging studies have found that emotional stimuli caused activation in brain regions known to process emotional information (e.g. the amygdala) regardless of attentional allocation and even when participants were not aware of the stimuli (Etkin et al., 2004; Morris, Ohman & Dolan, 1998; Vuilleumier et al., 2001; Vuilleumier et al., 2002; Whalen et. al., 1998), others have not found such activity in the absence of awareness and have in fact shown that the availability of attention is required for such activity to arise (Pessoa, McKenna, Gutierrez & Ungerleider, 2002; Pessoa, Kastner, & Ungerleider, 2002; Pessoa, Japee, Sturman & Ungerleider, 2006).

The present chapter has shown that emotional valence information can affect guessing behavior such that performance can exceed chance despite participants claiming they are unaware of the stimulus valence. Seeing that the findings of Chapter 2 only apply to words that are fully attended to, the next step

should therefore be to address the issue of whether the perception of emotion is dependent (or not) on attention by manipulating the attention directed at the presented emotional stimuli.

**Chapter 3:**  
**Enhanced Detection of Negative Valence:**  
**The Role of Attention**

### **3.1 Introduction**

In the highly demanding environment we live in today, humans are constantly bombarded with different sources of information. We thus face the challenge of focusing our attention on goal-relevant stimuli whilst being ready to detect potentially significant stimuli occurring simultaneously outside of that focus. Our attentional capacity is limited, leaving little or no space left to process goal-irrelevant stimuli when full (Lavie, 1995; 2005). As reviewed previously in Chapters 1 and 2, there is broad evidence in the literature, however, for the prioritized processing of emotional stimuli over neutral stimuli (e.g. Pessoa, 2005; Phelps, 2006 for a review). But does this preferential processing survive even the most stringent attentional demands placed upon us everyday, or is some attentional capacity still required for the perception of affective stimuli?

The results of Chapter 2 showed a consistent and significant enhanced detection sensitivity to the emotional valence of negative words over that of positive words in both supraliminal and subliminal conditions. Importantly, the effect remained present after ruling out any idiosyncratic differences in valence intensity as well as any arousal effects, thus providing conclusive evidence for an enhanced sensitivity for negative valence detection. However, the findings so far are limited to stimuli that were fully attended to. Given that a task was used with only one stimulus presented on each trial, attention should have been fully focused on the valence detection task. In Chapter 3, I therefore tested the effects of attention on valence detection. To address the role of attention in valence detection, the framework of the Load Theory of Attention and Cognitive Control was employed.

### *Perceptual load theory*

According to Lavie's perceptual load model (1995; 2005), the level of perceptual load involved in a task determines whether additional stimuli will be processed. Our attention has limited capacity; within this capacity, however, the perception of all stimuli, regardless of relevance, proceeds automatically. If a task occurs under conditions of high perceptual load, then the relevant task consumes most capacity, leaving little or none for irrelevant perception, thus preventing distractor detection and related neural activity. In contrast, low perceptual load leaves spare capacity which then spills over to the processing of irrelevant stimuli. Under such conditions distractors are perceived, elicit neural activity, and reach awareness. Perceptual load is conceptualized as either increasing the relevant items in the task or increasing the perceptual demands of the task with the same number of items.

Various behavioral and neuroimaging studies supporting the perceptual load theory have been conducted (see Lavie 2005; 2010 for reviews). For example, Lavie (1995) found that interference from irrelevant distractors occurred only under low perceptual load conditions. This was observed when load was manipulated by increasing the relevant task set size (see also Lavie & Cox, 1997), by increasing the demands in the task requiring either to detect colour (low load) or conjunctions of colour and shape (high load), and by performing either a simple detection task or a more complex identification task.

Other studies extended the effects to negative priming (NP). For example, Lavie & Fox (2000) requested participants to perform a letter search task under low and high perceptual load conditions while an irrelevant distractor that is to be

ignored appeared in the periphery. A negative priming effect is found when responses are slowed when the prime distractor is repeated as the probe target in comparison with trials that do not involve any repetition. They found that participants were distracted by response competing distractors showing both response competition effects and negative priming effects under low load but not under high load.

The effect of perceptual load on distractor processing was extended to meaningful distractor objects (Lavie, Lin, Zokaei, & Thoma, 2009) and to measures of attentional capture by irrelevant distractors (Forster & Lavie, 2008).

The neural processing of unattended stimuli also seems to depend on level of load, with high perceptual load diminishing distractor related activity in the brain (e.g. Schwartz, Vuilleumier, Hutton, Maravita, Dolan, & Driver, 2005; Yi, Woodman, Widders, Marois, & Chun, 2004; for a review see Lavie, 2005). For example, neural activity related to visual motion was found to be modulated by load as V5 response to moving dots was observed under low load but no increase in associated activity was found under high load (Rees, Frith, & Lavie, 1997).

### *Perceptual load and conscious detection*

The conclusions drawn from the previous studies investigating the effects of perceptual load on the perception of task-irrelevant stimuli are based mainly on indirect measures of perception such as response times (RTs) and neural activity, with no direct measure of whether high perceptual load truly eliminates conscious perception of irrelevant stimuli. One cannot deduce with full certainty that participants consciously perceived the distractors based solely on their effects on RTs. Distractor effects on target RTs under low load could instead reflect

unconscious processing of stimulus-response associations rather than awareness of the distractor.

In a study investigating the effects of perceptual load on conscious detection or conversely the lack of it (inattentional blindness, IB), Cartwright-Finch & Lavie (2006) found consistent evidence in support of a greater inattentional blindness rates to a critical unexpected stimulus under high load (detecting subtle differences in the length of the arms in a cross-task or a visual search task with highly similar letters) compared to low load (colour detection of the arms of the cross or a ‘pop-out’ visual letter search). However, inattentional blindness was not necessarily reflective of the absence of conscious perception. The results could instead be explained by memory effects (longer delays in responding in the high load or due to the processing of the surprise question may have lead to the rapid forgetting of the stimulus). Moreover, the unexpected nature of the critical stimulus could mean that it may have still been perceived but produced only a weak signal (see Barber & Folkard, 1972; Bashinski & Bacharach, 1980; Davis, Kramer, & Graham, 1983; Teichner & Krebs, 1974).

More relevant to the present thesis is evidence of reduced detection sensitivity under conditions where attentional resources are fully engaged in another task (Macdonald & Lavie, 2008): a phenomenon termed “load-induced blindness”. In Macdonald & Lavie’s (2008) study, participants performed a letter search task in a visual search array composed of a letter circle. Perceptual load was either low or high, and was manipulated by varying the non-target letters. At the same time as the letter circle, a small meaningless distractor that participants were required to detect appeared in the periphery.

The authors found an effect of perceptual load on the conscious detection of the critical stimulus (high perceptual load reduced the detection of the irrelevant stimuli), reporting this effect on both measures of detection accuracy and sensitivity, with no accompanying effect of response bias.

### *Aims of the present chapter*

Based on these previous findings, this chapter aimed to investigate the question of whether the availability of attentional resources is required for the enhanced sensitivity to negative valence by examining the effects of perceptual load on valence detection. Considering all the evidence of reduced distractor processing under conditions of high perceptual load, I predicted firstly that the detection sensitivity in general (i.e. for both the negative and positive valence) would be reduced in the high load condition.

The second and perhaps more important prediction at least here was that the negative valence detection advantage would also be reduced or even eliminated under conditions of high load compared to low load. Perceptual load has been shown to reduce amygdala activity related to fearful faces (e.g. Pessoa, Padmala, & Morland, 2005; Pessoa, et al., 2002). It is therefore possible that perceptual load would also reduce the negative valence detection advantage. On the other hand, there are cases of exceptions showing for example that famous distractor faces are unaffected by perceptual load (Lavie, Ro, & Russell, 2003). It is therefore also possible that the enhanced sensitivity to negative valence will not be affected by high perceptual load suggesting that the negative valence advantage is automatic. In order to test these predictions, an experiment was designed combining a valence detection paradigm with a perceptual load manipulation task.

Similarly to Chapter 2, a signal detection approach was employed measuring both sensitivity to negative and positive valence and response bias. The perceptual load design was adopted from Macdonald & Lavie (2008); in all experiments participants were presented with letters arranged in a circle including the target letter X or N and were asked to report the target letter. Perceptual load was manipulated by varying the remaining non-target letters; being small O's in the low load condition or different angular letters in the high load condition. A word was also presented on each trial simultaneously with the letters in the centre of the letter circle at fixation. Word valence was either emotional (negative or positive depending on the block) or neutral, and participants were required to categorize the presented word according to its valence. By blocking emotional valence in this way, hits and false alarm rates could be assessed separately for each valence.

Prioritizing the letter search was stressed to participants, while the valence detection task was instructed to be of secondary significance. Participants responded first to the letter search task and then to the valence task.

### **3.2 Experiment 4**

#### **Method**

##### *Participants*

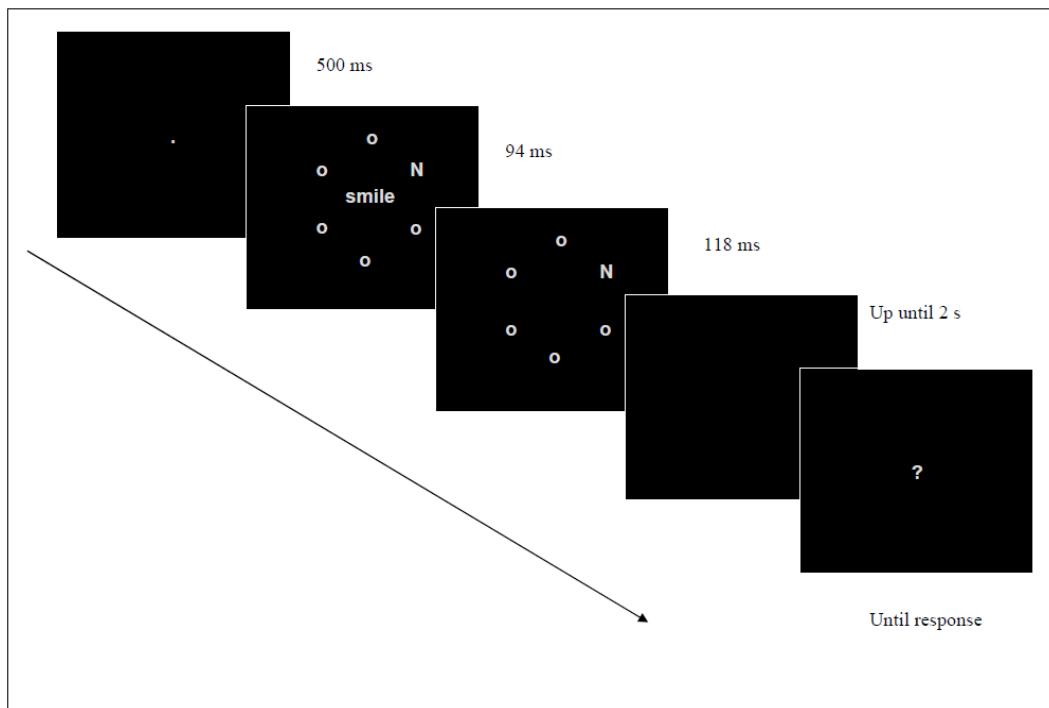
Sixteen volunteers recruited from University College London's online participant pool participated in the first experiment and were paid £6 for their participation. All participants in all experiments were native English speakers and had normal or corrected-to-normal vision. Two participants were excluded from the analyses due to extremely low accuracy on the letter-search task in the high load

condition (less than 55% accuracy). The remaining fourteen participants had a mean age of 19 (range 18 – 21; 11 females).

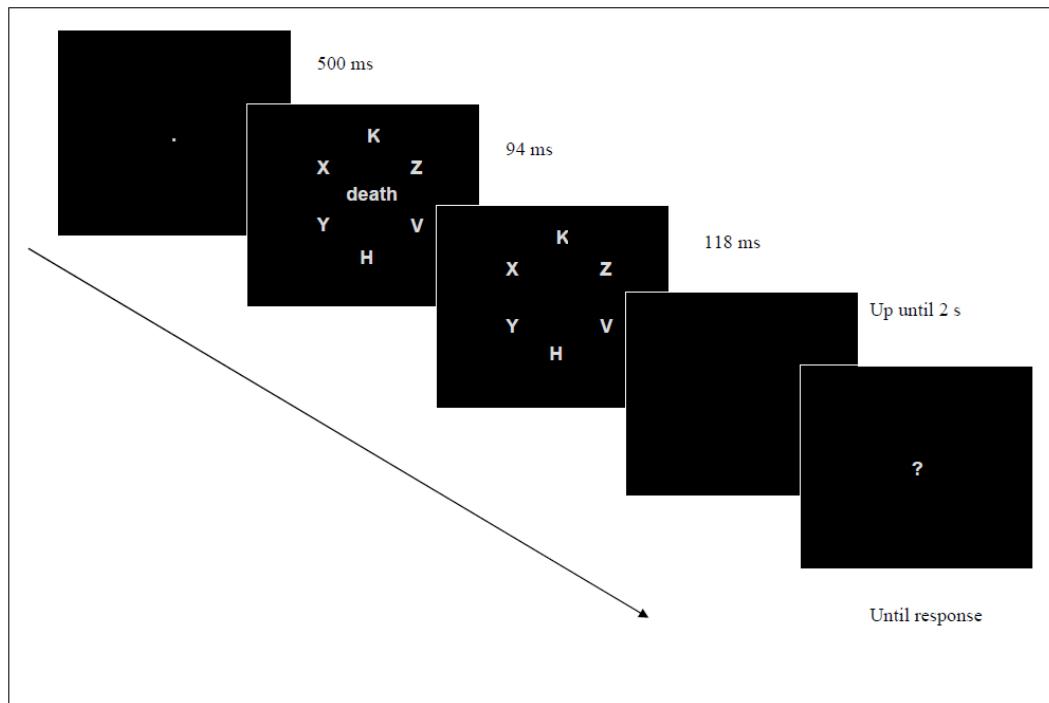
### *Stimuli and Procedure*

The word set applied was the same used in the experiments in Chapter 2.

The experimental setting was similar to that in Chapter 1 except for the refresh rate of the monitor being 85 Hz. Each trial began with a fixation dot presented for 500 ms on a black screen, followed immediately by the presentation of a centrally located circle ( $2.8^\circ$  radius circle; as measured from fixation to the top of the letter) for 212 ms. The letter display was made up of the target letter (equally likely to be either an X or an N in randomized order) and five other non-target letters (each opposing  $0.7^\circ$  by  $0.5^\circ$ ), which were either small O's (low load condition: Figure 3.1) or the angular letters Y, H, Z, K, V (high load condition: Figure 3.2). A word was also presented at the same onset of the letter circle but disappeared after 94 ms (eight refresh rates of 11.7 ms). Piloting tests indicated that this duration made the valence detection possible (i.e. not at “floor”) yet challenging. Following the offset of the stimuli, a blank screen was displayed during the response interval for the letter search; until response or until the 2-second time-limit has passed. Finally, a question mark indicating the response time for the valence detection followed immediately after and remained on-screen until response.



**Figure 3.1: Trial sequence in Experiment 4.** Trial onset was indicated by a fixation cross. Then, simultaneously, the letter circle (in this case low load) and a word (in this case: positive) appeared. The word disappeared before the letter circle. Participants indicated by key presses the target letter (in this case: 'N') and then, after appearance of the question mark, whether the word was emotional or neutral.



**Figure 3.2: Trial sequence in Experiment 4.** Trial onset was indicated by a fixation cross. Then, simultaneously, the letter circle (in this case high load) and a word (in this case: negative) appeared. The word disappeared before the letter circle. Participants indicated by key presses the target letter (in this case: 'X') and then, after appearance of the question mark, whether the word was emotional or neutral.

The instructions clearly emphasized the importance of prioritizing the letter search task and the secondary nature of the valence detection task. Participants were required to respond to the letter search as fast as possible while maintaining accuracy, by pressing '0' on the numerical keypad for 'X' and '2' for 'N'. Auditory feedback (a short 'beep') was given if the time limit was exceeded or if an incorrect response had been made. Immediately following the letter search response

participants were required to press ‘A’ if the word was emotional – negative or positive, according to the block – or ‘S’ if the word was neutral when the question mark appeared.

All word stimuli were presented in the centre of the screen in light grey on a black background (luminance of the target word and background were 2.51 cd/m<sup>2</sup> and 0.03 cd/m<sup>2</sup>, respectively). The words were shown in lower-case Arial Narrow font size 12. The lengths of the words ranged between 0.5° and 2.3°, and the height ranged between 0.5° and 0.4°.

The allocation of neutral words to negative or positive blocks was also counterbalanced across participants. Participants completed eight experimental blocks of 44 trials each (22 emotional and 22 neutral words, in randomized order). This resulted in having four positive blocks (two low load and two high load), as well as four negative blocks (again two low load and two high load). Before each block, participants were informed of the load and valence of the upcoming block. Load was ordered in an ABBAABBA manner, with A and B representing either low or high load, counterbalanced across participants; valence was run in an ABABABAB order with A & B representing positive and negative valence, also counterbalanced across participants. Before the experiment, participants completed four practice blocks of 12 trials each. Each word was used once throughout the experiment, and different words were used for the practice blocks and the experimental blocks.

As in Chapter 2, participants were asked to provide subjective valence ratings using a scale from 1 (very negative) to 7 (very positive) upon completion of the experiment. Following the valence-ratings session, participants also rated each word on arousal using the Self-Assessment Mannequin (Lang, 1980; see Chapter

2). The scale ranged from 1 (very calm) to 9 (very aroused), and 5 being neither calm nor aroused. The valence and arousal ratings were assessed to ensure that the valence and arousal levels of both emotional word categories were comparable, using the same procedure followed in Chapter 2.

The mean valence ratings of the emotional word categories were initially 1.75 ( $SD = .5$ ) and 5.84 ( $SD = .51$ ) for the negative and positive words respectively. No neutral words had to be excluded as their mean valence ratings did not differ significantly from 4 ( $M = 3.95$ ,  $SD = .29$ ).

Most participants rated the negative words as higher in arousal ( $M = 5.94$ ,  $SD = 1.88$ ) than the positive words ( $M = 4.99$ ,  $SD = 1.29$ ). The mean arousal ratings of the neutral words was 4.49 ( $SD = 0.87$ ). To address any potential role for arousal in the effect of valence, the emotional word categories were matched on arousal, using the same method as in Chapter 2.

Matching the words on both valence and arousal resulted in a total of forty-two negative and forty-one positive words remaining on average for the analyses per participant, with mean valence ratings of 1.93 ( $SD = .51$ ) for the negative words and 6.09 ( $SD = .56$ ) for the positive words and mean arousal ratings of 5.75 ( $SD = .93$ ) for the negative words and 5.75 ( $SD = .94$ ) for the positive words<sup>2</sup>.

## Results

Incorrect responses and missed trials were excluded from the results of both the letter search RTs and the valence detection in all experiments in Chapters 3 and 4. Furthermore, the results reported for all the experiments in this thesis from here on are those for words matched on valence intensity and arousal.

---

<sup>2</sup> Two participants were excluded from the analyses: one did not participate in the call-back session to provide arousal ratings, another one had no words left in one of the conditions after matching for arousal.

### *Letter search*

Letter search RTs in the high load were significantly slower ( $M = 960$  ms) compared to the low load ( $M = 797$ ;  $t(11) = 3.872$ , SEM = 42.26,  $p = .003$ ), and accuracy rates were significantly lower in the high load ( $M = 77\%$ ) than in the low load ( $M = 87\%$ ;  $t(11) = 7.34$ , SEM = .014,  $p < .001$ ). These results confirm that the load manipulation was successful.

### *Valence detection*

The results are summarized in Table 3.1. A 2 (load: low vs. high)  $\times$  2 (valence: negative vs. positive) repeated measures analysis of variance (ANOVA) was conducted on the hit rates, the  $d'$  scores, and on the beta scores for all experiments in Chapter 3.

**Table 3.1.** Experiment 4: Mean % Hit Rates,  $d'$  and Beta scores as a Function of Load and Valence

Load						
	Low			High		
	Negative	Positive	Neg - Pos	Negative	Positive	Neg - Pos
HR % (FA)	66 (22)	49 (22)	17	45 (34)	31 (20)	14
$d'$	1.50	.92	.58	.36	.45	-.09
Beta	2.89	2.43	.46	1.33	1.69	-.36

The ANOVA on the hit rates revealed a significant main effect of load ( $F(1, 11) = 47.43$ ,  $MSE = 94.561$ ,  $p < .001$ ) indicating greater accuracy in the low compared to the high load supporting the hypothesis that high perceptual load would significantly reduce the detection of emotional valence (Table 3.1). The main effect of valence was also significant ( $F(1, 11) = 14.45$ ,  $MSE = 212.591$ ,  $p = .003$ ). As shown in Table 3.1, the accuracy was higher for the negative compared to the positive words. The interaction between load and valence was not significant ( $F < 1$ ). Thus a negative valence advantage was found on accuracy and this did not depend on the level of load. The  $d'$  analyses reported next addresses the important question of whether these effects reflect a true perceptual sensitivity advantage and whether perceptual sensitivity would also be unaffected by load.

