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**Behavioural and Neurophysiological Correlates of Emotional Modulation of Exogenous Spatial Attention:
Evidence from Inhibition Of Return.**

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Abstract

The cue validity effect and Inhibition Of Return (IOR) are attentional phenomena first observed in a spatial cueing task. The cue validity effect represents faster responses to validly cued compared to invalidly cued targets and IOR is associated with faster responses to invalidly cued compared to validly cued targets. In cue-target paradigms IOR is usually observed at 300 ms. SOAs and at shorter SOAs the cue-validity effect is found. In this study an attempt is made to study emotional modulation of both attentional effects on a behavioural and neurophysiological level. Participants conducted an emotional modified spatial cueing task while EEG was recorded. Instructed threat conditioning was applied to modulate the level of threat of the cue. Cues consisted of neutral faces and one face was paired to an aversive sound while the other face was paired to a neutral tone. ERPs locked to cues and targets were measured and one of the main aims of this study was to examine cue-locked EEG activity originating from medio-frontal areas at a 200-400 ms. time window. Based on previous research an attempt was made to delay the onset of IOR in order to examine emotional modulation of the cue validity effect and measure cue-locked EEG activity 200-400 ms. post-cue. The experiment consisted of four different conditions. Target localization and target discrimination was randomized between subjects and short (200 ms.) and long (400 ms.) SOAs were randomized within subjects. An effect of task on the onset of IOR was observed, with an earlier onset of IOR in the localization compared to the discrimination task. However, IOR was present in three conditions: at both SOAs in the localization task and at the long SOA in the discrimination task. No IOR or cue validity effect was present at the short SOA in the discrimination task. Several task parameters may have contributed to the failed

attempt to sufficiently delay the onset of IOR. Emotional modulation of the cue-validity effect could thus not be assessed, so emotional modulation of the IOR effect was examined. A reduction in the amount of IOR was observed after presentation of the threat cue compared to the neutral cue. In the localization task IOR was reduced by faster reaction times to valid and slower reaction times to invalid targets following the threat cue. In the discrimination task IOR was reduced only by faster reaction times to valid targets. This difference may be induced by different attentional set adopted in localization and discrimination tasks or by differences in motor-related processes. The target-locked P1 showed an IOR effect with larger amplitudes to invalid compared to valid targets. No evidence was found for the involvement of early visual and attentional processes, represented by the P1 related to the cue and target, in relation to the reduction in IOR, suggesting that other processes may be involved. A significant stronger P2a amplitude, with a medio-frontal scalp distribution, in response to the threat cue compared to the neutral cue was observed. It is suggested that this may represent an attention selection mechanism located in the MFC sensitive not only to task-relevant items, but also to affective and motivational relevant stimuli.

Keywords: Attention, Emotion, Spatial Cueing, Inhibition Of Return (IOR), Threat, EEG.

Introduction

It is believed that a primary task of visual-spatial attention is to rapidly detect and process new objects appearing in the environment (Yantis, 1996). From an evolutionary perspective, rapid detection and processing of motivationally relevant stimuli in the environment, especially potential threats, is a highly adaptive mechanism. This mechanism could have been shaped during evolution to stimulate appropriate actions and behaviours which increase the likelihood of survival (Ohman & Mineka, 2001). These action tendencies may be intimately linked to emotional processes (Lang, 1979; Frijda, 1986) and enhanced allocation of cognitive resources towards motivationally relevant stimuli, like potential threats, is an essential adaptive aspect of emotional processing (Frijda, 1986; Eysenk, 1992). With this evolutionary framework in mind it is likely that some objects, such as threatening ones, are analyzed by our attentional system more readily and thoroughly than neutral events.

Support for this idea comes from clinical and experimental work. Neuropsychological studies in patients suffering from impaired spatial attention and hemi-neglect, due to parietal-lobe lesions, are better in detecting emotional pictures compared to neutral ones in the neglected (contralesional) visual field (Vuilleumier and Schwartz, 2001; Vuilleumier et al., 2002; Fox, 2002). Although detection was still impaired in these patients, facilitated spatial attention towards emotional compared to neutral events was observed.

Such an attentional bias for emotional stimuli was also observed in experimental research in normal healthy subjects. Several lines of research have investigated the effect of threat-related stimuli on behavioural responses and attentional processes. Pratto and John (1991) using the Stroop task found significant longer reaction times for colour naming of threat-related words compared to neutral words, suggesting that threat-related information automatically captured attention and lead to more interference in colour naming. Also, facilitated detection and response times of threat-related stimuli compared to neutral stimuli have been observed in cognitive tasks such as the visual search task (Fox et al., 2000) and the dot-probe task in high anxious subjects (Macleod et al., 1986; for review see Mogg & Bradley, 1998).

In the dot-probe task developed by Macleod, Mathews and Tata (1986) two words, one neutral and one related to threat, were simultaneously presented at two separate spatial locations. After a short interval a small dot probe was presented at either the same (valid) spatial location as the previous presented threat-related word or at the location previously occupied by the neutral word (invalid). Participants were asked to response as quickly as possible to the dot probe. These response latencies provide a “snap-shot” of a participant’s

attentional allocation towards emotional stimuli by analyzing the difference in reaction times and/or accuracy to the dot-probes appearing at the invalid and the valid location (Bradley et al., 2000). In the original study by Macleod and colleagues (1986) participants either high or low in anxiety were compared. The authors reasoned that if the threat-related cues would capture attention more strongly in the high-anxious subjects compared to the low anxious subject, than faster reaction times would be present on valid compared to invalid targets in the threat condition for high anxious individuals and this is indeed what was found. These results were replicated in another study using faces as cues (Bradley et al., 1998) and led to the assumption that people with higher levels of anxiety show a bias in the initial orientation of attentional resources towards threat-related stimuli, showing heightened vigilance and facilitated detection of threat, which had been already hypothesized by Eysenck (1992).

This interpretation of a facilitated attentional capture effect by the threat-related object has been challenged by more recent research in which a different paradigm was used. Although the dot-probe task can provide insight into attentional biases, it is difficult to determine what mechanism is at work here. Faster reaction times for valid compared to invalid targets following threatening stimuli could arise due to enhanced attentional capture effects by the emotional cue. In this case attention is biased towards the location of threat and results in faster responses to a target that appears at the same location. However, faster reaction times to the targets could also be explained by a different mechanism, namely difficulty in disengaging attention from the location previously occupied by a threat. Such difficulty could lead to a slower response to targets on invalid trials. Thus faster reaction times on valid trials compared to invalid trials could thus be caused by slower reaction times to targets on invalid trials instead of facilitated response times to targets on valid trials. Whether the differences in response times to targets between valid and invalid trials is due to facilitated attentional capture, difficulty in disengaging attention or perhaps both is an important question and the Dot-Probe task may not be suitable for providing an answer.

However, a different paradigm can be used to investigate what mechanism underlies this attentional bias. This paradigm is called the emotional modified spatial cueing task and is derived from Posner's exogenous covert orienting task (Posner, 1980). In this task a target is preceded by a cue that either correctly predicts the location of the upcoming target (valid) or incorrectly predicts the location (invalid). Results show faster reaction times for validly compared to invalidly cued targets, which is called the '*cue validity effect*'. This task is capable of distinguishing between three different stages of attention processes, namely shifting, engagement and disengagement (Posner & Peterson, 1990). Emotional modifications

of this task have been frequently used to investigate which aspect of attention is influenced by emotional content of the stimuli. By using different cues, for instance both threat related cues and cues with a neutral valence, it is possible to examine whether the cue validity effect is influenced by the emotional content of the cue. If target detection is enhanced on valid trials in which the cue was threat-related compared to neutral, than this would suggest facilitated attentional engagement by threat. If reaction times are slower on invalid trials when a threat-related cue was presented compared to a neutral cue, than this would point to difficulties in attentional disengagement from the location previously occupied by a threat.

In a series of experiments by Fox and colleagues (2001) words, schematic faces and pictures of real faces were used as cues and a consistent disengagement effect was found for threatening compared to neutral cues, especially but not exclusively in people with high levels of self-reported anxiety. However, no support for facilitated engagement was found. These findings have been replicated in a series of studies (Fox, Russo & Dutton, 2002; Yield & Matthews, 2001).