A similar ANOVA on the  $d'$  showed that, as expected,  $d'$  scores were also significantly higher in the low load compared to the high load ( $F(1, 11) = 7.79$ ,  $MSE = .232$ ,  $p < .001$ ; see Table 3.1). Detection sensitivity was therefore higher in the low load compared to the high load, as one would expect since more resources are available for additional processing under conditions of low perceptual load compared to high perceptual load. This result is consistent with Macdonald & Lavie (2008) and extends it to the detection of emotional valence. The main effect of valence found on the hit rates was not replicated for the  $d'$  scores ( $F(1, 11) = 3.028$ ,  $MSE = .241$ ,  $p = .11$ ).

Crucially, the interaction between load and valence was significant ( $F(1, 11) = 5.603$ ,  $MSE = .239$ ,  $p = .037$ ). As shown in Table 3.1, this interaction revealed a detection sensitivity advantage for the negative compared to the positive valence under low load ( $t(11) = 2.57$ ,  $SEM = .224$ ,  $p = .025$ ) but not under high load  $t(11) = .505$ ,  $SEM = .173$ ,  $p = .62$ ). The enhanced sensitivity to the negative

valence in the low load is in line with the negative valence detection advantage established in Chapter 2. Note that the low load conditions of Chapter 4 are more akin to the experimental conditions in Chapter 2 as attentional capacity was more available to the valence detection task in the low load condition. These findings support the prediction of a modulation of the negative valence detection advantage by perceptual load contradicting the idea that the enhanced sensitivity to negative valence is automatic.

The ANOVA on the beta scores revealed a main effect of load ( $F(1,11) = 8.06$ ,  $MSE = 1.954$ ,  $p = .016$ ). The higher beta scores in the low load compared to the high load (see Table 3.1) indicate that the participants had adopted a more conservative criterion in the low load condition compared to the high load condition. A possible account for this is that participants may feel that under the low load they can make more accurate decisions and therefore be more cautious in their decision criterion thus becoming more conservative under the low load conditions compared to high load conditions.

There was no significant main effect of valence ( $F < 1$ ) or interaction ( $F(1,11) = 1.151$ ,  $MSE = 1.773$ ,  $p = .306$ ). While the main effect of load on detection sensitivity was accompanied by an effect on response bias, the interaction between load and valence was not. The absence of a significant interaction between load and valence on the beta scores is important as the load by valence interaction on the  $d'$  scores is the crucial finding. Clearly the effect of perceptual load on detection sensitivity was not accompanied by an effect on response criterion.

These results are suggestive of a mediating role of attention in the enhanced detection sensitivity to negative word valence. Before this suggestion can be taken as conclusive evidence, however, an important factor needed to be addressed.

### Effects of search RTs

The search task RTs were longer in the high load than in the low load conditions. This could have resulted in participants forgetting the word presented or their valence decision more often by the time they had to make their valence detection response in the high load compared to the low load conditions. Thus an alternative account in such terms can explain both the overall reduction in detection sensitivity in the high (compared to low) load condition (see Macdonald & Lavie, 2008) and more importantly the reduction in the negative valence advantage in high (compared to low) load condition. In other words one may claim that the detection advantage for negative valence was no longer found in the high load condition because the participants were more likely to forget the word by the time they made their search task response in the high load condition. More precisely, one may attribute the findings to a form of inattentional emotional amnesia (Wolfe, 1999).

To address this alternative account, a median split analysis was conducted on the basis of the load RT effect. The difference in search RTs between the high and low load conditions was calculated per each individual and then the group was split across the median of these RT load differences. This resulted in splitting the data into two groups; one below the median (indicating a small difference in RT

between the low load and high load conditions), and one above the median (indicating a larger difference between the low load and high load conditions).

A  $2 \times 2 \times 2$  mixed-model ANOVA with group as a between-subjects factor and load and valence as the within-subjects factors revealed no significant main effect of group ( $F(1,10) = 2.017, p = .186$ ). The interactions between group and load ( $F(1,10) = .107, p = .75$ ) and between group and valence ( $F(1,10) = .046, p = .835$ ) were also not significant. Finally, the three-way interaction between group, load, and valence was not significant ( $F(1,10) = .376, p = .553$ ).

These results rule out alternative accounts in terms of slower search RTs for the effect of load, valence or the interaction.

#### *Lexical frequency*

In order to rule out the possibility that the effects of negative valence were due to the negative words having a lower frequency (e.g. being perhaps more unique), the average frequencies of the three word categories were matched following the same procedure in Chapter 2. After matching the mean frequencies of all word categories in addition to the valence intensity and arousal levels of the emotional word categories, the interaction between load and valence on the  $d'$  scores remained significant ( $F(1,11) = 4.984, MSE = .268, p = .047$ ), revealing again an enhanced detection sensitivity for the negative valence ( $M = 1.47$ ) compared to the positive valence ( $M = .95$ ) under low load ( $t(11) = 2.312, SEM = .225, p = .041$ ) but not under high load ( $M_{\text{negative}} = .35, M_{\text{positive}} = .49; t(11) = .778, SEM = .187, p = .453$ )

Experiment 4 clearly demonstrated an advantage for the detection of negative word valence in the low load but not in the high load, indicating that attentional resources are required for an enhanced detection sensitivity of negative valence.

### **3.3 Experiment 5**

Although no significant interactions with group were found in the median split analyses, a potential concern is that this lack of effect may simply be due to the lack of power (since a smaller number of subjects are included in each group). In order to more conclusively rule out an alternative account in terms of the potential confounds (e.g. memory) involved with the different search RTs under the different conditions of load, in Experiment 5 the search task procedure was changed in an attempt to match the search RTs between the high and low load conditions. A 1-second time-window was added after onset of the stimuli before participants made the letter search response to provide a wait that is longer than the RT of the high load condition ( $M = 960$  ms) in Experiment 4, with the prediction of finding a similar pattern of results as in Experiment 4.

## **Method**

### *Participants*

Fourteen participants took part in Experiment 2 (mean age 22, range 18 – 33; 8 females).

### *Stimuli and Procedure*

Stimuli and procedure were the same as in Experiment 4, except that participants had to wait for 1 second between stimulus onset until any response could be made. Following this time-window, the presentation of “X/N?” response probe signalled the time to make the letter search response within the two seconds the probe remained on-screen. The instructions still emphasized the primary importance of the letter search task. Upon making the letter search response, a question mark indicating the time to make the valence detection response followed and remained on-screen until response as in the previous experiment.

As before, the emotional word categories were matched on valence and arousal. Neutral words were not excluded as their mean ratings did not differ from 4 ( $M = 4$ ,  $SD = .1$ ). The mean valence ratings of the emotional word categories were initially 2.12 ( $SD = .63$ ) and 5.41 ( $SD = .59$ ) for the negative and positive words respectively. Eight of the fourteen participants rated the negative words as higher in arousal ( $M = 5.33$ ,  $SD = 1.68$ ) than the positive words ( $M = 5.05$ ,  $SD = .98$ ) with the neutral words having a mean arousal rating of 4.77 ( $SD = .54$ ).

After the emotional word categories were matched on both valence and arousal, a total of forty-nine negative and forty-eight positive words remained for the analyses with mean valence ratings of 2.45 ( $SD = .66$ ) for the negative words, and 5.57 ( $SD = .66$ ) for the positive words and mean arousal ratings that were matched to 5.43 ( $SD = .56$ ) for the negative words, and 5.43 ( $SD = .56$ ) for the positive words<sup>3</sup>.

---

<sup>3</sup> One participant did not have any words left in at least one of the conditions after matching the words on both valence and arousal, and was thus excluded from the analyses.

## Results

### *Letter search*

Search responses were no longer significantly slower in the high load ( $M = 411$  ms) compared to the low load ( $M = 382$  ms;  $t(12) = 1.7$ , SEM = 17.02,  $p = .116$ ). However, accuracy rates were significantly lower in the high load ( $M = 80\%$ ) compared to the low load condition ( $M = 94\%$ ;  $t(12) = 6.36$ , SEM = .02,  $p < .001$ ), confirming that the manipulation of load remained effective.

### *Valence detection*

Table 3.2 shows the results of Experiment 5.

**Table 3.2.** Experiment 5: Mean % Hit Rates,  $d'$  and Beta scores as a Function of Load and Valence

Load					
	Low		High		
	Negative	Positive	Neg - Pos	Negative	Positive
HR % (FA)	66 (10)	49 (12)	.17	54 (24)	43 (19)
$d'$	1.91	1.26	.65	1.01	.85
Beta	3.18	2.43	.75	2.93	2.71

The ANOVA on the participants' hit rates revealed a significant main effect of load ( $F(1, 12) = 4.773$ , MSE = 226.298,  $p = .049$ ) reflecting greater accuracy in the low than in the high load as expected and in line with the findings of Experiment 4. Accuracy was also significantly greater for the negative compared to the positive words ( $F(1,12) = 5.727$ , MSE = 399.651,  $p = .034$ ; see Table 3.2). No significant interaction was found ( $F < 1$ ). These results replicate the pattern found on the accuracy results in Experiment 4.

Detection sensitivity was also higher in the low load compared to the high load ( $F(1, 12) = 12.106$ , MSE = .46,  $p = .005$ ) in line with the prediction that the detection of emotional valence would be adversely affected by high perceptual load as in Experiment 4. Detection sensitivity was significantly higher for the negative valence compared to the positive valence ( $F(1, 12) = 8.574$ , MSE = .248,  $p = .013$ ; Table 3.2).

More importantly, the interaction between load and valence was also significant ( $F(1,12) = 5.258$ , MSE = .147,  $p = .041$ ), revealing again an enhanced sensitivity to the negative valence compared to the positive valence in the low load condition ( $t(12) = 3.95$ , SEM = .164,  $p = .002$ ) but not significant in the high load condition ( $t(12) = .875$ , SEM = .184,  $p = .399$ ; Table 3.2). These findings replicate the results of Experiment 4 supporting once again the enhanced sensitivity to negative valence found in Chapter 2 under conditions of no perceptual load and show that this effect can also be found under conditions of low load where sufficient attentional resources are available while ruling out the potential confounds involved with the different search RTs in the different conditions of load.

The ANOVA on the beta scores revealed no main effect of load ( $F < 1$ ) contrary to the results of Experiment 4. This suggests that the difference in response bias between the two conditions of load found in Experiment 4 might be due to differences in search RTs between the load conditions. Although Table 3.2 shows a difference between the beta scores of the negative and positive words that appears to be larger under low load in comparison with the high load, no main effects of valence ( $F(1,12) = 1.535$ ,  $MSE = 2.024$ ,  $p = .239$ ), or an interaction ( $F < 1$ ) were observed. Thus similarly to the previous experiment, the effect of load on valence detection was not accompanied by an effect on response bias.

#### Lexical frequency

Matching the three word categories on mean lexical frequencies in addition to matching the valence intensity and arousal levels of the emotional word categories weakened the interaction between load and valence on the  $d'$  scores (Low load:  $M$  negative = 1.90,  $M$  positive = 1.30; High load:  $M$  negative = 1.03,  $M$  positive = .74;  $F(1,12) = 1.395$ ,  $MSE = .229$ ,  $p = .26$ ), although in the same direction. The lack of an interaction found here is most likely due to the increase in the negative valence detection advantage under high load in the present experiment (mean difference of .29) compared to before the frequency levels were matched (mean difference of .14). The negative valence advantage did not markedly differ in the low load (mean difference of .60 after matching mean frequencies versus a difference of .65 before matching for frequency). The main effect of valence remained significant ( $F(1,12) = 9.551$ ,  $MSE = .274$ ,  $p = .009$ ).

It appears therefore that when the mean frequencies of the word lists were matched, the negative valence detection advantage became stronger under high load. Bearing in mind that the overall response latencies were longer in this experiment relative to Experiment 4 due to the forced 1-second wait, this could lead to a greater likelihood of forgetting, and low frequency words are known to be more prone to forgetting than high frequency words. Given that the negatively valenced words were of lower overall frequency this would have disadvantaged the negative valence when attentional resources were scarce (under high load) so that the advantage was no longer found. Once the lexical frequencies were equated, this allowed the negative valence advantage to be reinstated even in the high load condition. In addition, this appears to be due to the greater detection of high frequency positive words in the high load which may have masked the negative valence detection advantage as shown by lower  $d'$  scores for the positive valence in the high load when the frequency levels were matched (mean  $d' = .74$ ) compared to before matching the mean lexical frequencies (mean  $d' = .85$ ). This finding does not challenge the effect of load on the negative valence detection advantage found in Experiment 4, however, as it reflects potential effects of frequency on memory.

In summary, Experiment 5 ruled out potential confounds involved with different RTs in different load conditions and supported the results of Experiment 4, providing further evidence of a modulation of the negative valence detection advantage by perceptual load. However, when frequency levels were matched, the negative valence advantage was unveiled in the high load suggesting a potential effect of frequency on memory that may have concealed the enhanced sensitivity to the negative valence in the previous experiment.

### **3.4 Experiment 6**

The results of Chapter 2 showed that the enhanced detection of negative valence occurs even in the absence of subjective awareness of the words. This raises the interesting question with regards to attention and whether the valence detection of words presented under conditions of unconscious processing would also depend on attention. In other words, when perceptual load is manipulated, would the detection of negative valence for subliminally presented words be modulated by load? Perceptual load has been found to also influence unconscious processing. For example, Bahrami, Lavie, & Rees (2007) provided support for modulation of neural activity by perceptual load in primary visual cortex (V1) in response to irrelevant neutral stimuli that were made invisible by continuous flash suppression (CFS). Responses to the presence of an invisible object were significantly reduced under high perceptual load. In another paradigm that involved a task-irrelevant oriented grating that was suppressed from awareness, perceptual load also modulated the orientation-specific adaptation (i.e. adaptation was only found in low load and not in high load; Bahrami, Carmel, Walsh, Rees, & Lavie, 2008). The effect of perceptual load is therefore not limited to consciously-perceived stimuli.

Considering this evidence in addition to evidence of an enhanced sensitivity to negative valence in unconsciously presented words in Chapter 2, Experiment 6 was conducted to investigate whether the effect of perceptual load on the negative valence advantage may extend to subliminally-presented emotional words. It was firstly predicted therefore that, as in Experiments 4 and 5, a reduction of detection

sensitivity in general would be found from low load to high load. In addition, based on the findings in Experiments 4 and 5 showing an elimination of the negative valence detection advantage under high load, the second and more critical question was whether perceptual load would also modulate the negative valence advantage even under conditions that produce more instances of unconscious processing. But given that the present experiment involves early processing, one might find alternatively that the enhanced sensitivity to negative valence may not be affected by attention.

## **Method**

### *Participants*

Thirty new participants were recruited and paid £7 for their participation. Three participants were excluded on the basis of adopting a constant response (having a 100% false alarm rate) and one participant was excluded due to extremely low accuracy on the letter search task (less than 55%) in the high load. This resulted in a final number of twenty-six participants (mean age 23, range 18 – 40; 22 females).

### *Stimuli and procedure*

The stimuli and procedure were similar to those in Experiment 4. However, in order to achieve subliminal processing of the words a few crucial changes were made: the word was presented for only 35 ms, its brightness was reduced, and it was followed by a mask of eight hash characters for the remaining display duration (165 ms). After responding to the word valence detection task, a confidence rating scale represented by the phrase ‘How sure are you?’, to which participants

indicated from 1 (pure guess) to 5 (absolutely sure) how confident they were about their valence categorization of the word, was presented. Confidence ratings were collected to assess the level of awareness.

Again, all word stimuli were presented in the centre of the screen in light grey (luminance: target word = 1.75 cd/m<sup>2</sup>, mask = 2.08 cd/m<sup>2</sup>) on a black background (.03 cd/m<sup>2</sup>). The length of the mask was 2.5° and its height was 0.5°.

As in the previous experiments, the valence and arousal ratings of the words were collected and matched. The neutral words' mean valence ratings did not significantly differ from 4 ( $M = 3.93$ ,  $SD = .41$ ), and were therefore not excluded. The mean valence ratings for the negative and positive words were initially 2.15 ( $SD = .81$ ) and 5.41 ( $SD = .77$ ) respectively. Across all participants, the mean arousal ratings were 4.98 ( $SD = 1.86$ ) for the negative words, 4.48 ( $SD = 1.26$ ) for the positive words, and 4.07 ( $SD = 1.44$ ) for the neutral words.

An average of thirty-eight negative and thirty-seven positive words remained in the analyses per participant after matching the word lists on both valence and arousal, resulting in mean valence ratings of 2.45 ( $SD = .81$ ) for negative words and 5.57 ( $SD = .92$ ) for positive words<sup>4</sup>, as well as a mean arousal rating of 4.81 ( $SD = 1.18$ ) for each of the negative and positive word lists.

## Results

### *Letter search*

Response times were significantly slower in the high load ( $M = 969$  ms) than in the low load ( $M = 838$  ms;  $t(25) = 5.884$ ,  $SEM = 22.33$ ,  $p < .001$ ). In

---

<sup>4</sup> One participant was excluded from the analyses due to an insufficient number of words left in at least one of the conditions after matching the word categories on valence and arousal.

addition, accuracy rates were significantly lower in the high load ( $M = 75\%$ ) than in the low load condition ( $M = 89\%$ ;  $t(25) = 7.98$  SEM = .018,  $p < .001$ ).

### *Valence detection*

The results are summarized in Table 3.3.

**Table 3.3.** Experiment 6: Mean % Hit Rates,  $d'$ , Beta scores, and Confidence ratings as a Function of Load and Valence

		Load					
		Low		High			
		Negative	Positive	Neg - Pos	Negative	Positive	Neg - Pos
HR % (FA)	55 (35)	50 (39)	5	54 (45)	50 (47)	4	
$d'$	.62	.44	.18	.39	.06	.33	
Beta	1.44	1.29	.15	1.06	1.66	-.60	
Confidence	2.44	2.21	.23	1.74	1.59	.15	

The ANOVA on the hit rates revealed no significant main effects of load, valence, or an interaction (all  $F$ 's  $< 1$ ). This is not too surprising given that the hit rates were close to guessing level and did not differ from chance (50%) even in the low load (all  $p$ 's  $> .438$ ; see Table 3.3) as commonly seen in the literature of unconscious processing.

The  $d'$  scores were reduced in the low load compared to the high load although this effect only reached marginal significance ( $F(1,24) = 4.149$ ,  $MSE = .571$ ,  $p = .053$ , Table 3.3). This finding goes in line with the results of Experiments

4 and 5 and supports the first hypothesis of a reduction of detection sensitivity under high load compared to low load.

More importantly, there was a significant main effect of valence ( $F(1,24) = 6.005$ ,  $MSE = .279$ ,  $p = .022$ ), indicating an enhanced sensitivity to negative valence under both load conditions (Table 3.3) as shown by the lack of an interaction ( $F < 1$ ). The lack of an interaction found here is in contrast with Experiments 4 and 5. I note that although the negative valence detection advantage in the present experiment is smaller than that found in the low load conditions of Experiment 4 and 5, these findings may indicate an early-level processing advantage.

They suggest that early perceptual processing that has not reached full consciousness may show a negative valence advantage that is unaffected by attention. This conclusion is different to the previously established effects of perceptual load on the processing of non-emotional unconscious stimuli (e.g. Bahrami et al., 2007; Bahrami et al., 2008). It suggests that unlike other early perceptual processes (e.g. in the case of orientation, (Bahrami et al. 2008) or pictures of tools (Bahrami et al., 2007)) the early unconscious processing of negative valence may be automatic.

Valence detection was significantly greater than chance in all conditions (low load: negative:  $t(24) = 3.624$ ,  $SEM = .172$ ,  $p = .001$ ; positive:  $t(24) = 3.398$ ,  $SEM = .13$ ,  $p = .002$ ; high load: negative:  $t(24) = 3.928$ ,  $SEM = .1$ ,  $p = .002$ ) except for the positive words in the high load ( $t(24) = .522$ ,  $SEM = .111$ ,  $p = .606$ ). Note that the low load conditions are more equivalent to the conditions in Chapter 2, but here the results showed that the  $d'$  scores of the negative words were significantly greater than chance in the low load unlike in Chapter 2 where their  $d'$  scores did

not differ from chance. This may reflect that the conditions in the present experiment were less successful in producing unconscious processing on as many trials as in Chapter 2. This effect is corroborated by the confidence ratings reported below.

The ANOVA on the beta scores revealed no main effects of both load ( $F < 1$ ) or valence ( $F(1,24) = 1.286$ ,  $MSE = .941$ ,  $p = .268$ ). As can be seen in Table 3.3, the difference between the beta scores of the negative and positive words appears to be in opposite directions in the low and high load conditions. This interaction, however, was not significant ( $F(1,24) = 3.402$ ,  $MSE = 1.039$ ,  $p = .078$ ). The valence effects found were therefore not accompanied by effects of response bias.

#### *Lexical frequency*

After equating all word categories on frequency and the emotional word categories on valence intensity and arousal, the enhanced detection sensitivity for the negative words compared to the positive words under both load conditions became weaker (Low load:  $M$  negative = .66,  $M$  positive = .45; High load:  $M$  negative = .40,  $M$  positive = .13;  $F(1,24) = 3.779$ ,  $MSE = .397$ ,  $p = .064$ ). The negative valence detection advantage increased slightly from .18 before matching the frequency levels to .21 after matching the mean lexical frequencies in the low load, whereas it decreased slightly in the high load from .33 to .27 respectively. The weaker valence effect found after the mean lexical frequencies were matched might be due to power issues (a weaker power of the analysis as a result of having less trials because of more exclusions) or of a contribution of frequency effects on valence detection.

### *Confidence ratings*

The overall confidence ratings were fairly low (2.12 for negative, 1.85 for neutral, 1.94 for positive words), bearing in mind that the scale ranged from 1 (pure guess) to 5 (absolutely sure). As confidence ratings were nearer to the ‘pure guess’ end of the scale, this indicates that participants were guessing on most of the trials. Wilcoxon signed-rank tests showed no significant difference between the overall confidence ratings of the neutral words compared to the confidence ratings for positive words ( $Z = 1.802$ ,  $p = .072$ ). But confidence ratings were significantly higher for negative words compared to both neutral words ( $Z = 3.122$ ,  $p = .002$ ), and positive words ( $Z = 2.258$ ,  $p = .024$ ). Moreover, the confidence ratings of the negative words were significantly higher than those of the neutral words under both low load ( $M_{\text{neutral}} = 2.12$ ;  $Z = 2.971$ ,  $p = .003$ ) and high load ( $M_{\text{neutral}} = 1.53$ ;  $Z = 2.157$ ,  $p = .031$ ) conditions. Although the confidence ratings of the negative words appear to be slightly higher than those of the positive words under each of the load conditions (as shown in Table 3.3), neither these differences nor the difference between the confidence ratings of the positive and neutral words under low and high load were significant (all  $p$ 's  $> .136$ ).

The higher confidence ratings of the negative words suggest that some of the negative words had possibly accessed awareness more frequently than the neutral and positive words. It should be noted that both the overall confidence ratings and the confidence ratings in the low load were slightly higher in this experiment than the confidence ratings in Chapter 2 (recall that the mean confidence ratings were 1.62, 1.54, and 1.55 for the negative, positive, and neutral words respectively). This is in line with the results of the  $d'$  scores suggesting that

the presentation conditions of the present experiment may have been less successful than those of Chapter 2 in reliably producing subliminal processing.

Similarly to Chapter 2 therefore, I sought to examine only the trials that did produce unconscious processing by comparing responses with a confidence rating of 1 ('pure guess')<sup>5</sup>. However, after excluding some trials to match for valence and arousal, a large number of participants did not have sufficient trials left in at least one of the conditions when only trials of a confidence rating of 1 were included. The power of these comparisons was therefore too weak for them to be conducted after discarding the data of so many participants.

Finally, as in Chapter 2, an assessment of awareness of the words by examining whether or not participants were more confident on correct responses compared to incorrect responses was attempted. Once again, however, many of the participants had to be excluded as splitting the data into the correct and incorrect trials after excluding some words to match the valence and arousal levels left too few or sometimes even no trials in at least one of the conditions. These comparisons were therefore not conducted due to the consequent lack of power.

In summary, a main effect of valence was observed in Experiment 6. No interaction between load and valence was found; indicating that the advantage for the detection of negative words over positive words was present in both load conditions. Though the confidence ratings were low overall suggesting that participants were guessing most of the time, the confidence ratings of the negative words indicate that some of the negative words had possibly accessed participants'

---

<sup>5</sup> Eight participants had to be excluded for not having any trials with a confidence rating of "1" left in at least one of the conditions.

awareness more often than the positive words, reflecting perhaps a lower conscious threshold for the negative valence.

It is clear that a negative valence detection advantage is still found when the words are presented for a shorter duration under conditions that produce more trials of reduced awareness, with no effect of load. Still, it is possible that with reduced processing time of the word task, participants were prioritizing the valence detection task and were consequently performing better in the high load than previously. This does not appear to be the case here, however, as high load did effectively reduce the detection sensitivity to the words.

### **3.5 Summary and conclusions**

The present chapter investigated whether the negative valence detection advantage established in the previous chapter is modulated by attentional load and showed that under some circumstances attention is required for the enhanced sensitivity to negative valence. The findings of the present chapter were once again obtained after matching the emotional word categories on valence intensity, arousal, and frequency levels, and were not accompanied by a difference in response bias between the negative and positive valence.

The results of this chapter demonstrated that perceptual load reduces conscious detection advantage for negative valence, but a small advantage remains irrespective of attentional load in conditions of subliminal presentations that are more likely to produce unconscious processing. This offers a possible resolution to previous controversies regarding the relation of emotional information to both attention versus automaticity and conscious versus unconscious processing (e.g.

Pessoa, 2005; Pessoa et al., 2002; Vuilleumier et al., 2001; Whalen et al., 1998).

Specifically, the results of Chapter 3 suggest that while unconscious processing of negative emotional valence may be automatic, the ‘full-blown’ conscious detection of emotional valence does require attention. I discuss each of these findings in turn.

The negative valence detection advantage for consciously perceived words was modulated by the level of attentional load in the primary task, in line with Lavie’s (1995) perceptual load theory. Sensitivity to the negative valence was greater than to the positive valence under low perceptual load but the advantage was eliminated under high perceptual load even after ruling out differences in overall RTs as alternative accounts for the effect of load. These findings confirm the prediction that high load would modulate the negative valence detection advantage and are consistent with previous research showing a modulation of the processing of negative emotion by attentional load (e.g. to fearful faces; Pessoa et al., 2005). The present chapter thus extends the effects of perceptual load on perception established in previous research showing for the first time a modulation of the negative valence detection advantage by attention.

Although relatively small (a .33 valence effect in the high load of Experiment 6 (Table 3.3) compared to a .58 effect in Experiment 4 (Table 3.1)), a negative detection advantage was still found under conditions of both low and high perceptual load for subliminal presentations. This finding indicates that the enhanced detection sensitivity to negative valence is not modulated by load when processed subliminally. The suggestion that unconscious processing is automatic is inconsistent with previous findings of a modulating role of perceptual load on non-emotional subliminal stimuli (e.g. Bahrami et al., 2007). This suggests that the effects of attention on unconscious processing established in previous research may

not extend to the case of negative emotional processing when processed at an early stage. However, differences in the methods used here and in the previous studies (e.g. Bahrami et al., 2007; 2008) preclude a firm conclusion. Future research can examine whether CFS suppression would lead to load modulation of the negative valence advantage. Finally, the results of the present chapter also implied an automatic processing of negative valence (and potentially a lower conscious threshold) even when attentional resources are scarce as indicated by sensitivity that was greater than chance performance in contrast with the positive valence.

**Chapter 4:**

**Emotion Detection and Attention: The Role of Individual  
Differences in Anxiety**

#### **4.1 Introduction**

The present chapter examined the role of individual differences in anxiety levels in emotion detection under different levels of attentional load. Previous research has established that higher anxiety levels are associated with a greater processing priority for negative valence using a vast range of methods (for a review see Bar-Haim et al., 2007), but this negative advantage in anxiety has not been established with respect to detection sensitivity. As reviewed in the General Introduction, Manguno-Mire et al. (2005) examined the effects of anxiety levels on the detection of negative words but found a response bias for negative words in high anxiety compared to low anxiety with no difference in detection sensitivity between the two groups. The question of whether negative valence is truly better detected than positive valence in individuals with high anxiety levels thus remains open.

The results of Chapter 2 clearly showed an enhanced detection sensitivity to negative valence (versus positive valence), however these findings apply to the general population and do not address any individual differences in anxiety. The first aim of the present chapter, therefore, was to ask whether individual differences in anxiety would affect the negative valence detection advantage. Specifically, would high anxiety be associated with a greater sensitivity to negative valence? Previous claims of an increased vigilance to threat in anxiety (e.g. Fox et al., 2001; MacLeod & Rutherford, 1992; Mogg et al., 1993) leads to the following predictions: High anxiety will be associated with higher detection sensitivity to the negative valence (as expressed in higher  $d'$  scores) compared low anxiety and may also be associated with more extreme valence ratings for the negative words. It is

important to note that if any correlation is found between anxiety levels and the valence ratings, this will not affect the results concerning the valence detection as any differences in extremeness of valence ratings between the negative and positive valences was corrected for on an individual basis. I note that as the previous literature did not establish that high anxiety is associated with a greater detection sensitivity to negative valence, it remains an open question that this would be found with detection sensitivity measures.

The second and perhaps most important aim of the present chapter was to ask how levels of trait anxiety interact with the effects of attention on valence detection. Chapter 3 has established that attentional load eliminated the detection advantage to negative valence. In the present chapter I therefore examined whether this holds regardless of anxiety levels. Alternatively, high anxiety levels would be associated with a reduced effect of attention on the negative detection advantage given that individuals with high anxiety are more tuned to negative valence (e.g. Richards et al., 1992; Mathews & MacLeod, 1985; Fox, 1993) and may remain more tuned to it even when less attentional resources are available (e.g. Fox et al., 2005).

As detailed in the General Introduction of this thesis, studies have shown using the attentional cueing paradigm that negative words capture and engage attention to a greater extent than neutral words (e.g. Salemink et al., 2007; MacLeod et al., 1986) and positive words (Fox et al., 2001) in high compared to low anxiety. In addition, a large body of research has shown that unattended negative words compared to positive words produce greater interference in individuals with high compared to low anxiety (e.g. Richards et al., 1992; Mathews & MacLeod, 1985; MacLeod & Rutherford, 1992; Mogg et al., 1993) as shown by

longer response latencies to negative words in the emotional Stroop task. Negative words compared to positive or neutral words have also been found to cause greater disruption (as shown by slower responses) when acting as distractors in highly anxious participants (e.g. Mathews et al., 1990; Mathews et al., 1995).

The findings of studies showing that trait anxiety is associated with greater interference and capture of attention from negative words are confined to measures of response times, as such they cannot inform about any advantage for the negative words in detection per se. In other words, one cannot conclude from previous research revealing effects on response latencies what would be the effect of anxiety on detection sensitivity.

The effect of anxiety levels on the brain processing of emotion, however, has been found to be modulated by perceptual load. For example, Bishop et al. (2007) found that individuals with high trait anxiety showed no significant increase in DLPFC activity that is normally found in response to fearful faces under low load in contrast with the low anxious participants who did. No such increase was observed for either anxiety group under high perceptual load. As these findings revealed that high perceptual load eliminated individual differences in anxiety, one may expect that no modulation of the negative valence detection by anxiety will be found under high perceptual load in the present chapter. I note, however, that Bishop et al. (2007) did not measure detection sensitivity, and their study involved emotional faces (as opposed to words in the present thesis) that were entirely unattended (in contrast with the task in Experiment 7 where participants are required to detect the valence of the words while prioritizing the letter search). It is possible, therefore, that under these conditions, individual differences in anxiety will be associated with a modulation of the effect of load on valence detection.

Anxiety seems to have an effect not only on the processing of emotional stimuli, but also on the processing of information in general (for example, the attentional control system has been found to be affected in individuals with high anxiety; Eysenck et al., 2007). Of potential relevance to the present chapter is the Processing Efficiency theory of anxiety (Eysenck & Calvo, 1992) that describes individuals with high anxiety as having a reduced attentional capacity (due to the presence of worrisome thoughts that take up most of the available attentional resources) that adversely affects processing efficiency of tasks. Taking this model into account, one would expect that the processing of additional stimuli would be greatly diminished in dual tasks under conditions where attentional capacity is taken up by another task (i.e. high load) in high anxiety, due to the lack of available attentional capacity. This suggests that detection sensitivity to emotional valence would be greatly diminished under conditions of high attentional load in individuals with high anxiety. However, previous research on the effects of anxiety on attentional capacity was mainly focused on higher level cognitive control functions such as working memory and dual-task coordination rather than perceptual load per se and so it is not clear whether similar effects would be established in conditions of high perceptual load. In fact, previous load studies showed opposite effects of cognitive load and perceptual load on distractor processing (e.g. Lavie, Hirst, de Fockert, & Viding, 2004).

To sum up, considering the literature showing an increased vigilance to threat as well as a reduced attentional capacity in anxiety, in this chapter I sought to establish firstly, whether differences in the enhanced detection of negative versus positive valence would be found between different anxiety groups. A second major aim of this chapter was to investigate whether individual differences in anxiety

would modulate the load effect found on the negative valence detection advantage.

Experiment 7 was therefore conducted following the same paradigm used in Experiment 4 of Chapter 3 with the addition of collecting participants' State and Trait anxiety levels.

## 4.2 Experiment 7

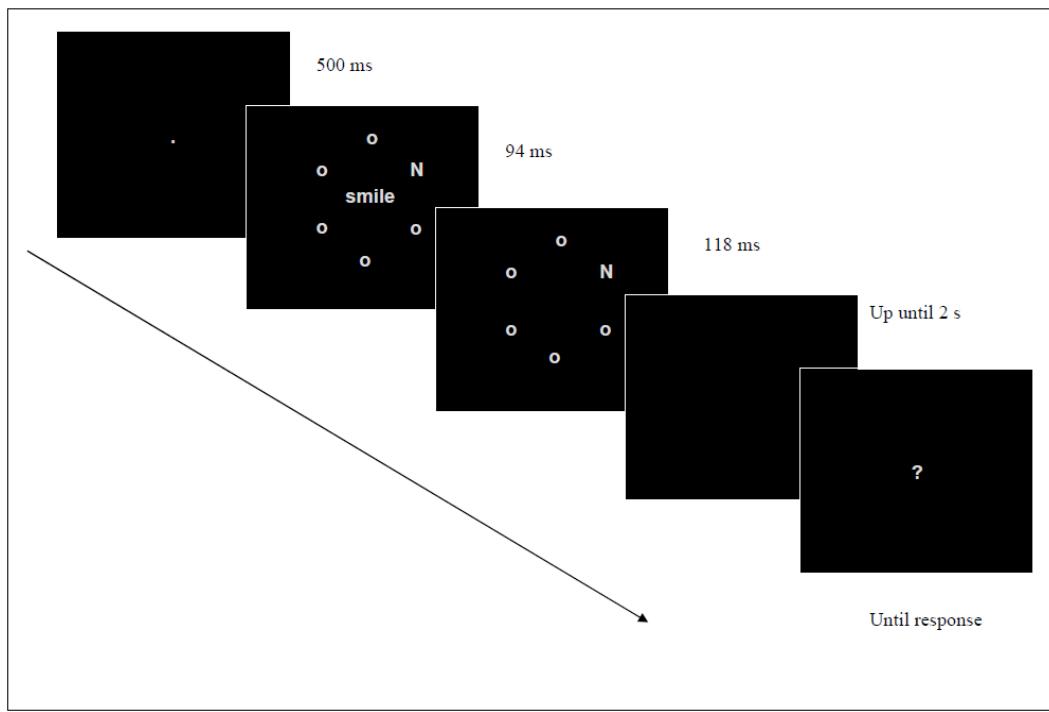
### Method

#### *Participants*

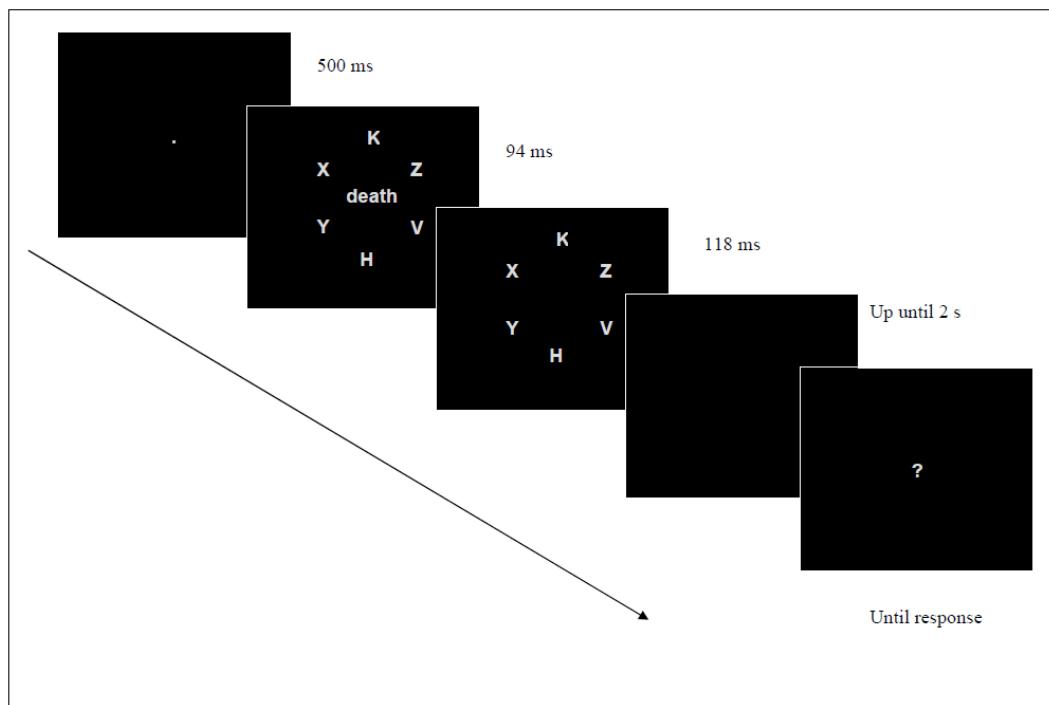
A total of one hundred participants recruited from University College London's online participant pool participated in the study on a voluntary basis and were paid £7 for their participation. All except two participants (were excluded as a result) were native English speakers and had normal or corrected-to-normal vision. One participant reported the misattribution of the response keys on several trials during the experiment and was thus excluded from the analyses of the study and a final one was excluded from the analyses due to extremely low accuracy on the letter-search task in the high load condition (less than 50% accuracy). The remaining ninety-six participants had a mean age of 22 (range 18 – 46, 57 females).

#### *Stimuli and Procedure*

The procedure followed in Experiment 7 was identical to that of Experiment 4 in Chapter 3 with the following exception (Figure 4.1 and Figure 4.2). Prior to commencing the experimental phase of the study, each participant completed a computerized version of the Spielberger State-Trait Anxiety Inventory (STAI).



**Figure 4.1: Trial sequence in Experiment 7.** Trial onset was indicated by a fixation cross. Then, simultaneously, the letter circle (in this case low load) and a word (in this case: positive) appeared. The word disappeared before the letter circle. Participants indicated by key presses the target letter (in this case: 'N') and then, after appearance of the question mark, whether the word was emotional or neutral.



**Figure 4.2: Trial sequence in Experiment 7.** Trial onset was indicated by a fixation cross. Then, simultaneously, the letter circle (in this case high load) and a word (in this case: negative) appeared. The word disappeared before the letter circle. Participants indicated by key presses the target letter (in this case: 'X') and then, after appearance of the question mark, whether the word was emotional or neutral.

As in Chapters 2 and 3, participants provided subjective valence and arousal ratings for each of the words upon completion of the experiment. The mean valence ratings of the emotional word categories were initially 2.08 ( $SD = .57$ ) and 5.34 ( $SD = .5$ ) for the negative and positive words respectively. No neutral words had to be excluded as their mean valence ratings did not differ significantly from 4 ( $M = 3.86$ ,  $SD = .39$ ). Most participants gave the negative words higher arousal ratings than the positive words. The mean arousal ratings across all participants

were originally 4.99 ( $SD = 1.85$ ), 4.33 ( $SD = 1.33$ ), and 3.53 ( $SD = 1.51$ ) for the negative, positive, and neutral words respectively.

After matching the words on both valence and arousal, an average of fifty-three negative and fifty-one positive words remained per participant for the analyses with mean valence ratings of 2.39 ( $SD = .52$ ) for the negative words and 5.69 ( $SD = .54$ ) for the positive words and mean arousal ratings of 4.71 ( $SD = 1.42$ ) for the negative words and 4.71 ( $SD = 1.41$ ) for the positive words<sup>6</sup>.

## Results

### Overall group performance

#### *Letter search*

Letter search RTs were significantly slower in the high load ( $M = 995$  ms) compared to the low load ( $M = 811$  ms;  $t(95) = 17.55$ ,  $SEM = 10.486$ ,  $p < .001$ ) and accuracy rates were significantly lower in the high load ( $M = 77\%$ ) than in the low load condition ( $M = 90\%$ ;  $t(95) = 16.999$ ,  $SEM = .007$ ,  $p < .001$ ), confirming that the load manipulation was successful.

#### *Valence detection*

The results are shown in Table 4.1. A 2 (load: low vs. high) x 2 (valence: negative vs. positive) repeated measures ANOVA was conducted across all participants on the hit rates, the  $d'$  scores, and the beta scores.

---

<sup>6</sup> Two participants did not have any words left for the analyses in at least one of the conditions and were therefore not included in the valence detection results.

**Table 4.1.** Experiment 7: Mean % Hit Rates, d' and Beta scores as a Function of Load and Valence

		Load					
		Low		High			
		Negative	Positive	Neg - Pos	Negative	Positive	Neg - Pos
HR % (FA)	65 (16)	51 (16)	14	53 (26)	41 (21)	12	
d'	1.67	1.26	.41	.86	.73	.13	
Beta	1.84	2.79	-.95	2.82	3.78	-.96	

The ANOVA on the hit rates revealed a significant main effect of load ( $F(1,93) = 47.292$ ,  $MSE = 248.478$ ,  $p < .001$ ) indicating greater accuracy in the low compared to the high load condition. As seen in Table 4.1, accuracy was also significantly higher for the negative compared to the positive words ( $F(1,93) = 45.502$ ,  $MSE = 358.331$ ,  $p < .001$ ). No significant interaction between load and valence was observed ( $F < 1$ ). These results replicate those found in Chapter 3.

The d' scores were significantly higher in the low load compared to the high load ( $F(1,93) = 85.658$ ,  $MSE = .496$ ,  $p < .001$ ; Table 4.1). The main effect of valence was also significant for the d' scores ( $F(1,93) = 20.365$ ,  $MSE = .333$ ,  $p < .001$ ) reflecting an enhanced detection sensitivity to the negative compared to the positive valence. More importantly, the interaction between load and valence was also significant ( $F(1,93) = 9.461$ ,  $MSE = .212$ ,  $p = .003$ ). As can be seen in Table 4.1, this interaction indicated a greater enhancement of detection sensitivity to the negative valence compared to the positive valence in the low load than in the high load, in line with the findings in Chapter 3. While the negative word valence had

significantly higher d' scores than the positive valence in the low load ( $t(93) = 5.178$ , SEM = .08,  $p < .001$ ), the numerical trend for higher detection sensitivity to the negative valence versus positive valence did not reach significance in the high load ( $t(93) = 1.704$ , SEM = .072,  $p = .092$ ) as in Experiments 4 and 5.

The pattern of these results replicates the pattern found in the same paradigm in Chapter 3, however, the load effect on valence detection found here appears to be smaller (a mean difference of .28 between the low and high load) than that found in Experiment 4 (mean difference of .67). A Mixed Factor ANOVA with the between-subjects factor of Experiment and within-subjects factors of load and valence showed no interaction with Experiment ( $F(1,104) = 1.755$ ,  $p = .188$ ), thus this difference was not significant.

The ANOVA on the beta scores revealed a main effect of load ( $F(1,93) = 21.413$ , MSE = 5.545,  $p < .001$ ), indicating higher beta scores (and thus a more conservative criterion) under high load compared to low load. This could be due to the participants feeling they can perform more accurately under conditions of low load and thus adopt a more careful and conservative criterion. Similar results showing higher beta scores in the low load compared to the high load were observed in Experiment 4 (Chapter 3).

The main effect of valence was also significant ( $F(1,93) = 4.25$ , MSE = 4.496,  $p = .042$ ; Table 4.1), showing that participants were more conservative with the detection of the positive words compared to the negative words. The interaction between load and valence was not significant ( $F < 1$ ). This bias was not found in the previous chapter. While it is not clear why there is a difference between the present results and those of Chapter 3, it may be due to the inclusion of a greater variation of participants specifically those with extremely low or extremely high

anxiety. However, notice that these results go in line with those found in the longer exposure duration (33 ms) of Experiment 1 (Chapter 2) where participants showed a more conservative bias in response to the positive valence compared to the negative valence. While the negative valence sensitivity advantage may sometimes be accompanied by a less conservative criterion for the negative words, given that the two measures of  $d'$  and beta are independent of each other, this clearly does not undermine the negative detection advantage established. Note also that although participants showed a more conservative bias in detecting the positive valence compared to the negative valence, the response bias for the negative valence was still conservative (mean beta  $> 1$  indicating a conservative criterion: see Table 4.1).

#### *Lexical frequency*

As in all previous experiments, some of the positive and neutral words with the highest frequencies were excluded from the analyses until the remaining words had similar average frequencies to the negative words. Matching the word categories on valence intensity, arousal levels, and mean frequencies did not change the direction or significance of any of the mean effects of load, valence, or the interaction between load and valence for the  $d'$  scores (all  $p$ 's remained  $< .05$ ).

#### The role of trait anxiety

Participants' Trait and State anxiety scores ranged from 27 to 70 ( $M = 44$ ) and from 20 to 55 ( $M = 35$ )<sup>7</sup> respectively. There was a significant positive correlation between participants' Trait and State anxiety scores ( $r = .622$ ,  $p < .001$ ),

---

<sup>7</sup> The data for the state anxiety scores of five participants were lost and were thus excluded from these analyses.

which is expected since Trait and State anxiety are known to be highly correlated (Fox, Russo, Bowles, & Dutton, 2001; Eysenck, 1992). State anxiety was not manipulated; therefore the analyses reported in the remainder of this chapter will focus on individual differences in Trait anxiety.

In order to examine whether high anxiety is associated with a tendency to interpret the words more negatively, Pearson correlations were conducted on participants' Trait anxiety scores and the individual mean valence ratings for each word category. These analyses revealed that Trait anxiety was negatively correlated with the valence ratings of the negative words ( $r = -.234$ ,  $p = .023$ ), in support with the prediction that high anxiety is associated with lower (i.e. more extreme) valence ratings for the negative words. No significant correlation was found between the Trait anxiety scores and the mean valence ratings of the positive words ( $r = .019$ ,  $p = .856$ ).

Interestingly, Trait anxiety was also negatively correlated with the valence ratings of the neutral words ( $r = -.247$ ,  $p = .016$ ), implying that high anxiety is related to a tendency to evaluate neutral information more negatively. Considering that high anxiety is associated with a greater distance between the valence ratings of the positive words and the neutral words, and given that the ratings of the neutral words were not corrected for and thus remain closer to the negative end, one might expect to find a better ability to distinguish the positive valence from the neutral valence in high anxiety. As the results show below, however, this was not the case. I note that although high anxiety was associated with more extreme negative valence ratings, this correlation does not affect the results concerning the rest of the

analyses as the intensities of the subjective valence ratings between the negative and positive valences were matched for each participant.

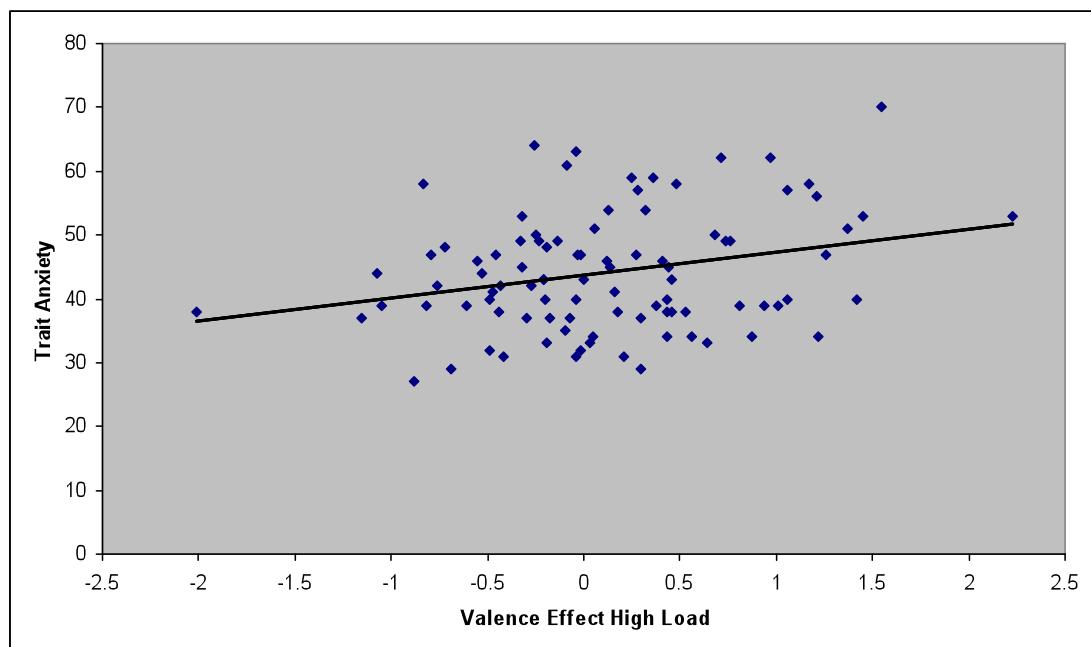
### *Valence detection results*

Pearson correlations were conducted across all participants on the Trait anxiety scores and the load effect on the hit rates (hit rates in the low load minus the hit rates in the high load) and on the d' scores (d' scores in the low load minus the d' scores in the high load) and showed no significant correlations with either load effects (hit rates:  $r = -.162$ ,  $p = .119$ ; d' scores:  $r = -.163$ ,  $p = .115$ ). These findings do not support the idea that high anxiety is associated with reduced attentional capacity (as one hypothesis is that high anxiety should be associated with a greater load effect). As discussed in the Chapter Introduction, this is not surprising given that previous research has implicated a reduced capacity for higher cognitive control functions rather than perceptual capacity.

Pearson correlations between participants' Trait anxiety scores and the valence effect on the hit rates (hit rates of the negative words minus the hit rates of the positive words) and on detection sensitivity (d' scores of the negative words minus the d' scores of the positive words) were also conducted. These analyses revealed no significant correlations with the valence effect on the hit rates ( $r = -.004$ ,  $p = .969$ ), whereas a marginally-significant positive correlation between Trait anxiety and the valence effect on detection sensitivity was found ( $r = .199$ ,  $p = .054$ ). This indicates that the negative valence detection advantage increased as Trait anxiety increased, supporting the hypothesis that high anxiety is associated with an increased sensitivity to negative valence. Thus note that even when

detection sensitivity is matched for the valence ratings an increased sensitivity was still found in high anxiety.

In order to investigate this correlation in more detail, Pearson correlations were conducted on the Trait anxiety scores and the valence effect on sensitivity under each condition of load separately. These revealed that although Trait anxiety did not correlate with the valence effect in the low load ( $r = .052$ ,  $p = .619$ ), it positively correlated with the valence effect in the high load ( $r = .273$ ,  $p = .008$ ), suggesting that the negative valence detection advantage was increased with higher Trait anxiety in the high load condition (as can be seen in Figure 4.1).



**Figure 4.3:** Correlation of Trait anxiety scores with the valence effect on  $d'$  in the high load condition.

The association between Trait anxiety and the valence effect on sensitivity in the high load implies potential differences between anxiety groups in the sensitivity to emotion especially when less attentional resources are available to process the valence of the word. This is in line with previous research on anxiety that has found, for example, that high anxiety is associated with increased vigilance to negative valence in tasks where the word is unattended (e.g. emotional Stroop task; Williams et al., 1996; MacLeod & Rutherford, 1992). But note that this is the first instance where this association is established for detection sensitivity.

The implication that high Trait anxiety is associated with increased sensitivity to the negative valence under conditions of inattention is examined further in the following analyses comparing the high versus low anxiety groups. An ANOVA looking at the two groups was conducted in order to examine differences in valence processing and its modulation by attention between individuals with extreme levels of low or high anxiety.

### High versus Low Anxiety

Participants whose trait anxiety scores lied in the bottom quartile of all the anxiety scores (38 and below;  $M = 34$ ) were categorized as “low trait anxious (LTA)”, and participants having a trait anxiety score in the top quartile (50 and above;  $M = 57$ ) were categorized as “high trait anxious (HTA)”. Anxiety scores were significantly higher for the HTA group compared to the LTA group ( $t(49) = 19.541$ ,  $SEM = 1.169$ ,  $p < .001$ ), as expected from this group selection. This resulted in having twenty eight LTA (mean age = 22, range 18 – 31, 12 females) and twenty three HTA participants (mean age = 22, range 18 – 46, 19 females).

The results are summarized in Table 4.2. A 2 x 2 x 2 Mixed Factor ANOVA with the between-subjects factor of Anxiety Group (LTA vs. HTA) and within-subjects factors of load (low vs. high) and valence (negative vs. positive) was conducted on the hit rates, the d' scores, and the beta scores.

**Table 4.2.** Experiment 7: Mean % Hit Rates, d' and Beta scores as a Function of Load, Valence, and Anxiety Group

Load						
	Low			High		
LTA	Negative	Positive	Neg - Pos	Negative	Positive	Neg - Pos
HR % (FA)	70 (19)	57 (16)	13	56 (32)	43 (19)	13
d'	1.70	1.53	.17	.72	.80	-.08
Beta	2.82	3.78	-.96	1.84	2.79	-.95
HTA						
HR % (FA)	63 (19)	45 (14)	18	52 (21)	37 (26)	15
d'	1.43	1.11	.32	.91	.37	.54
Beta	2.51	3.26	-.75	1.28	1.46	-.18

The main effect of group was not significant for the hit rates ( $F(1,49) = 2.039$ ,  $p = .16$ ). Anxiety Group did not significantly interact with either load ( $F(1,49) = 1.267$ ,  $p = .266$ ) or valence ( $F < 1$ ). Similarly, the three-way interaction between Anxiety Group, load, and valence did not reach significance ( $F < 1$ ). As can be seen in Table 7, therefore, both LTA and HTA participants had greater

accuracy in the low compared to the high load condition, and for the negative valence compared to the positive valence.

No difference between the LTA ( $M = 1.19$ ) and HTA ( $M = .96$ ) groups on the overall  $d'$  scores was observed ( $F(1,49) = 1.166$ ,  $p = .286$ ) indicating no difference between the LTA and HTA groups on detection sensitivity in general. Although the main effect of group on overall  $d'$  scores was not significant, there appears to be a numerical trend for lower  $d'$  scores in the HTA group even in the low load conditions (Table 4.2), possibly suggesting a reduced capacity in high anxiety (perhaps due to demands on cognitive control due to dual-task coordination in both conditions of low and high load). Note that the  $d'$  values were lower for the HTA group than the LTA group in all conditions except for the negative valence under high load (Table 4.2). This effect is discussed further in relation to the three-way interaction.

Anxiety Group did not interact with load ( $F(1,49) = 1.072$ ,  $p = .306$ ), suggesting that, in line with the findings from the correlational analyses, high anxiety was not associated with a greater load effect on detection sensitivity. As discussed earlier for the correlations with the load effect, this is inconsistent with the implication that individuals with high anxiety are characterized by a diminished attentional capacity (as suggested in the Processing Efficiency theory of anxiety, Eysenck & Calvo, 1992) and would thus show a greater effect of high attentional load. This is not surprising given that high perceptual load has been found to ‘make everybody equal’; individual differences in distractibility were observed under low load but not under high load (Forster & Lavie, 2009).

However, a significant interaction between Anxiety Group and valence was found ( $F(1,49) = 5.294$ ,  $p = .026$ ). This interaction reflected an enhanced sensitivity

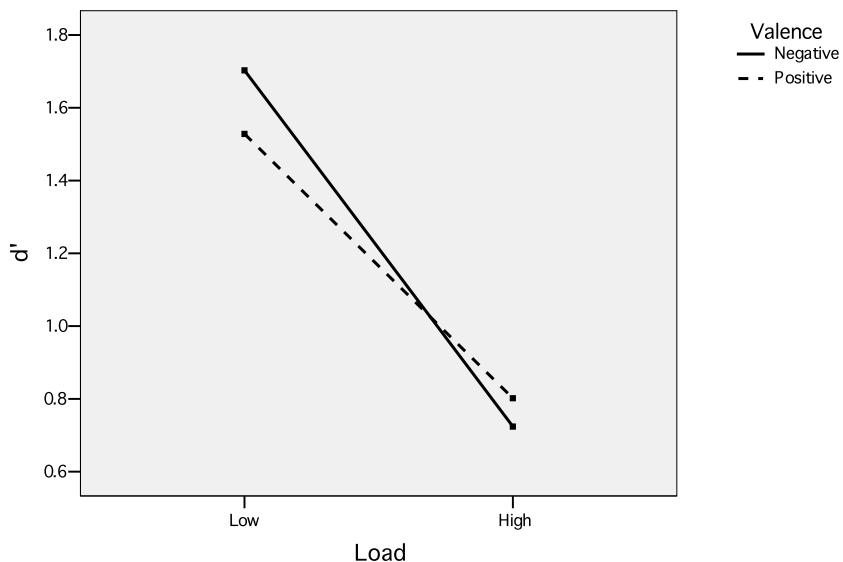
to the negative valence compared to the positive valence for the HTA group ( $F(1,22) = 10.097$ ,  $MSE = .423$ ,  $p = .004$ ), but not for the LTA group ( $F < 1$ ). This concurs with the correlation findings showing a positive correlation between Trait anxiety and the valence effect. Both of the correlation and the ANOVA findings suggest a hypersensitivity to negative valence in high anxiety as I predicted.

This conclusion appears to be inconsistent with previous findings that showed no differences between the anxiety groups in detection sensitivity to negative words but instead showed a response bias to evaluating ambiguous information as threatening in high anxiety (Manguno-Mire et al., 2005). However, the results of the present chapter do not actually contradict those of Manguno-Mire et al. (2005) considering that the enhanced sensitivity to negative valence in the present thesis is defined in terms of an advantage in the detection of negative compared to positive information (rather than in terms of the detection of only negative words). In fact, the  $d'$  of the negative words in the present chapter are not higher for the HTA group ( $M = 1.17$ ) than the LTA group ( $M = 1.21$ ; Table 4.2), in line with the results of Manguno-Mire et al. (2005). The difference between the  $d'$  scores of negative and positive  $d'$ , on the other hand, is greater for the HTA group than the LTA group. What the present findings suggest, therefore, is that it is the ability to detect the negative valence over that of the positive valence that is enhanced in high anxiety rather than the detection of negative valence per se.

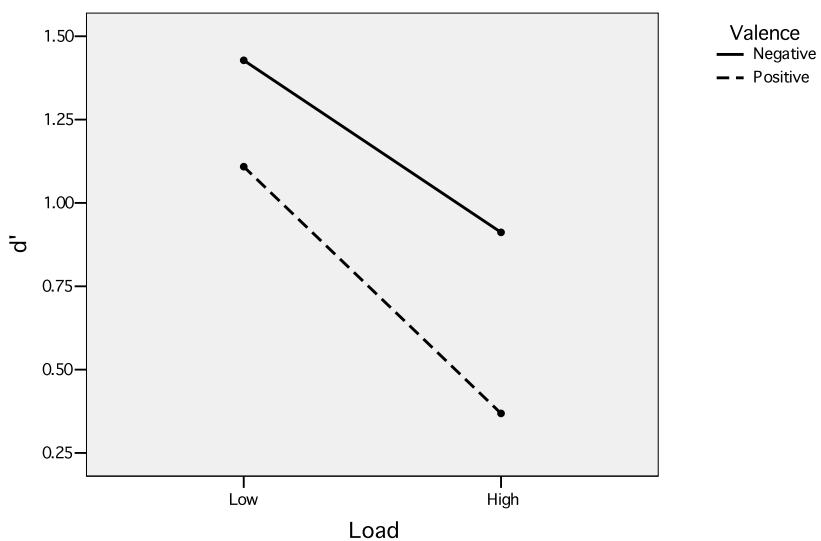
The lack of a negative valence detection advantage for the LTA group is inconsistent with previous research that has showed some orientation towards highly threatening pictures in individuals with low anxiety (Koster et al., 2006) and greater vigilance to high compared to mild threat even in low anxious participants (Mogg et al., 2000). However, it is likely that threatening pictures may have greater

effects than words. In addition, given that previous research has found an effect of high (but not mild) threat in low anxiety, it is possible that no significant negative valence detection advantage was found for the LTA group in the present chapter because of the exclusion of the most extremely rated negative words.

Crucially, a significant three-way interaction between Anxiety Group, load, and valence was also observed ( $F(1,49) = 4.574$ ,  $p = .037$ ). As Table 4.2 shows, this interaction reflected that whereas there was a greater enhanced detection sensitivity to the negative valence compared to the positive valence in the high versus the low load for the HTA group, a reversed pattern was observed for the LTA group (as indicated by a smaller, and in fact reversed, difference between the negative and positive valence in the high versus the low load; see Figure 4.2). The enhancement in the negative valence detection advantage from the low load to the high load for the HTA group was supported by a significant interaction between load and valence for the HTA group ( $F(1,22) = 4.899$ ,  $MSE = .059$ ,  $p = .038$ ; see Figure 4.3). On the contrary, the reduction in the negative valence advantage from the low to the high load condition for the LTA group was not significant, as shown by a non-significant interaction between load and valence for the LTA group ( $F(1,27) = 1.888$ ,  $MSE = .236$ ,  $p = .181$ ). Follow-up paired samples t-tests revealed a detection advantage for the negative valence compared to the positive valence under both low load ( $t(22) = 2.367$ ,  $SEM = .135$ ,  $p = .027$ ) and high load ( $t(22) = 3.524$ ,  $SEM = .154$ ,  $p = .002$ ) for the HTA group (Table 4.2 and Figure 4.3). These findings are in line with the hypothesis predicting a reduced load effect on the negative valence advantage in high anxiety compared to low anxiety.



**Figure 4.4:** Interaction between Load and Valence on the  $d'$  scores in the LTA group.



**Figure 4.5:** Interaction between Load and Valence on the  $d'$  scores in the HTA group.

The amplification of the negative valence detection advantage in the high load for the HTA group appears to be due to the fact that while a reduction in  $d'$  scores from low load to high load was observed for both the negative and positive valences, the reduction was even greater for the positive valence for the HTA group compared to the LTA group (see Table 4.2; although this difference was not significant ( $t(49) = 1.843$ ,  $p = .071$ ). This finding reflects that highly anxious individuals are more tuned to the negative valence compared to the positive valence even in conditions where attentional resources are limited.

This finding extends previous literature that suggests an early attentional bias to threat (e.g. Fox, 2008; Eimer & Kiss, 2007) and a hypervigilance of the threat detection system in anxiety (e.g. Bradley et al., 1998; Mogg & Bradley, 1998). Furthermore, the decreased modulation of the detection of the negative valence by load in comparison with the positive valence found in the HTA group concurs with previous research showing that the processing of negative emotion is less affected by attention in high anxiety (Fox et al., 2005; Bishop et al., 2004).

The main effect of group was not significant for the beta scores ( $F(1,49) = 1.923$ ,  $p = .172$ ). The interactions between Anxiety Group and both load and valence for the beta scores were also not significant (both  $F$ 's  $< 1$ ). In addition, no significant three-way interaction between Anxiety Group, load, and valence was found ( $F < 1$ ) indicating that the difference in the load effect on valence detection between the LTA and HTA groups was not accompanied by a similar difference in response bias.

### *Lexical frequency*

After matching the mean frequencies of all word categories as well as the valence intensity and arousal levels of the emotional word categories, the direction and significance of the interactions between Anxiety Group and both load and valence on the  $d'$  scores did not change. The three-way interaction between Anxiety Group, load, and valence became weaker ( $F(1,49) = 2.344$ ,  $p = .132$ ), although the  $d'$  scores showed a similar trend for an enhancement of the negative valence detection advantage in the high versus the low load in HTA individuals compared to LTA individuals with a slight reversal in the high load for the LTA compared to the HTA group (LTA: low load:  $M$  negative = 1.68,  $M$  positive = 1.53; high load:  $M$  negative = .78,  $M$  positive = .85; HTA: low load:  $M$  negative = 1.42,  $M$  positive = 1.12; high load:  $M$  negative = .91,  $M$  positive = .43).

### **4.3 Summary and conclusions**

The role of individual differences in anxiety on sensitivity to negative information and its interaction with attention was examined in this chapter. The results showed firstly a replication of the negative valence detection advantage established in the previous chapters and of the modulation of the negative detection advantage by load across all participants – an enhanced sensitivity to negative valence compared to positive valence was found in the low load but not in the high load.

Participants showed overall a more conservative bias in response to the positive valence compared to the negative valence, possibly reflecting lower confidence in categorizing the positive words as emotional in comparison with the

negative words. This difference in response bias is similar to that found in the 33 ms exposure condition of Experiment 1 (Chapter 2) but differs from the results of Chapter 3. This contrast is possibly due to a greater variance in participants' anxiety levels in the present chapter. It is important to bear in mind that participants still showed a conservative criterion for the detection of the negative valence. While this bias was found to be less conservative compared to the positive valence, it does not challenge the negative valence detection advantage given that the two measures of  $d'$  scores and beta are independent of one another. In addition, the effect of load on valence found for the  $d'$  scores was not accompanied by a similar effect on response bias.

The findings of the present chapter did not support the idea that high anxiety is associated with a diminished attentional capacity: According to the Processing Efficiency Theory of anxiety (Eysenck & Calvo, 1992) that states that individuals with high trait anxiety have a reduced attentional capacity, it would be expected that the HTA group would suffer to a greater extent in the overall detection of valence in high load compared to the LTA group. Results showed, however, that anxiety levels were not associated with the effect of load on valence detection. Although a numerical trend for lower  $d'$  scores was observed for the HTA group compared to the LTA group, no difference was found between the two groups with respect to the load effect on detection sensitivity. These results are not surprising considering that the present findings examined perceptual capacity as opposed to previous research that has established a reduced attentional capacity in high anxiety for higher cognitive control functions such as working memory.

Importantly, differences in Trait anxiety on the evaluation of negative information and valence detection were found. Firstly, Trait anxiety levels were

associated with the idiosyncratic valence ratings of the negative words – lower (i.e. more extreme) ratings were given for the negative words with increasing anxiety, indicating that individuals with high anxiety evaluate negative information more negatively than individuals with low anxiety. This finding provides support for the cognitive-motivational model of anxiety that claims that high anxiety is associated with a tendency to evaluate mild threat as highly threatening (Mogg & Bradley, 1998). According to this model, the Valence Evaluation System (which is responsible for the appraisal of a stimulus's threat value) is more sensitive in high anxiety, resulting in mild negative information being interpreted as highly threatening.

Secondly, individual differences in Trait anxiety levels were associated with the negative valence detection advantage, indicating an enhanced sensitivity to negative valence with higher Trait anxiety. A closer look at the results revealed that while individuals with low Trait anxiety showed no sensitivity advantage to negative information compared to positive information, individuals with high Trait anxiety demonstrated an enhanced sensitivity to negative valence not only when attentional capacities were available but also when attention was taken up by another task. This is adding to the vast evidence of a hypervigilance towards threat in anxiety when attention is focused on another task (e.g. Mogg et al., 1993; Fox, 1993) now also providing a new line of evidence for a more sensitive threat evaluation system in high anxiety (e.g. Mogg & Bradley, 1998). These findings support the hypothesis of a hypersensitivity to negative valence in high anxiety.

The negative valence advantage found in the present chapter in high anxiety versus low anxiety with no difference between the two groups in response criterion is inconsistent with previous research that revealed a response bias for the detection

of negative words in high anxiety compared to low anxiety with no difference between the anxiety groups in detection sensitivity to negative words (Manguno-Mire et al., 2005). Although the results found by Manguno-Mire et al. (2005) seem to be inconsistent with those of the present thesis, they do not in fact contradict the conclusions of the present chapter. As mentioned previously (in the General Introduction and in Chapter 4), unlike the present chapter, no comparisons between the sensitivities of the negative and positive words were conducted in the Manguno-Mire et al. (2005) study. Instead, any group difference in sensitivity to negative information was assessed only by comparing the  $d'$  of the negative words of each anxiety group. On the other hand, the differences between the HTA and LTA groups found in the present chapter were defined in terms of differences between detection sensitivity measures of the negative and positive  $d'$  - in other words, it is not the detection of negative information per se that is elevated in high anxiety, but rather the ability to detect negative information over that of positive information.

In addition, there are methodological differences between the Manguno-Mire et al. (2005) study and the present thesis (see General Introduction for details). For example, the task in the present chapter could involve more connotations related to negative emotion due firstly to a greater number of words and secondly to the classification task (of emotional versus neutral) providing a wider scope for emotional connotations of negative valence. Future research using the present emotional classification task on their corpus of words or using their ‘dangerous’ versus ‘safe’ classification task on the corpus of words used in the present thesis could reveal whether the critical factor for finding a detection

sensitivity advantage is in terms of the ‘emotional’ versus ‘non-emotional’ classification task of the present thesis.

Another important finding of this chapter was the demonstration that this hypersensitivity to negative information in high anxiety was not dependent on allocation of attention. Given that no reduction of the negative valence detection advantage by high load was observed for individuals with high anxiety, the present findings support the prediction of a weaker load effect on the negative detection advantage in high anxiety compared to low anxiety. The present chapter extends previous research showing a reduced modulation of the processing of negative emotion by attention in high anxiety (e.g. Fox et al., 2005; Bishop et al., 2004) in establishing a reduced effect of perceptual load on the enhanced detection sensitivity to negative valence in high anxiety.

In the end, the present chapter established a hypersensitivity to negative information in high anxiety as opposed to low anxiety that was not modulated by attentional load, indicating a preferential processing of negative information in high anxiety even under conditions of limited attentional resources. These conclusions reflect anxiety-related differences in intrinsic cognitive processing styles and sensory function. But how does this extend to differences in human behaviour such as motivation levels? Previous studies have shown that the prospect of reward can modulate human behaviour (e.g. Kiss, Driver, & Eimer, 2009; Pleger, Blankenburg, Ruff, Driver, & Dolan, 2008). Chapter 5 aimed to address this issue by investigating whether any effects of the prospect of reward on valence detection will be found, i.e., whether the enhanced detection will be influenced by changes in motivation.

**Chapter 5:**

**The Effect of Reward on Detection Sensitivity to**

**Emotional Valence**

## **5.1 Introduction**

The motivating effects of reward on overt behaviour have been recognized for some time (Blake, Strata, Churchland, & Merzenich, 2002). Recent studies have focused on the influence of reward on cognition. As described in detail in the General Introduction, reward has been shown to have modulating effects on visual attention, for example by facilitating visual selection (Della Libera & Chelazzi, 2006) and increasing search efficiency of a singleton target (Kiss et al., 2009).

Moreover, studies have found that rewarding participants leads to faster responses when detecting novel or familiar items that were rewarded (Bunzeck et al., 2009), as well as to enhanced detection sensitivity to a target (Engelmann & Pessoa, 2007; Engelmann et al., 2009). Interestingly, the discrimination of sensory stimulation improved as reward level increased (Pleger et al., 2008). Reward has also been found to reduce orientation discrimination thresholds regardless of attentional load (Baldassi & Simoncini, 2009) suggesting that reward acts separately but similarly to attention through mediating activity of early sensory stages such as the visual cortex.

In conclusion, though reward has been shown to have effects on the perception of neutral stimuli and on attention, no study has been conducted exploring the potential effects of reward on the detection of emotional valence. Based on the evidence that reward facilitates visual selective attention and enhances the detection sensitivity of visual targets possibly through magnifying the activity in sensory cortex mediating perceptual processing, one may expect to find that sensitivity to emotional valence would also be affected. The aim of Chapter 5, therefore, was to address this issue and test two alternative hypotheses: First, would

the negative valence detection advantage be reduced or eliminated when the correct detection of emotional valence in general (that is for both negative and positive valence) is rewarded? If the negative valence detection advantage reflects participants adopting a particular strategy in which they prioritize the detection of the negative valence over that of the positive valence, one would expect to find an enhancement of the detection of the positive valence when it is given a high priority (via reward) thus decreasing the negative valence advantage.

On the other hand, it is also possible that the negative valence detection advantage would be unaffected by reward. If the enhanced sensitivity to negative valence is ‘hard-wired’ and does not simply reflect a prioritization strategy then no modulation of the negative valence advantage by reward should be found.

Chapter 5 thus aimed to investigate the effects of reward on the detection of emotional valence by varying whether or not participants were rewarded for correct performance on the valence detection task. In order to test this effect, a valence detection experiment similar to that used under supraliminal conditions in Chapter 2 was designed while manipulating the presence versus absence of monetary reward. Similarly to Chapters 2, 3, and 4, a signal detection approach was employed measuring both sensitivity to negative and positive valence and response bias. In half the blocks (for each valence) participants were informed that correctly classifying the valence (emotional/neutral) of the words would result in earning points which then increases payment.

## 5.2 Experiment 8

### Method

#### *Participants*

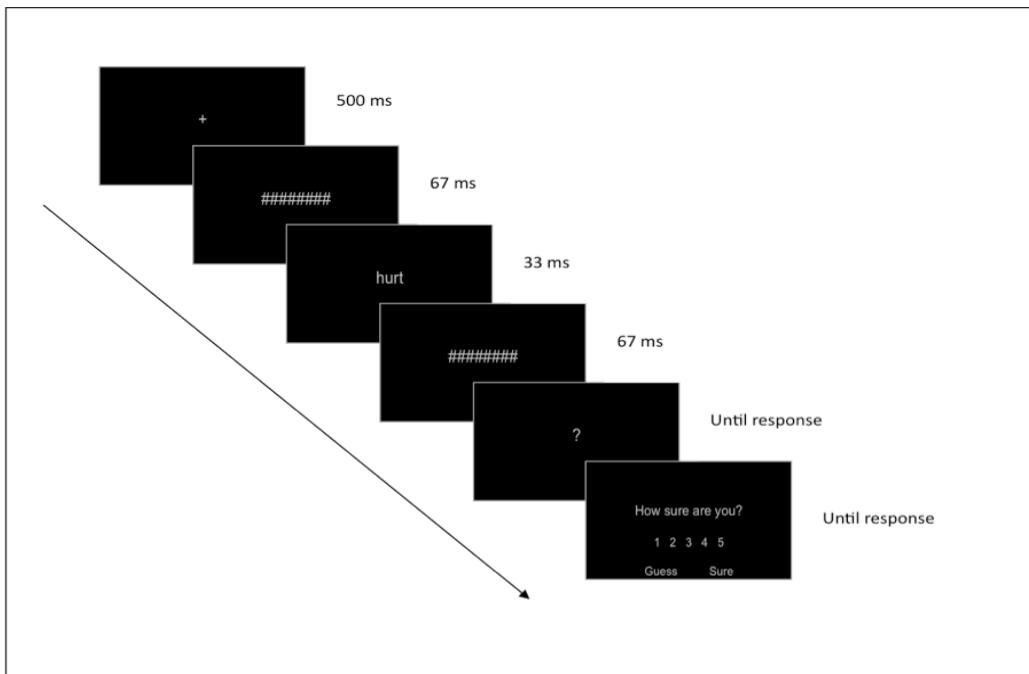
Twelve participants who were recruited on a voluntary basis from UCL's Psychology online Participant Pool took part in this experiment and had a mean age of 24 (range 19 – 32, 8 females). All participants in Experiments 8 and 9 were native English speakers, had normal or corrected-to-normal vision, and were paid between £5 and £7 depending on their performance (as described below).

#### *Stimuli and Procedure*

The experiment was similar to Experiment 1 in Chapter 2 with the following exceptions (Figure 5.1): The word was presented for only 33 ms, and the brightness of the masks was reduced. This was due to the fact that a different monitor was used for this experiment and piloting work revealed lower d' scores relative to Experiment 1 (Chapter 2). Therefore, the brightness of the masks was reduced in order to enhance performance. The crucial change was the addition of a 'reward' condition: in the reward blocks, if participants made a correct response, they got 1 point. Four blocks were 'no-reward' blocks, whereas in the remaining four 'reward' blocks participants were rewarded for correctly categorizing the words. The order of the blocks was intermixed and counterbalanced in such a way that half of the participants received the order RNNRRNNR (R for reward and N for no reward), whereas the remaining half were presented with the reversed order. Order of the blocks was also counterbalanced for valence across participants in an ABBABAAB order with A & B representing positive and negative valence.

Stimuli were generated via Matlab software (MathWorks, Natick, Massachusetts) using the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997) and were presented on a 15" CRT monitor (60 Hz refresh rate).

Participants first completed two practice no-reward blocks (one negative vs. neutral block and one positive vs. neutral block). The instructions given at the start of the experiment described the main valence detection task without providing details about the reward condition – they were only told that they will be rewarded for their performance in some blocks. Before each reward block, participants were informed that they would be given points for correctly categorizing the valence of the words and that for every 35 points earned they would get paid an extra 50p. Participants were encouraged to earn as many points as they can. At the end of each reward block, they were told how many points they had earned in that block, and the total number of points they earned. Instructions before the no-reward blocks explained that their performance in the coming block will not affect their points earned thus far.



**Figure 5.1: Trial sequence in Experiment 8.** Trial onset was indicated by a fixation cross. The presentation of a word (in this example, a negative one) was preceded and followed by masks. Participants then indicated by key presses first whether the word had been emotional or neutral, and then how confident they were of that response.

As in all previous experiments, the valence intensities and mean arousal ratings of the negative and positive words were matched. The mean valence ratings provided by the participants were 1.91 ( $SD = .48$ ), 5.10 ( $SD = .55$ ), and 3.85 ( $SD = .39$ ) for the negative, positive, and neutral words respectively. The mean arousal ratings were 5.01 ( $SD = 1.42$ ) for the negative words and 4.94 ( $SD = 1.26$ ) for the positive words. The neutral words had a mean arousal rating of 4.18 ( $SD = 1.29$ ).

An average of forty-five negative and forty-six positive words remained per participant after matching the emotional word categories on valence intensity and mean arousal levels. The negative and positive word lists had a final mean valence rating of 2.39 ( $SD = .66$ ) and 5.59 ( $SD = .63$ ) respectively. The mean arousal

ratings were matched to a mean rating of 5.11 (SD = 1.27) for both the negative and positive words.

## Results

The results are shown in Table 5.1. A repeated-measures ANOVA with the within-subject factors Reward (No-Reward vs. Reward) and Valence (Negative vs. Positive) was conducted on the Hit rates, the  $d'$  scores, and the beta scores.

**Table 5.1.** Experiment 8: Mean % Hit Rates,  $d'$  and Beta scores as a Function of Reward and Valence (averages across valences in bold)

Reward					
	No-Reward			Reward	
	Negative	Positive	Neg - Pos	Negative	Positive
HR % (FA)	68 (16)	47 (19)	21	69 (20)	51 (14)
Average	<b>57.5</b>			<b>60</b>	
$d'$	1.67	1.15	.52	1.59	1.38
Average	<b>1.41</b>			<b>1.49</b>	
Beta	2.99	4.38	-1.39	1.93	3.45
Average	<b>3.69</b>			<b>2.69</b>	

The hit rate ANOVA revealed a significant main effect of valence ( $F(1,11) = 19.187$ ,  $MSE = 242.93$ ,  $p = .001$ ; see Table 5.1), indicating higher accuracy for the negative compared to the positive valence, as in all previous experiments. There was a numerical trend for a 2.5% improvement with reward (see Table 5.1), but this effect was not significant ( $F < 1$ ) and the interaction of valence and reward

was not significant either ( $F < 1$ ). Thus reward failed to affect detection accuracy for both valences.

The ANOVA on the  $d'$  scores revealed that the main effect of valence on the  $d'$  scores was significant ( $F(1,11) = 7.902$ ,  $MSE = .202$ ,  $p = .17$ ): the greater sensitivity to the negative valence in comparison with positive valence (see Table 5.1) thus replicates the detection sensitivity advantage for negative valence found in all of the previous chapters. There was no main effect of reward ( $F < 1$ ) and although the difference between the  $d'$  of the negative and positive words appears to be smaller in the reward condition (in line with the prioritization strategy hypothesis), the interaction was not significant ( $F < 1$ ). Thus the experiment failed to show an effect of reward on detection sensitivity for both valences.

The main effect of reward on the beta scores did not reach significance ( $F(1,11) = 2.105$ ,  $MSE = 5.607$ ,  $p = .175$ ). No significant effect of valence was observed ( $F(1,11) = 2.828$ ,  $MSE = 8.921$ ,  $p = .121$ ), suggesting that the enhanced sensitivity to the negative valence was not accompanied by a difference in response criterion as in all previous experiments except Experiments 1 (Chapter 2) and 7 (Chapter 4). The interaction between reward and valence for the beta scores was not significant ( $F < 1$ ).

#### *Lexical frequency*

After matching the word categories on valence, arousal, and mean frequency levels, the main effect of valence was still found ( $F(1,11) = 5.837$ ,  $MSE = .168$ ,  $p = .034$ ) while the effect of reward as well as the interaction between reward and valence were yet again not significant (both  $F$ 's  $< 1$ ).

In summary, Experiment 8 replicated the negative valence detection advantage over positive valence but failed to show an effect of reward on detection sensitivity in general for both emotional valences.

### **5.3 Experiment 9**

A possible explanation for the lack of an effect of reward in Experiment 8 could be that the intermixed block design did not allow for the effects of reward to emerge – reward sessions were too short to have an effect and were followed by no-reward blocks where the participants' motivation levels were lower. Experiment 9 was therefore conducted to strengthen the effect of reward by blocking the reward and no-reward sessions separately and presenting the reward blocks either as the first or the last four blocks with the order counterbalanced across participants.

## **Method**

### *Participants*

Fourteen new participants took part in Experiment 9 and had a mean age of 22 years old (range 18 – 30, 8 females).

### *Stimuli and Procedure*

The stimuli and procedure followed in this experiment were identical to Experiment 8 with the exception of the block order: the four reward blocks were given first in successive order to one half of the participants followed by the four

no-reward blocks, whereas the four no-reward blocks were presented first to the remaining half of the participants followed by the reward blocks. When the no-reward blocks were presented first, no instructions regarding the reward contingency were given until right before the start of the reward blocks.

The mean valence ratings were 2.10 ( $SD = .59$ ) for the negative words and 5.33 ( $SD = .36$ ) for the positive words. No neutral words were excluded as their mean valence ratings did not differ significantly from 4 ( $M = 3.91$ ,  $SD = .25$ ). Most participants rated the negative words ( $M = 5.19$ ,  $SD = 1.56$ ) as higher in arousal than the positive words ( $M = 4.58$ ,  $SD = .87$ ). The neutral words had a mean arousal rating of 4.31 ( $SD = 1.26$ ).

An average of forty-nine negative and fifty positive words remained per participant after matching the emotional word categories on both valence intensity and arousal levels. The final word lists had mean valence ratings of 2.35 ( $SD = .61$ ) and 5.6 ( $SD = .60$ ) and mean arousal ratings of 5.04 ( $SD = 1.06$ ) and 5.03 ( $SD = 1.06$ ) for the negative and positive words respectively.

## Results

The results of Experiment 9 are shown in Table 5.2 and Table 5.3. A  $2 \times 2 \times 2$  mixed-factor ANOVA with reward (present vs. absent) and valence (negative vs. positive) as within-subjects factors and block order (reward first vs. reward second) as the between-subjects factor was conducted on the hit rates, the  $d'$  scores, and the beta scores.

**Table 5.2.** Experiment 9: Mean % Hit Rates, d' and Beta scores as a Function of Reward, Valence, and Block Order (averages across valences in bold)

Reward						
No-Reward						
Reward first	Negative	Positive	Neg - Pos	Negative	Positive	Neg - Pos
HR % (FA)	80 (13)	68 (15)	12	78 (15)	66 (14)	12
Average	<b>74</b>			<b>72</b>		
d'	2.05	1.57	.48	2.03	1.52	.51
Average	<b>1.81</b>			<b>1.78</b>		
Beta	1.91	1.64	.27	1.31	1.8	-.49
Average	<b>1.78</b>			<b>1.56</b>		
Reward second						
HR % (FA)	51 (16)	34 (16)	17	69 (13)	45 (13)	24
Average	<b>42.5</b>			<b>57</b>		
d'	1.24	.58	.66	1.78	1.29	.49
Average	<b>.91</b>			<b>1.54</b>		
Beta	2.07	1.37	.70	2.60	4.21	-1.61
Average	<b>1.72</b>			<b>3.41</b>		

**Table 5.3.** Experiment 9: Mean % Hit Rates, d' and Beta scores as a Function of Reward and Valence (averages across valences in bold)

	Reward					
	No-Reward			Reward		
	Negative	Positive	Neg - Pos	Negative	Positive	Neg - Pos
HR % (FA)	66 (15)	51 (16)	21	73 (14)	55 (14)	18
Average	<b>58.5</b>			<b>64</b>		
d'	1.65	1.06	.59	1.91	1.41	.50
Average	<b>1.36</b>			<b>1.66</b>		
Beta	1.99	1.51	.48	1.96	3	-1.04
Average	<b>1.75</b>			<b>2.48</b>		

The hit rates ANOVA revealed a main effect for valence; accuracy was higher for the negative compared to the positive valence ( $F(1,12) = 13.223$ ,  $MSE = 268.637$ ,  $p = .003$ ). The effect of valence did not interact with block order ( $F < 1$ ), indicating that the negative valence detection advantage was once again replicated. There was also a main effect of reward block order ( $F(1,12) = 10.233$ ,  $p = .008$ ; see Table 5.2): accuracy was greater when the reward blocks were first ( $M = 73\%$ ) compared to when they were second ( $M = 49\%$ ). Although there was a numerical trend for higher hit rates in the reward blocks compared to the no-reward blocks ( $M$  difference = 5.5%; Table 5.3), the main effect of reward was not significant ( $F(1,12) = 1.888$ ,  $MSE = 230.196$ ,  $p = .195$ ). No significant interaction between reward and block order was found on the hit rates ( $F(1,12) = 3.356$ ,  $MSE = 147.887$ ,  $p = .092$ ) either. Thus the accuracy results did not show any robust modulation by reward. The effect of reward-block order and the numerical trends

for higher hits rates with reward than with no reward do hint however that reward may affect emotional detection accuracy but this is clearly not a robust effect.

The  $d'$  ANOVA showed significantly higher  $d'$  scores for the negative valence than for the positive valence ( $F(1,12) = 8.511$ ,  $MSE = .487$ ,  $p = .013$ ) and no interaction between valence and block order ( $F < 1$ ). Thus the established enhanced sensitivity to the negative valence observed throughout the present thesis was once again replicated.

There was also a main effect of reward on the  $d'$  indicating that detection sensitivity was higher in the reward compared to the no-reward condition was significant ( $F(1,12) = 9.224$ ,  $MSE = .141$ ,  $p = .01$ ; see Table 5.3). Thus the manipulation of blocking was successful in revealing an effect of reward. However, the effect of reward interacted with the block order ( $F(1,12) = 10.384$ ,  $p = .007$ ) reflecting an effect of reward on the detection sensitivity when reward was presented second ( $F(1,6) = 13.257$ ,  $MSE = .208$ ,  $p = .011$ ; No-reward:  $M = .91$ ; Reward:  $M = 1.54$ ; Table 5.2). On the other hand, when the reward blocks were presented first, the effect of reward was not significant ( $F < 1$ ; No-reward:  $M = 1.81$ ; Reward:  $M = 1.78$ ; Table 5.2).

Although at first instance it appears that no effect of reward was observed when the reward blocks were first, I note that there was a numerical trend for higher  $d'$  scores when the reward blocks were first compared to when they were second (see Table 5.2; but the main effect of block order did not reach significance ( $F(1,12) = 4.193$ ,  $p = .063$ ). Moreover, a comparison of  $d'$  of the first blocks between reward and no reward blocks (when both are presented first) showed that the  $d'$  scores were significantly higher in the reward blocks ( $M = 1.78$ ) compared to no-reward blocks ( $M = .91$ ;  $t(12) = 2.75$ ,  $p = .018$  for the difference; Table 5.2).

Detection sensitivity was therefore higher in the first half of the experiment when the blocks were rewarded than when they were not rewarded.

This finding reveals that reward did in fact enhance participants' detection sensitivity even when reward was given first, and that this effect seemed to be maintained throughout the experiment; participants possibly had lower detection thresholds as a result of reward that allowed for better detection of the valence of the words (as supported by Baldassi & Simoncini, 2009). Thus the absence of a significant effect of reward when the reward blocks were first most likely reflects this carry-over effect onto the no-reward blocks rather than a lack of an effect of reward.

There was no interaction between reward and valence and no three-way interaction between reward, valence, and block order (both F's < 1). Thus even when reward was clearly effective in enhancing the  $d'$  scores, it did not affect the negative valence detection advantage, supporting the 'hard-wired' hypothesis.

These findings go in line with previous findings of an enhanced detection sensitivity for rewarded targets (Engelmann & Pessoa, 2007; Engelmann et al., 2009), and extend them to the detection of emotional valence in words. Moreover, as reward has been shown to reduce orientation discrimination thresholds (Baldassi & Simoncini, 2009), these results suggest that the detection thresholds of emotional valence can also be decreased, resulting in higher  $d'$  values. The paradigms used in most of the studies reported in this thesis that have examined the effects of reward most likely produced a high level of motivation that was maintained throughout the experiment. For example, in the study by Della-Libera & Chelazzi (2006), correct responses were immediately followed by a reward cue at trial level indicating the level of reward (low or high). Pleger et al. (2008) also presented reward on each

trial and grouped the different reward levels (0, 20, 50, or 80 pennies per correct trial) into miniblocks; therefore the majority of the blocks contained the possibility of reward thus requiring participants to be highly motivated to perform correctly and earn money throughout the experiment. Seeing that in previous studies reward was given on a trial-by-trial basis for correct performance and participants were informed that their task is to earn as much money as possible, it is not surprising that the effects of reward in the present chapter were only observed when a high level of motivation was maintained for a longer period of time (i.e. when the reward sessions were blocked rather than intermixed with no-reward blocks).

The main effect of block order on the beta scores was not significant ( $F(1,12) = 11.250$ ,  $p = .181$ ). The ANOVA on the beta scores revealed no significant effects of both valence ( $F(1,1n2) = 1.154$ ,  $MSE = .966$ ,  $p = .304$ ) or reward ( $F(1,12) = 2.375$ ,  $MSE = 3.16$ ,  $p = .149$ ). Interestingly, the interaction between reward and valence on the beta scores was marginally-significant ( $F(1,12) = 4.483$ ,  $MSE = 1.841$ ,  $p = .054$ ). As can be seen in Table 5.3, this interaction reflects higher beta scores for the positive valence than the negative valence in the reward condition (but this difference was only marginally-significant:  $t(13) = 2.09$ ,  $SEM = .503$ ,  $p = .057$ ), whereas there was a non-significant difference in the no-reward condition ( $t(13) = 1.287$ ,  $SEM = .377$ ,  $p = .22$ ). This difference in response bias found in the reward condition is replicating the same effect (with no reward) in Chapter 2 (Experiment 1) and Chapter 4 (Experiment 7). Reward did not affect beta scores, however, as no other comparisons were significant (interactions between block order and both valence and reward as well as the three-way interaction between valence, reward, and block order: all  $p$ 's  $> .068$ ).

These results suggest that when participants were rewarded for correctly categorizing the valence of the words, they were less confident about the detection of the positive valence and thus adopted a more conservative criterion in response to the positive words in order to avoid making mistakes. Introducing block order as a between-subjects factor revealed no significant comparisons between the groups (all p's > .092).

#### *Lexical frequency*

After matching the word categories on valence, arousal, and frequency levels, the main effect of valence on the d' scores remained significant ( $F(1,12) = 6.456, p = .026$ ) with no interaction with block order ( $F < 1$ ). The effect of reward was still found to be significant ( $F(1,12) = 16.383, p = .002$ ) as well as the interaction between reward and block order ( $F(1,12) = 8.127, p = .015$ ). Finally, both the interaction between reward and valence and the three-way interaction between reward, valence, and block order were not significant (both F's < 1).

In conclusion, a replication of the negative valence detection advantage established thus far in this thesis was found in both Experiments 8 and 9. However, the enhanced sensitivity to negative valence was not modulated by reward level, suggesting that the enhanced detection of negative valence does not simply reflect a prioritization strategy but rather a fixed characteristic of human cognition. A significant effect of reward was found when the reward blocks were presented second. In addition, it seems that even when participants commenced with the reward blocks, the d' scores were increased throughout the experiment.

#### **5.4 Summary and conclusions**

Considering previous research showing an improvement in perception, detection, and sensory function as a function of reward, Chapter 5 was conducted in order to examine the effects of monetary reward on the detection of emotional valence in words. The results showed firstly a replication of the negative detection advantage established in all previous chapters. In addition, the results suggested that participants adopted a more conservative criterion to detect the positive valence as opposed to the negative valence when correct performance on the valence detection task was rewarded, perhaps reflecting lower confidence in the detection of the positive valence when they were more motivated (through reward) to be accurate.

The present chapter revealed an enhancement of detection sensitivity to emotional valence in general as a result of reward but only when the effects of reward were strengthened (by blocking the reward sessions compared to when the reward and no-reward blocks were intermixed). This was demonstrated by higher detection sensitivity rates to both the negative and positive valence as a result of reward. These findings are consistent with previous reports of a facilitation of selective attention (Della Libera & Chelazzi, 2006) as well as an enhanced detection of targets (Engelmann & Pessoa, 2007; Engelmann et al., 2009) and of orientation discrimination sensitivity (Baldassi & Simoncini, 2009) as a function of reward. The results of the present chapter also extend previous findings of an improvement of sensory judgements as reward value increases (Pleger et al., 2008) to an increase in perceptual sensitivity to emotional information by reward. As previous reports that have demonstrated that reward reduces orientation

discrimination thresholds (Baldassi & Simoncini, 2009), the present findings imply that reward enhances the detection of emotional valence possibly by reducing the sensitivity thresholds.

Most importantly, the results of the present chapter suggest that the enhanced sensitivity to negative information does not simply reflect response strategies but rather may be ‘hard-wired’ as the negative detection advantage was not modulated by reward. In other words, if the negative sensitivity advantage was due to participants placing a higher priority for the detection of the negative valence versus the positive valence, then increasing the priority to detect the positive valence via reward would be expected to reduce the negative valence advantage. Given that reward did not affect the negative detection advantage, this suggests that the enhanced sensitivity to negative information is not a mere reflection of a prioritization strategy but rather a fundamental characteristic of human cognition.

## **Chapter 6:**

### **General Discussion**

## **6.1 Overview of findings**

The present thesis has established a detection advantage for negative emotional information presented in words. In an emotional valence detection task whereby participants classified a large corpus of words as having an emotional or neutral meaning, this advantage was demonstrated on both accuracy and detection sensitivity measures and was typically not accompanied by a change in the response criterion (except for two cases: the 33 ms duration condition in Experiment 1 (Chapter 2) and Experiment 7 (Chapter 4)). It is important to bear in mind firstly that given the independence of the  $d'$  and response bias measures, any difference in response bias between the negative and positive valence does not cast any doubt on the sensitivity advantage found. Secondly, the response criterion for the negative valence was still always conservative. The detection advantage extended across both supraliminal and subliminal presentations, and alternative accounts in terms of lexical frequency, idiosyncratic differences in valence intensities, and arousal ratings were ruled out. The influence of arousal level during performance was also ruled out (Chapter 2) but only for accuracy.

The research in the present thesis has also demonstrated that the detection advantage for negative valence depends on the allocation of attention to the words. Using the framework of perceptual load theory (Lavie, 1995), the results showed that enhanced sensitivity to the negative valence was found in the low load but not in the high load. Under subliminal presentations, however, a small detection advantage remained irrespective of the allocation of attention (Chapter 3). The role of individual differences in anxiety levels was also addressed (Chapter 4) and the results established a hypersensitivity to negative valence in high anxiety that did

not depend on allocation of attention. Finally, a potential role of reward was also examined (Chapter 5). While reward improved detection sensitivity overall, it did not interact with the negative valence sensitivity advantage, suggesting that the negative detection advantage does not reflect response strategies but instead is more likely to be ‘hard-wired’: a fundamental characteristic of human perception.

#### *A true sensitivity advantage for negative information*

The research reported in the present thesis provides the first demonstration of a clear advantage in the detection of negative versus positive emotional information that is expressed with detection sensitivity. This conclusion adds to previous research showing a processing advantage for negative words over neutral words (e.g. in terms of greater Stroop interference; White, 1996; Sutton et al., 2007). However, as many of the previous studies have not directly compared negative to positive words, one cannot conclude whether their findings reflect a specific processing advantage for negative words rather than a general emotionality advantage. Although some studies that have addressed this issue have found a selective attention for negative words over positive words (e.g. McKenna & Sharma, 1995; Pratto & John, 1991), no detection advantage as such can be inferred from their conclusions given that the advantage was found on measures of response times and not on detection sensitivity per se.

Previous research on the detection of emotional words has found not only a general emotion advantage shown for example by greater naming and recognition accuracy (for negative compared to neutral words, Gaillard et al., 2006; for both negative and positive words compared to neutral words, Zeelenberg et al., 2006) but also a detection advantage for negative words compared to positive words on

accuracy measures (Dijksterhuis & Aarts, 2003). While the present thesis does not rule out a general emotional advantage overall, it highlights an additional advantage specifically for negative valence detection sensitivity. The results of the present thesis showing greater accuracy and detection sensitivity for the negative valence compared to the positive valence can accommodate the previous findings and suggest that the advantage for negative words in naming and accuracy has been mediated by an advantage in perceptual sensitivity rather than a response bias.

The results of one previous study appear to conflict with the conclusion of the present thesis. Snodgrass & Harring (2005) found that detection sensitivity was better for positive words compared to negative words. The discrepancy between our conclusions may be due to their use of a smaller set of words (14 words of each category). Such small sets are more open to sampling biases such as forming more cohesive categories (allowing for more inter-category semantic priming effects). For example, if all the positive words were related to the concept of ‘love’ and thus resulted in priming effects, this would facilitate the identification of all other love-related words.

The negative sensitivity advantage seems to survive even subliminal conditions – an enhanced detection sensitivity to negative valence (compared to both positive valence and chance level) was observed even when the words were presented for very brief durations and surrounded by masks and participants’ confidence ratings indicated no awareness of the words’ emotional content. This finding suggests that less information is required for negative (versus positive) information to be perceived. This suggestion is consistent with previous findings indicating that information about the word’s valence can be extracted from a written word even if participants claim to be guessing the target valence (Gaillard

et al., 2006). Specifically, their results showed that participants were more likely to name a wrong negative word after a negative than after a neutral target. The absence of positive words in their study, however, precludes any conclusions regarding the present issue of sensitivity to negative valence rather than to any emotion. By also including positive words in this thesis, the results showed that the ability to extract valence information, distinguishing an emotional word from a neutral one even under subliminal conditions, is specific to negative valence.

Taking LeDoux's (1996) model into account, these results could potentially be explained by the idea that threatening stimuli are nevertheless unconsciously perceived through their effect of their processing in the 'low road' (including the subcortical pathways into the amygdala and the resultant autonomic response). Such 'low road' processing can allow for an emotional response to the stimuli even when these remain unconscious. The production of such an emotional response could in turn influence 'guessing' performance in such a way that participants get an 'intuition' about the word as a result of this emotional response, indicating it was negative without full awareness of the emotion of the word. Moreover, that the amygdala projects back to the sensory cortex possibly enhances the sensory signal resulting in negative stimuli being perceived even when presented unconsciously.

The demonstration in the present thesis of an enhanced sensitivity to negative information under both supraliminal and subliminal conditions provides compelling evidence of a true negative detection sensitivity advantage. Additional strong evidence suggesting that the processing advantage for negative information appears to reflect a fundamental characteristic of human perception rather than simple response strategies was demonstrated by the findings of Chapter 5 where participants' motivation levels were manipulated through presenting monetary

rewards for correct performance. Crucially, if the enhanced detection of negative valence was due to participants giving the detection of negative valence a higher priority than the detection of the positive valence, then increasing participants' motivation to detect the positive valence as well through reward would be expected to reduce the negative advantage. However, reward did not affect the negative valence advantage suggesting that the enhanced sensitivity to negative information reflects a 'hard-wired' characteristic and not simply a prioritization strategy.

Although reward did not modulate the negative detection advantage, the results did show an improvement in detection sensitivity to both negative and positive information overall by reward, in line with previous research that has shown a magnifying effect of reward on attention (e.g. Della-Libera & Chelazzi, 2006; Kiss et al., 2009) and perception (e.g. Bunzeck et al., 2009; Pleger et al., 2008; Baldassi & Simoncini, 2009). Based on previous suggestions of increased activity of sensory cortices such as V1 through reward, it is possible that a similar mechanism applies to the detection of emotional valence – the presence of reward in the current experiments may have amplified the perceptual processing of the words in visual cortex, thus leading to their enhanced detection. The present findings are the first to demonstrate that the effects of reward extend to sensitivity to emotional information overall without hindering the negative advantage.

#### *Hypersensitivity to negative information in anxiety*

Although the enhanced ability to detect the emotional valence in negative words is not modulated by reward, it appears to be mediated by anxiety levels. Previous research has indicated a hypervigilance to threat in high anxiety (e.g. Williams et al., 1996; Fox et al., 1993; Mathews & MacLeod, 1985; Richards et al.,

1992; Mogg et al., 1993). The present thesis extends the previous literature in demonstrating hypersensitivity in anxiety to negative (compared to positive) information on both idiosyncratic ratings and detection sensitivity measures. Specifically, individual differences in anxiety levels were associated with the subjective valence ratings of the negative words revealing that individuals with high anxiety evaluated negative information more negatively than individuals with low anxiety. High trait anxiety was also associated with better detection sensitivity to the negative valence even under conditions of high attentional load. I discuss each of these findings in turn.

The finding of the effects of anxiety levels on the valence ratings provides evidence for previous claims that high anxiety leads to interpreting mild threat as higher threat. According to the cognitive-motivational model of anxiety proposed by Mogg & Bradley (1998), a Valence Evaluation System appraises a stimulus's threat value which includes both automatic and fast assessment of crude stimulus features (for example through the 'low road' proposed by LeDoux, 1996) and more fine-tuned details. In high trait anxiety, this Valence Evaluation System is more sensitive, resulting in mild negative information being marked as highly threatening. Output from this system is then sent to a Goal Engagement System, which is responsible for the allocation of attentional resources (allocating attention towards high threat and disrupting current task or avoiding low threat and maintaining current goals).

The cognitive-motivational model of anxiety therefore predicts that increased sensitivity to mild threat in high anxiety leads to the interpretation of the threat as high. This prediction was supported by the association of anxiety levels with the negative valence ratings found in Chapter 4. Moreover, the cognitive-

motivational model proposes that attentional resources will be allocated towards the source of threat in high anxiety as a result. On the other hand, in low anxiety, although the tendency to allocate attention towards a stimulus increases as the threat value of the stimulus increases, mild threat is ignored in favour of goal-relevant information.

Strong evidence for this prediction was provided in the present findings that high trait anxiety was associated with an increased negative detection sensitivity advantage. Particularly, a hypersensitivity to negative information was found in high anxiety in such a way that while individuals with low trait anxiety showed no negative valence advantage in either of the load conditions, individuals with high trait anxiety showed an enhanced detection sensitivity to negative information under both low load and high load conditions. I note that these findings also reveal that one exception to the negative valence sensitivity advantage established in the present thesis is for individuals with extremely low trait anxiety.

The lack of a negative valence detection advantage for individuals with low anxiety in the present thesis is inconsistent with previous research showing a vigilance towards highly threatening pictures (compared to mild threat) even for low anxious participants (e.g. Koster et al., 2006; Mogg et al., 2000). However, considering that the highly negative words were excluded in the present thesis to match the valence intensities of the negative and positive valence, this may account for the lack of a negative detection advantage in the LTA group. Moreover, it is possible that threatening pictures may have a stronger effect than words.

A previous claim has been made that anxiety is associated with a response bias to interpret ambiguous information as threatening rather than an enhanced sensitivity to negative information (Manguno-Mire et al., 2005). Careful

consideration of the findings suggests that this claim that at first sight appears to be contradictory to my claim can in fact be reconciled with my conclusion. While no difference was found between the anxiety groups on the sensitivity to the negative words when comparing the detection sensitivity measures of only the negative words both in the Manguno-Mire et al. (2005) study and in the present study, the results of the present thesis reveal that when detection sensitivity to the negative words is compared to that to the positive words, an advantage for negative information is observed that is amplified with higher levels of anxiety. The conclusion of the present thesis therefore is that high anxiety (compared to low anxiety) is associated with an enhanced sensitivity to negative information over positive information and not with a greater ability to detect negative valence per se.

Although no differences in response criterion between the anxiety groups were observed in the present thesis (in contrast with the findings of Manguno-Mire et al., 2005), this may be due to differences in the tasks of the two studies with their task being to classify the words as ‘dangerous’ or ‘safe’. This particular categorization may be subject to response bias effects whereas the general classification of words as emotional or neutral in my task appears less susceptible to effects of response bias. An additional possibility is that no response bias was found for the high anxiety group in the present thesis because the negative words with the most extreme valence ratings were excluded to match the valence intensities of the negative and positive words. Given that individuals with high anxiety did in fact rate the negative words more extremely than individuals with low anxiety, it is possible that a response bias would have been found had these extreme negative words not been eliminated.

### *Relation to attention*

It is important to bear in mind that the suggestion of the present thesis that the sensitivity advantage for negative information is a fundamental characteristic of human perception does not necessarily mean that perceptual capacity is not required for negative valence perception. Previous research on whether emotional stimuli are processed automatically or whether their processing requires attention produced mixed conclusions (Pessoa, 2005) with many studies showing that the availability of attention is required for the processing of emotional stimuli (Pessoa et al., 2002; Eimer, Holmes, & McGlone, 2003; Holmes, Vuilleumier, & Eimer, 2003; Hsu & Pessoa, 2007; Bishop et al., 2007).

The present thesis provides further support for this conclusion and extends it to showing that attention is required for the negative valence detection advantage to emerge. By manipulating the allocation of attention through a manipulation of perceptual load (e.g. Lavie, 1995), an enhanced sensitivity to the negative valence compared to the positive valence was found under conditions of low load but not under high load. This demonstrated that conscious detection of the negative valence did require attentional resources.

The conclusion that the detection advantage for negative (compared to positive) valence is dependent on attention is consistent with previous demonstrations that negative word perception does require attention. For example in an attentional blink paradigm, Kihara & Osaka (2008) showed that a negative first target led to an enhanced AB for a negative second target suggesting that the detection of negative information does require attention.

On the contrary, other AB studies have demonstrated that negative words (Anderson, 2005; Anderson & Phelps, 2001; Keil & Ihssen, 2004; Ogawa & Suzuki, 2004), as well as non-verbal, fearful face stimuli (e.g., Milders, Sahraie, Logan, & Donnellon, 2006) are more likely than the corresponding neutral stimuli to escape the attentional blink (Shapiro et al., 1997), indicating that negative stimuli may have preferential access to processing resources (although in some of these cases this could be due to arousal rather than valence; see Anderson, 2005).

The discrepancy between these previous findings and those of the present thesis could be due to the fact that although the AB task is demanding on attention, it may be demanding on resources that are different to those that are in demand in the task of the present thesis. Specifically, while the present task loaded a visual search task presented concurrently with the word, each stimulus in the AB paradigm is presented alone on each trial and the demands are mainly placed on temporal processing resources due to fast presentations.

In addition, results in other studies that have suggested that negative valence perception does not require attention (such as neuroimaging studies that claim that the processing of negative emotional stimuli is automatic; e.g. Vuilleumier et al., 2001; Dolan & Vuilleumier, 2003; Bishop, et al., 2004) were obtained in tasks that did not place sufficient demands on attention, thus leaving spare attentional resources. For example, in one study, participants were presented with four pictures, each pair (either two houses or two faces) arranged either vertically or horizontally, and were instructed to attend to one of two pairs of stimuli while ignoring the other pair (Vuilleumier et al., 2001). However, research on the role of attentional load (e.g. Lavie, 2005; reviewed previously in Chapter 3) has shown that the mere instruction to ignore a stimulus does not automatically

prevent unattended stimuli from being processed – as long as there is spare attentional capacity, distractors will be processed. In this thesis, an established paradigm that has been proven to effectively manipulate attentional load was used (Lavie & Cox, 1997; Lavie & Fox, 2000; Beck & Lavie, 2005; Bahrami et al., 2007; Pinsk et al., 2003; Yi, et al., 2004), in which the high load condition did appear to consume most capacity.

#### *Exceptions to the attention-dependent valence perception hypothesis*

While the negative valence advantage was found to be dependent on attention (for supraliminal presentations), an exception to this rule was observed – the enhanced sensitivity to negative valence does not appear to be dependent on allocation of attention when processed at an early subliminal stage. Chapter 3 demonstrated a smaller but consistent negative detection advantage under both conditions of load when the presentations conditions increased the likelihood of subliminal processing of the words. The results showed not only an advantage in sensitivity to negative information over that of positive information, but also an ability to detect the negative valence that is greater than chance even in the high load, suggesting that for certain types of stimuli, in this case negative emotional information, subliminal perception may be automatic.

Although high perceptual load did reduce the detection sensitivity to emotional valence in general under subliminal presentation conditions too, one may wonder why the negative detection advantage remained given that previous research has shown that high load eliminated the subliminal perception and the related primary cortex response to non-emotional visual stimuli (e.g. Bahrami et al., 2007; 2008). Here, it is important to bear in mind that the task in the present

thesis did require the detection of the valence of the words (although with a lower priority than the primary letter search task), whereas previous effects of load on subliminal processing (e.g. Bahrami et al., 2007;2008 studies) were obtained in tasks that required participants to ignore the subliminal information. It is possible and highly likely that processing resources are allocated to the stimuli when participants are required to process the stimuli even as a secondary priority more so than when the stimuli are ignored.

A second exception to the dependence of the negative valence sensitivity advantage on attention established in the present thesis is in relation to high levels of trait anxiety. Specifically, the present thesis demonstrated an enhanced sensitivity to negative (compared to positive) valence under both conditions of low and high load that was even augmented under high load in individuals with high anxiety (when compared to individuals with low anxiety).

Notice that the modulation of the negative detection advantage by anxiety seems to conflict with the suggestion of Chapter 5 that the negative valence advantage is ‘hard-wired’ and is not amplified by reward. However, the lack of a modulation of the negative advantage by reward was obtained under conditions that were more akin to the low load conditions in Chapter 4, whereas the enhancement in the negative detection advantage in high anxiety was observed under conditions of high load. This suggests that presenting reward under conditions of high load could also amplify the negative valence advantage. Future research could potentially address this interaction.

The results of the present thesis are thus the first to establish that the hypersensitivity to negative information in high anxiety is not dependent on allocation of attention. This conclusion is inconsistent with previous findings on

the effects of perceptual load on individual differences in anxiety. For example, as mentioned earlier (in the General Introduction), differences in DLPFC activity (suggesting differences in cognitive control) between the anxiety groups were found only under conditions of low load (Bishop, 2009). Further evidence of an elimination of individual differences in anxiety under conditions of high perceptual load was demonstrated in another study (Bishop et al., 2007). The results revealed that while an increase in activity of the DLPFC or the ACC is typically found for exercising attentional control to inhibit the processing of distractors, individuals with high trait anxiety showed no such increase in related brain activity under low load. Under high load however, no such differences between the anxiety groups were observed.

Although these findings seem to be inconsistent with the results of Chapter 4, the previous studies (Bishop et al., 2007; Bishop, 2009) differ methodologically from the present thesis: Specifically, while the earlier studies revealed neural imaging components in response to facial stimuli that were intended to be ignored (thus reflecting differences in cognitive control abilities), the results of the present thesis measured effects on behavioural performance in response to verbal information that was attended to a certain extent (I note that although detection of the word valence was required, attention to the words was secondary given that the letter search was prioritized).

While previous findings that have shown a reduced ability to exert attentional control in individuals with high anxiety (e.g. Bishop et al., 2007) are in line with the Processing Efficiency theory of anxiety (Eysenck & Calvo, 1992) that implies a diminished attentional capacity in high anxiety, the present thesis found no evidence of a similar effect of anxiety on perceptual capacity in terms of a

greater effect of load on detection sensitivity in high anxiety. This is not surprising considering that previous research implicating a reduced attentional capacity in high anxiety examined differences in higher cognitive control functions rather than perceptual capacity as such. That high perceptual load did not affect performance to a greater extent in high anxiety in the present thesis suggests that unlike working memory, perceptual capacity is not reduced in high anxiety.

## **6.2 Implications for future research and daily life**

### *Speed of information accrual*

For the simple yet significant goal of deepening our understanding of the negative valence sensitivity advantage, further research will have to elucidate the mechanism underlying the present findings. One plausible mechanism may be via higher speed of information accrual for negative (versus positive) valence. Categorization of stimuli as negative or positive is made on the basis of very little information (e.g. Murphy and Zajonc, 1993). Assuming that the amount of information available about a stimulus is a monotonic function of exposure duration, the present findings suggest that negative (compared to positive) valence either increases the rate of information accrual or requires less information to be available for correct categorization. This conjecture is indirectly supported by the finding that attention speeds perceptual information processing (Carrasco & McElree, 2001) coupled with research showing that emotional stimuli attract attention (e.g., in emotional Stroop tasks: McKenna & Sharma, 1995; Pratto & John, 1991). For orthographic stimuli, the attention-grabbing effect of emotional stimuli may be limited to tasks requiring semantic analysis (rather than

phonological or graphic analysis; Huang et al., 2008), implicating the lexical-semantic system and speed of accrual of semantic information in mediating the negative-word advantage.

In addition, obtaining physiological evidence by conducting an ERP study and collecting EEG measures would strengthen the conclusions drawn from this investigation and would allow for the examination of potential temporal differences in the perception of negative versus positive words. Collecting both behavioural and neural components, therefore, will not only provide converging evidence from different methodologies in the exploration of potential differences in the speed of information accrual between the negative and positive valence, but can also clarify the psychological mechanisms involved (e.g. regarding speed of information accrual).

### *Unconscious processing*

Another issue that merits further investigation arises from the findings of the present thesis on the unconscious processing of emotional valence. The demonstrations of individual differences in anxiety levels on the sensitivity to negative information in Chapter 4 were obtained from supraliminal presentation conditions and therefore apply only to consciously-perceived words. Considering previous research showing greater interference from subliminally-presented negative words in high anxiety (e.g. MacLeod & Rutherford, 1992; Mogg et al., 1993; Fox, 1996), it would be worthwhile to explore whether similar differences would emerge between the anxiety groups in the detection of negative versus positive valence when awareness of the words is precluded.

The effects of reward on valence detection established in the present thesis are also only indicative of effects on words that were presented above subjective awareness levels (Chapter 5). Future studies should therefore seek to potentially extend these findings to unconsciously processed words. Reward has been shown to affect the subliminal processing of non-emotional visual stimuli (Seitz, Kim, & Watanabe, 2009). In this study, participants were deprived of food and water before each training phase and were then rewarded on some occasions with drops of water while passively viewing stimuli. The stimuli were rendered unconscious by continuous flash suppression and results showed an improvement of visual sensitivity (as measured by a psychometric function of the signal-to-noise ratio) to orientation when associated with reward even in the absence of awareness of the stimuli. Considering this finding of a modulation of subliminal processing by reward, one prospective relevant direction would be to examine the effects of reward on the detection of emotional valence under subliminal word presentations.

A final noteworthy potential direction in elaborating the findings on the unconscious processing of emotional valence is to obtain neural imaging data. The present thesis provided strong behavioural evidence of differences in the processing of negative versus positive information in terms of detection sensitivity. It would thus be extremely valuable to understand the differential brain activity in response to negative and positive information. Previous research has addressed this issue in relation to consciously-perceived words (Kensinger & Schacter, 2006). In an fMRI study investigating arousal-based and valence-based brain activity in response to viewing negative, positive, and neutral pictures or words presented for 2500 ms, the results showed amygdala, dorsomedial PFC, and ventromedial PFC activity in response to all highly-arousing stimuli that was more left-lateralized for

words and right-lateralized for pictures. Valence differences (between negative and positive items) were strongest for pictures and showed a lateral PFC response to negative stimuli while the medial PFC showed increased activity to positive stimuli. Though these findings provide significant insight into the underlying neural response to emotional valence, given that they apply only to stimuli processed at a conscious level, it would be highly valuable to extend these findings and conduct an fMRI study on the detection of emotional valence for words presented under subliminal conditions.

#### *Trait versus state anxiety*

An extension of the current hypersensitivity to negative valence in anxiety to other anxiety states would have potentially significant implications for human behaviour. The present thesis established a hypersensitivity to negative information in high trait anxiety with no investigation of any mediating effects of state anxiety on the detection of emotional information (as state anxiety was not manipulated). Based on previous findings that have demonstrated that individuals with high compared to low state anxiety show greater vigilance to threatening words (e.g. Fox et al., 2001) as well as selective amygdala activity in response to negative stimuli (Bishop et al., 2004), a potential direction would be to see how inducing high state anxiety would affect participants' sensitivity to negative valence. Alternatively, considering that previous literature has indicated a mood-congruent Stroop interference (e.g., Gilboa-Schechtman et al., 2000), it would be interesting to see if inducing a positive mood would enhance the detection of positive information and thus reduce the negative valence advantage.

### *Implications for daily life*

Although the conclusions of the present thesis are derived from measures obtained from laboratory settings, the findings are based on word stimuli that are, in reality, often encountered in life. The results thus have some interesting implications for daily life; for example, one potential use of the findings is for marketing purposes. As this thesis established, negative information is detected to a greater extent than positive information, and even under conditions where the individual is not fully aware of the stimulus. This suggests that the attention-grabbing power of negative words, although unpleasant, may have a more rapid impact than positive words and can thus be more effective in marketing campaigns. More controversial is the implication of the enhanced detection of unconscious negative valence in subliminal advertising. Market researcher James Vicary (1957) claimed that flashing messages on the screen during a movie in New Jersey about eating popcorn and drinking coke increased their prospective sales. Though he later admitted to the fabrication of his results, his claim triggered a massive interest and quite a number of studies investigating this issue (that have, however, produced little or no support). Interestingly, in 2000, George W. Bush was accused of employing suspicious campaigning techniques in the presidential elections by subliminally-presenting opponent Al Gore's face in conjunction with the word 'RATS' in one of the television ads (Dijksterhuis, Aarts, & Smith, 2005). Clearly, it is a fascinating suggestion that subconscious negative information can be more powerful than positive information.

Finally, significant implications for personal safety (for instance while driving) can be elicited from the conclusions of the present thesis. For example, 'kill your speed' would be more effective than a neutral 'slow down', but only

under conditions of low load. The results of Chapter 3 showed that the detection sensitivity to emotional valence in general is not only reduced under conditions of high perceptual load, but the advantage in detection for the negative valence is also eliminated. What these findings seem to suggest then is that potentially hazardous objects or warning signs alerting one to impending danger can be missed under conditions of high attentional load such as when driving through heavy traffic and being bombarded by roadside billboards. It would thus be highly recommendable to make roadside warning signs sufficiently salient, especially on highly loaded roads.

### **6.3 Conclusions**

In summary, the present thesis contributes to emotion research by firstly establishing a significant advantage in detection sensitivity to negative information in words compared to positive information. This advantage was typically not accompanied by differences in response bias or accounted for by differences in arousal, subjective valence ratings or lexical frequency. The enhanced sensitivity to negative information was observed for both supraliminal and subliminal presentations and was not affected by reward, indicating that it is a fundamental characteristic of human perception. Although ‘hard-wired’, sufficient attentional resources appear necessary for the negative valence detection advantage to emerge, except under subliminal conditions and for individuals with high trait anxiety who instead show a hypersensitivity to negative information.

## References

- Anderson, A. K. (2005). Affective influences on the attentional dynamics supporting awareness. *Journal of Experimental Psychology: General*, *134*(2), 258-281.
- Anderson, A. K., & Phelps, E. A. (2001). Lesions of the human amygdala impair enhanced perception of emotionally salient events. *Nature*, *411*, 305-309.
- Ansari, T.L., & Derakshan, N. (2010). Anxiety impairs inhibitory control but not volitional action control. *Cognition and Emotion*, *24*(2), 241-254.
- Ansari, T.L., Derakshan, N., & Richards, A. (2008). Effects of anxiety on task switching: Evidence from the mixed antisaccade task. *Cognitive, Affective, and Behavioral Neuroscience*, *8*(3), 229-238.
- Aquino, J. M., & Arnell, K. M. (2007). Attention and the processing of emotional words: Dissociating effects of arousal. *Psychonomic Bulletin & Review*, *14*, 430–435.
- Arnell, K. M., Killman, K. V., & Fijavz, D. (2007). Blinded by emotion: Target misses follow attention capture by arousing distractors in RSVP. *Emotion*, *7*(3), 465-477.
- Baayen, R. H., Piepenbrock, R., & Gulikers, L. (1995). *The Celex Lexical Database* [CD-ROM]. Linguistic Data Consortium, University of Pennsylvania, Philadelphia, U.S.A.
- Bahrami, B., Carmel, D., Walsh, V., Rees, G., & Lavie, N. (2008). Unconscious orientation processing depends on perceptual load. *Journal of Vision*, *8*(3), 1-10.
- Bahrami, B., Lavie, N., & Rees, G. (2007). Attentional load modulates responses of

human primary visual cortex to invisible stimuli. *Current Biology*, 17, 509–513.

Baldassi, S., & Simoncini, C. (2009). Reward sharpens orientation coding independently on attention. Available from Nature Precedings <http://hdl:10101/npre.2009.3023.1>

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin*, 133(1), 1-24.

Baumeister, R. F., Bratslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is stronger than good. *Review of General Psychology*, 5(4), 323-370.

Beck, D. M., & Lavie, N. (2005). Look here but ignore what you see: Effects of distractors at fixation. *Journal of Experimental Psychology: Human Perception & Performance*, 31, 592–607.

Becker, E. S., Rinck, M., Margraf, J., & Roth, W. T. (2001). The emotional Stroop effect in anxiety disorders: General emotionality or disorder specificity? *Anxiety Disorders*, 15, 147-159.

Bernat, E., Bunce, S., & Shevrin, H. (2001). Event-related brain potentials differentiate positive and negative mood adjectives during both supraliminal and subliminal visual processing. *International Journal of Psychophysiology*, 42(1), 11-34.

Bishop, S. J. (2009). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience*, 12, 92-98.

Bishop, S. J., Jenkins, R, & Lawrence, A. (2007). The neural processing of task

irrelevant fearful faces: effects of perceptual load and individual differences in trait and state anxiety. *Cerebral Cortex*, 17, 1595-1603.

Bishop, S. J., Duncan, J., & Lawrence, A. (2004). State Anxiety modulation of the amygdala response to unattended threat-related stimuli. *Journal of Neuroscience*, 24(46), 10364-10368.

Blake, D. T., Strata, F., Churchland, A. K., & Merzenich, M. M. (2002). Neural correlates of instrumental learning in primary auditory cortex. *Proceedings of the National Academy of Sciences of the USA*, 99(15), 10114-10119.

Borkenau, P., & Mauer, N. (2006). Processing of pleasant, unpleasant, and neutral words in a lateralised emotional Stroop task. *Cognition and Emotion*, 20(6), 866-877.

Bradley, B. P., Mogg, K., & Millar, N. H. (2000). Covert and overt orienting of attention to emotional faces in anxiety. *Cognition and Emotion*, 14(6), 789-808.

Bradley, B. P., Mogg, K., Falla, S. J., & Hamilton, L. R. (1998). Attentional bias for threatening facial expressions in anxiety: Manipulation of Stimulus Duration. *Cognition and Emotion*, 12(6), 737-753.

Brainard, D. H. (1997) The Psychophysics Toolbox, Spatial Vision 10:433-436.

Bunzeck, N., Doeller, C. F., Fuentemilla, L., Dolan, R. J., & Duzel, E. (2009). Reward motivation accelerates the onset of neural novelty signals in humans to 85 milliseconds. *Current Biology*, 19(15), 1294-1300.

Calvo, M. G., & Castillo, M. D. (2005). Processing of threat-related information outside the focus of visual attention. *The Spanish Journal of Psychology*, 8(1), 3-11.

Carrasco, M., & McElree, B. (2001). Covert attention accelerates the rate of visual

information processing. *Proceedings of the National Academy of Sciences of the USA*, 98, 5363-5367.

- Cartwright-Finch, U., & Lavie, N. (2006). The role of perceptual load in Inattentional Blindness. *Cognition* 102(3), 321-340.
- Dalgleish, T., Moradi, A. R., Taghavi, M. R., Neshat-Doost, H. T., & Yule, W. (2001). An experimental investigation of hypervigilance for threat in children and adolescents with post-traumatic stress disorder. *Psychological Medicine*, 31, 541-547.
- Della-Libera, C., & Chelazzi, L. (2006). Visual selective attention and the effects of monetary rewards. *Psychological Science*, 7(3), 222-227.
- Derakshan, N. & Eysenck, M.W. (2009). Anxiety, processing efficiency and cognitive performance: New developments from attentional control theory. *European Psychologist*, 14(2), 168–176.
- Dijksterhuis, A., & Aarts, H. (2003). On wildebeests and humans: The preferential detection of negative stimuli. *Psychological Science*, 14, 14–18.
- Dijksterhuis, A., Aarts, H., & Smith, P. K. (2005). The power of the subliminal: On subliminal persuasion and other potential applications. In R. Hassin, J. S. Uleman, & J. A. Bargh (Eds.), *The new unconscious* (pp. 77–106). New York: Oxford University Press.
- Dolan, R. J., & Vuilleumier, P. (2003). Amygdala automaticity in emotional processing. *Annals of the New York Academy of Sciences*, 985, 348–355.
- Eimer, M., Holmes, A., & McGlone, F. P. (2003). The role of spatial attention in the processing of facial expression: An ERP study of rapid brain responses to six basic emotions. *Cognitive, Affective, and Behavioral Neuroscience*, 3, 97–110.

- Eimer, M., & Kiss, M. (2007). Attentional capture by task-irrelevant fearful faces is revealed by the N2pc component. *Biological Psychology*, 74, 108-112.
- Engelmann, J. B., & Pessoa, L. (2007). Motivation sharpens exogenous spatial attention. *Emotion*, 7(3), 668-674.
- Engelmann, J. B., Damaraju, E., Padmala, S., & Pessoa, L. (2009). Combined effects of attention and motivation on visual task performance: transient and sustained motivational effects. *Frontiers in Human Neuroscience*, 3(4), 1-17.
- Etkin, A. Klemenhagen, K., Dudman, J., Rogan, R., Hen, E., Kandel, E. R., & Hirsch, J. (2004). Individual differences in trait anxiety predict the response of the basolateral amygdala to unconsciously processed fearful faces. *Neuron*, 44(6), 1043-1055.
- Eysenck, M. W. (1992). *Anxiety: The Cognitive Perspective*. Hove, UK: Lawrence Erlbaum Associates Ltd.
- Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition and Emotion*, 6(6), 409-434.
- Eysenck, M.W., Derakshan, N., Santos, R., & Calvo, M. (2007). Anxiety and cognitive performance: The Attentional Control Theory. *Emotion*, 7(2), 336-353.
- Eysenck, M.W., Payne, S., & Derakshan, N. (2005). Trait anxiety, visuo-spatial processing, and working memory. *Cognition and Emotion*, 19(8), 1214–1228.
- Forster, S. & Lavie, N. (2007). High perceptual load makes everybody equal: Eliminating individual differences in distractibility with load. *Psychological Science*, 18(5), 377-381.

- Forster, S. & Lavie, N. (2008). Failures to ignore entirely irrelevant distractors: The role of load. *Journal of Experimental Psychology: Applied*, 14, 73-83.
- Fox, E. (1993). Attentional bias in anxiety: Selective or not? *Behaviour Research and Therapy*, 31(5), 487-493.
- Fox, E. (1996). Selective processing of threatening words in anxiety: The role of awareness. *Cognition and Emotion*, 10(5), 449-480.
- Fox, E., Derakshan, N. & Shoker, L. (2008). Trait anxiety modulates the electrophysiological indices of rapid spatial orienting towards angry faces. *Neuroreport*, 19(3), 259-263.
- Fox, E., Russo, R., & Georgiou, G. A. (2005). Anxiety modulates the degree of attentive resources required to process emotional faces. *Cognitive, Affective, and Behavioral Neuroscience*, 5(4), 396-404.
- Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General*, 130(4), 681-700.
- Franken, I. H. A., Gootjes, L., & van Strien, J. W. (2009). Automatic processing of emotional words during an emotional Stroop task. *NeuroReport*, 20, 776-781.
- Gaillard, R., Del Cul, A., Naccache, L., Vinckier, F., Cohen, L., & Dehaene, S. (2006). Nonconscious semantic processing of emotional words modulates conscious access. *Proceedings of the National Academy of Sciences of the USA*, 103(19), 7524-7529.
- Gilboa-Schechtman, E., Revelle, W., & Gotlib, I. H. (2000). Stroop interference following mood induction: Emotionality, mood congruence, and concern relevance. *Cognitive Therapy and Research*, 24(5), 491-502.

- Harris, C. R., & Pashler, H. (2004). Attention and the processing of emotional words and names. *Psychological Science*, 15(3), 171-178.
- Holmes, A., Vuilleumier, P., & Eimer, M. (2003). The processing of emotional facial expression is gated by spatial attention: evidence from event-related brain potentials. *Cognitive Brain Research*, 16, 174–184.
- Hsu, S. M., & Pessoa, L. (2007). Dissociable effects of bottom-up and top-down factors on the processing of unattended fearful faces. *Neuropsychologia*, 45, 3075–3086.
- Huang, Y., Baddeley, A., & Young, A. W. (2008). Attentional capture by emotional stimuli is modulated by semantic processing. *Journal of Experimental Psychology: Human Perception and Performance*, 34(2), 328-339.
- Jackson, M. C., Wolf, C., Johnston, S. J., Raymond, J. E., & Linden, D. E. J. (2008). Neural correlates of enhanced visual short-term memory for angry faces: an fMRI study. *Public Library of Science One*, 3, 1–10.
- Kawahara, J., Di Lollo, V., & Enns, J. T. (2001). Attentional requirements in visual detection and identification: evidence from the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance*, 27, 969–984.
- Keil, A., & Ihssen, N. (2004). Identification facilitation for emotionally arousing verbs during the attentional blink. *Emotion*, 4(1), 23-35.
- Kensinger, E. A., & Corkin, S. (2003). Memory enhancement for emotional words: Are emotional words more vividly remembered than neutral words? *Memory and Cognition*, 31, 1169–1180.
- Kensinger, E. A., & Schacter, D. L. (2006). Processing emotional pictures and

- words: Effects of valence and arousal. *Cognitive, Affective, and Behavioral Neuroscience*, 6(2), 110-126.
- Kihara, K., & Osaka, N. (2008). Early mechanism of negativity bias: An attentional blink study. *Japanese Psychological Research*, 50(1), 1-11.
- Kiss, M., Driver, J., & Eimer, M. (2009). Reward priority of visual target singletons modulates ERP signatures of attentional selection. *Psychological Science*, 20, 245-251.
- Koster, E. H. W., Crombez, G., Verschueren, B., & De Houwer, J. (2004). Selective attention to threat in the dot probe paradigm: Differentiating vigilance and difficulty to disengage. *Behaviour Research and Therapy*, 42, 1183–1192.
- Koster, E. H. W., Crombez, G., Verschueren, B., & De Houwer, J. (2006). Attention to threat in anxiety-prone individuals: Mechanisms underlying attentional bias. *Cognitive Therapy and Research*, 30, 635-643.
- Koven, N. S., Heller, W., Banich, M. T., & Miller, G. A. (2003). Relationships of distinct affective dimensions to performance on an emotional Stroop task. *Cognitive Therapy and Research*, 27(6), 671-680.
- Laboue, C. L. (2004). Commentary: Is there a real preferential detection of negative stimuli? *Psychological Science*, 15(5), 364-365.
- Lang, P. J. (1980). Behavioral treatment and bio-behavioral assessment: Computer applications. In J. B. Sidowski, J. H. Johnson, & T. A. Williams (Eds.), *Technology in mental health care delivery systems* (pp. 119–137). Norwood, NJ: Ablex.
- Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, 21, 451-468.

- Lavie, N. (2005) Distracted and confused?: selective attention under load. *Trends in Cognitive Sciences*, 9, 75-82.
- Lavie, N. (2010). Attention, distraction and cognitive control under load. *Current Directions in Psychological Science*, (in press).
- Lavie, N., & Cox, S. (1997). On the efficiency of attentional selection: Efficient visual search results in inefficient rejection of distraction. *Psychological Science*, 8, 395–398.
- Lavie, N., & Fox, E. (2000). The role of perceptual load in negative priming. *Journal of Experimental Psychology: Human Perception and Performance*, 26, 1038–1052.
- Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General*, 133(3), 339-354.
- Lavie, N., Lin, Z., Zokaei, N., Thoma, V. (2009). The role of perceptual load in object recognition. *Journal of Experimental Psychology: Human Perception and Performance*, 21(1), 42-57.
- Lavie, N., Ro, T., & Russell, C. (2003). The role of perceptual load in processing distractor faces. *Psychological Science*, 14, 510-515.
- Lavy, E., & van den Hout, M. (1993). Selective attention evidenced by pictorial and linguistic Stroop tasks. *Behavior Therapy*, 24, 645-657.
- LeDoux, J. E. (1996). *The Emotional Brain*. New York: Simon & Schuster.
- LeDoux, J. E., (2000). Emotion circuits in the brain. *Annual Review of Neuroscience*, 23, 155-184.
- Macdonald, J.S.P., & Lavie, N. (2008). Load Induced Blindness. *Journal of*

*Experimental Psychology: Human Perception and Performance*, 34(5), 1078-1091.

MacLeod, C., & Mathews, A. (1988). Anxiety and the allocation of attention to threat. *The Quarterly Journal of Experimental Psychology Section A*, 40(4), 653-670.

MacLeod, C., & Rutherford, E. M. (1992). Anxiety and the selective processing of emotional information: Mediating roles of awareness, trait and state variables, and personal relevance of stimulus materials. *Behaviour Research Therapy*, 30(5), 479-491.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, 95(1), 15-20.

Manguno-Mire, G. M., Constans, J. I., & Geer, J. H. (2005). Anxiety-related differences in affective categorizations of lexical stimuli. *Behaviour Research & Therapy*, 43, 197-213.

Mathews, A., & MacLeod, C. (1985). Selective processing of threat cues in anxiety states. *Behaviour Research & Therapy*, 23(5), 563-569.

Mathews, A., May, J., Mogg, K., & Eysenck, M. (1990). Attentional bias in anxiety: selective search or defective filtering? *Journal of Abnormal Psychology*, 99(2), 166-73.

Mathews, A., Mogg, K., Kentish, J., & Eysenck, M. (1995). Effect of psychological treatment on cognitive bias in generalized anxiety disorder. *Behaviour Research and Therapy*, 33, 293-303.

Mathewson, K. J., Arnell, K. M., & Mansfield, C. A. (2008). Capturing and holding attention: The impact of emotional words in rapid serial visual presentation. *Memory and Cognition*, 36(1), 182-200.

- McKenna, F. P., & Sharma, D. (1995). Intrusive cognitions: An investigation of the emotional Stroop task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 21(6), 1595-1607.
- McGinnies, E. M. (1949). Emotionality and perceptual defense. *Psychological Review*, 56, 471-482.
- Milders, M., Sahraie, A., Logan, S. & Donnellon, N. (2006). Awareness of faces is modulated by their emotional meaning. *Emotion*, 6(1), 10-17.
- Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy*, 36, 809-848.
- Mogg, K., Bradley, B., Williams, R., & Mathews, A. (1993). Subliminal processing of emotional information in anxiety and depression. *Journal of Abnormal Psychology*, 102(2), 304-311.
- Mogg, K., McNamara, J., Powys, M., Rawlinson, H., Seiffer, A., & Bradley, B. P. (2000). Selective attention to threat: A test of two cognitive models of anxiety. *Cognition and Emotion*, 14(3), 375–399.
- Mogg, K., Millar, N. H., & Bradley, B. P. (2000). Biases in eye movements to threatening facial expressions in generalized anxiety disorder and depressive disorder. *Journal of Abnormal Psychology*, 109(4), 695-704.
- Morris, J. S., DeGelder, B., Weiskrantz, L., & Dolan, R. J. (2001). Differential extrageniculostriate and amygdala responses to presentation of emotional faces in a cortically blind field. *Brain*, 124, 1241-1252.
- Morris, J. S., Ohman, A., & Dolan, R. J. (1998). Conscious and unconscious emotional learning in the human amygdala. *Nature*, 393, 467-470.
- Most, S. B., Chun, M. M., Widders, D. M., & Zald, D. H. (2005). Attentional

rubbernecking: Cognitive control and personality in emotion-induced blindness. *Psychonomic Bulletin & Review*, 12(4), 654-661.

Murphy, S. T., & Zajonc, R. B. (1993). Affect, cognition, and awareness: Affective priming with optimal and suboptimal stimulus exposures. *Journal of Personality and Social Psychology*, 64(5), 723-739.

Naccache, L., Gaillard, R., Adam, C., Hasboun, D., Clémenceau, S., Baulac, M., Dehaene, S., & Cohen, L. (2005). A direct intracranial record of emotions evoked by subliminal words. *Proceedings of the National Academy of Sciences of the USA*, 102(21), 7713-7717.

Nolen-Hoeksema, S. (2004). *Abnormal Psychology*. New York: McGraw-Hill.

Ogawa, T., & Suzuki, N. (2004). On the saliency of negative stimuli: Evidence from attentional blink. *Japanese Psychological Research*, 46(1), 20-30.

Pelli, D. G. (1997) The VideoToolbox software for visual psychophysics: Transforming numbers into movies, *Spatial Vision* 10:437-442.

Perez-Edgar, K., & Fox, N. A. (2003). Individual differences in children's performance during an emotional Stroop task: A behavioral and electrophysiological study. *Brain and Cognition*, 52, 33-51.

Pessoa, L. (2005). To what extent are emotional stimuli processed without attention and awareness? *Current Opinion of Neurobiology*, 15, 188-196.

Pessoa, L., Japee, S., Sturman, D., & Ungerleider, L.G. (2006). Target visibility and visual awareness modulate amygdala responses to fearful faces. *Cerebral Cortex*, 16, 366-375.

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

- Pessoa, L., McKenna, M., Gutierrez, E., & Ungerleider, L.G (2002). Neural processing of emotional faces requires attention. *Proceedings of the National Academy of Sciences of the USA*, 99, 11458-11463.
- Pessoa, L., Padmala, S., & Morland, T. (2005). Fate of unattended fearful faces in the amygdala is determined by both attentional resources and cognitive modulation. *Neuroimage*, 28, 249-255.
- Phelps, E.A. (2006). Emotion and cognition: Insights from studies of the human amygdala. *Annual Review of Psychology*, 24, 27–53.
- Pleger, B., Blankenburg, F., Ruff, C. C., Driver, J., & Dolan, R. J. (2008). Reward facilitates tactile judgments and modulates hemodynamic responses in human primary somatosensory cortex. *The Journal of Neuroscience*, 28(33), 8161-8168.
- Pleyers, G., Corneille, O., Luminet, O., & Yzerbyt, V. (2007). Aware and (dis)liking: item-based analyses reveal that valence acquisition via evaluative conditioning emerges only when there is contingency awareness. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 33(1), 130-144.
- Pratto, F., & John, O. P. (1991). Automatic vigilance : the attention-grabbing power of negative social information. *Journal of personality and social psychology*, 61(3), 380-391.
- Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance*, 18, 849–860.
- Rees, G., Frith, C., & Lavie, N. (1997). Modulating irrelevant motion perception by

varying attentional load in an unrelated task. *Science*, 278(5343), 1616-1619.

Richards, A., French, C.C., Johnson, W., Naparstek, J. and Williams, J., 1992.

Effects of mood manipulation and anxiety on performance of an emotional Stroop task. *British Journal of Psychology*, 83(4), 479-491.

Salemink, E., Van den Hout, M. A., & Kindt, M. (2007). Selective attention and threat: Quick orienting versus slow disengagement and two versions of the dot probe task. *Behaviour Research and Therapy*, 45, 607-615.

Seitz, A. R., Kim, D., & Watanabe, T. (2009). Rewards evoke learning of unconsciously processed visual stimuli in adult humans. *Neuron*, 61, 700-707.

Shapiro, K. L., Raymond, J. E., & Arnell, K.M. (1997). The attentional Blink. *Trends in Cognitive Sciences*, 1, 291–296.

Silvert, L., Delplanque, S., Bouwalerh, H., Verpoort, C., & Sequeira, H. (2004). Autonomic responding to aversive words without conscious valence discrimination. *International Journal of Psychophysiology*, 53(2), 135-145.

Snodgrass, L. L., & Harring, K. E. (2005). Right hemisphere positivity bias in preconscious processing: Data from five experiments. *Current Psychology: Developmental, Learning, Personality, Social*, 23(4), 318-335.

Spielberger, C. D., Gorsuch, R.L., Lushene, R., Vagg, P.R., & Jacobs, G.A. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Sutton, T. M., Altarriba, J., Gianico, J. L., Basnight-Brown, D. M. (2007). The automatic access of emotion: Emotional Stroop effects in Spanish-English bilingual speakers. *Cognition and Emotion*, 21(5), 1077-1090.

- Thomas, S.J., Johnstone, S.J., & Gonsalvez, C.J. (2007). Event-related potentials during an emotional Stroop task. *International Journal of Psychophysiology*, 63(3), 221-231.
- Toglia, M. P., & Battig, W. F. (1978). *Handbook of semantic word norms*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.
- van Honk, J., Tuiten, A., de Haan, E., Van den Hout, M., & Stam, H. (2001). Attentional biases for angry faces: Relationships to trait anger and anxiety. *Cognition and Emotion*, 15(3), 279-297.
- Vuilleumier, P., Armony, J. L., Clarke, K., Husain, M., Driver, J., & Dolan, R. J. (2002). Neural responses to emotional faces with and without awareness: Event related fMRI in a parietal patient with visual extinction and spatial neglect. *Neuropsychologia*, 40, 2156-2166.
- Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2001). Effects of attention and emotion on face processing in the human brain: An event-related fMRI study. *Neuron*, 30, 829-841.
- Whalen, P. J., Rauch, S. L., Etcoff, N. L., McInerney, S. C., Lee, M. B., & Jenike, M. A. (1998). Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *Journal of Neuroscience*, 18(1), 411-418.
- White, M. (1996). Automatic affective appraisal of words. *Cognition and Emotion*, 10(2), 199-211.
- Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin*, 120(1), 3-24.
- Wolfe, J.M. (1999). *Inattentional amnesia*. In V. Coltheart (Ed.). Fleeting

memories: Cognition of brief visual stimuli (pp. 71 – 94). Cambridge, MA: MIT Press.

- Yi, D.-J., Woodman, G. F., Widders, D., Marois, R., & Chun, M. M. (2004). Neural fate of ignored stimuli: Dissociable effects of perceptual and working memory load. *Nature Neuroscience*, 7, 992–996.
- Yiend, J. (2010). The effects of emotion on attention: A review of attentional processing of emotional information. *Cognitive and Emotion*, 24(1), 3-47.
- Yiend, J., & Mathews, A. (2001). Anxiety and attention to threatening pictures. *Quarterly Journal of Experimental Psychology A*, 54(3), 665–681.
- Zald, D. H. (2003). The human amygdala and the emotional evaluation of sensory stimuli. *Brain Research Reviews*, 41, 88-123.
- Zeelenberg, R., Wagenmakers, E. J., & Rotteveel, M. (2006). The impact of emotion on perception: Bias or enhanced processing? *Psychological Science*, 17(4), 287-291.

## Appendix

<b>Negative</b>	<b>Positive</b>	<b>Neutral</b>	
ache	air	accord	note
agony	amuse	account	number
anger	beach	adding	oblique
army	beauty	after	orderly
ashamed	bed	age	ounce
bad	blossom	aim	oven
beg	calm	allow	packs
bitter	cheerful	also	page
bomb	comfort	angle	paper
bore	cottage	area	pedal
bored	country	author	peer
cage	dance	back	pen
cancer	dawn	banker	permit
casket	deer	bark	phase
cheat	dinner	basement	piece
coffin	dream	beak	platter
cowardly	eagle	bean	pliers
crime	fantasy	belt	point
cruel	father	blew	pole
dandruff	feel	blow	post
dead	flower	booth	pots
death	forest	bowl	pour
debt	free	box	powder
decay	freedom	brick	prop
deface	friend	building	pump
defeated	fruit	business	quart
degraded	garden	cable	ramp
despair	generous	capsule	reason
despise	gentle	card	rocket
destroy	glad	cellar	roll
die	grass	center	roof
dungeon	happy	chart	rope
fail	home	choral	rural
failing	honesty	clove	sack
flood	honey	coach	said
fraud	icecream	cockpit	science
frigid	kiss	collar	seen
grave	lake	combine	sequel
greedy	laugh	cord	shape
guilt	lemonade	course	sidewalk
gun	lips	crawl	since
hate	mermaid	cup	slang
hazard	merry	custom	slice
hell	mother	deal	slide

hostage	mountain	deck	some
hurt	music	dense	south
ignore	new	dial	spoke
insult	nice	docile	sponge
jail	ocean	drizzle	stair
kill	passion	duty	stand
liar	peace	ear	state
lice	peaceful	eight	steel
measles	peach	engine	stone
misery	pet	exposure	straight
morbid	playing	feet	street
morgue	praise	finite	string
mosquito	pretty	five	suit
murder	pup	foot	sweep
nag	quilt	form	table
nervous	rejoice	front	tail
never	rose	gate	tape
offend	sail	glasses	theory
perish	sailboat	graph	thick
perjury	sea	hairpin	thing
pimple	sex	helmet	thread
polio	shower	highway	three
poor	sing	ignition	threw
punish	ski	imitate	throw
rancid	sky	ink	ticket
rape	smile	jargon	tooth
rejected	soft	jump	trace
retard	softly	junction	tractor
sewer	song	kettle	trailer
shot	spring	lesson	tray
sick	spruce	level	trend
sickness	sun	lift	triangle
slavery	sunset	load	tube
slay	sweet	long	veil
soldier	swimming	loop	vertical
tragedy	tranquil	magnet	vest
trash	travel	math	vote
trouble	tree	meeting	waist
ugly	trust	method	wash
unjust	truth	mile	watts
vile	wisdom	molecule	work
vulgar	wise	napkin	years
weak	woman	nine	zipper
wreck	youth	nose	zone