Reasoning from an evolutionary perspective, the lack of support for the attentional capture effect in the laboratory may be somewhat surprising. Models of attention to threat state that the allocation of attentional resources to the location of threat is a phylogenetically old mechanism present in all of us, because of its survival value (Mathew & Mackintosh, 1998; Mogg & Bradley, 1998). It was argued that perhaps the stimuli used thus far, words and pictorial stimuli, are not strong enough indicators for the occurrence of an aversive event (Stormark, Hugdahl, & Posner, 1999) and may not exceed the threshold for finding attentional capture effects. In a study conducted by Koster and colleagues (2006), facilitated attentional engagement was found in both high and low anxious subject when pictures of the International Affective Picture System (IAPS, Lang, Bradley & Curthbert, 1995) were used that were rated by participants as highly threatening. This supports the idea that the amount of threat can have an impact on attentional capture effects and may explain why previous studies, using perhaps less threatening stimuli, had difficulties in finding an attentional capture effect. Facilitated engagement was also found when an aversive-conditioning procedure was used in which a cue was coupled to direct aversive stimulation (burst of white noise) (Koster et al., 2004).

Taken together these result suggest that people posses an attentional system that is modulated by the emotional valance of stimuli. Evidence is found for enhanced detection and processing of threat-related stimuli compared to neutral stimuli if the threat is sufficiently

strong. Also, threat delays attentional disengagement from that location, making it more difficult to respond to targets appearing elsewhere.

Although these processes seem to be of adaptive value, they can go awry. It is believed that biased attentional processing of threatening information plays a role in the causation and maintenance of anxiety disorders (Beck, Emery & Greenberg, 1985; Eysenk, 1992, Mathews & Mackintosh, 1998; Mathews & MacLeod, 1994; Mogg & Bradley, 1998; Wells & Matthews, 1994; Williams, Watts, MacLeod & Mathews, 1988). Indeed, numerous studies have found enhanced attention to threat in high trait anxious (HTA) compared to low trait anxious (LTA) groups (for reviews see Mogg & Bradley, 1998; Williams, Watts, MacLeod & Mathews, 1997). In a study conducted by Koster and colleagues (2006) pictures that were rated as highly or moderately threatening were used in a modified exogenous cueing task. Results showed that all individuals, both low and high in anxiety, orient strongly to highly threatening pictures (IAPS), but the HTA group oriented more strongly to the moderately threatening pictures compared to the LTA group. This attentional bias was due to difficulties in disengagement from threat. In another study conducted by Massar and colleagues (in press) an instructive threat procedure was used. In this paradigm one cue was associated with an aversive stimulus (an aversive noise) and participants were explicitly instructed before the experiment started which cue would be associated with the aversive sound. Results showed that trait anxiety was correlated with an increase in engagement and present in individuals with high compared to low levels of anxiety. However, in contrast to the study by Koster and colleagues (2006) using pictorial stimuli, but in line with results from Koster and colleagues (2004) using the same auditory stimulus, impaired attentional disengagement was found in all individuals regardless of anxiety level, providing further support that attentional bias to threat is not confined exclusively to anxious people when the level of threat is sufficiently strong, but is also present in people lower in anxiety.

Although behavioural data give important insights into emotional and cognitive processes that shape behaviour, it does not provide information about the neural mechanisms at work. Techniques such as neuro-imaging and the electro-encephalogram make it possible to get more insight into these neural systems.

In a fMRI study conducted by Armony and Dolan (2001) the experimenters investigated how emotion, specifically fear, influences attentional processes. The dot-probe task was used and fear-conditioning was applied in which one face (CS+) was paired to an aversive event, a burst of white noise, while the other face was not paired (CS-). Results indicated slower reaction times to invalid targets following the CS+ compared to valid targets.

Whether this is due to enhanced attentional capture or difficulties in disengaging attention away from threat, it suggests a preference of the attentional system for the location occupied by the threatening cue. Results also showed that the modulation of spatial attention by the conditioned stimulus was associated with enhanced activity in the fronto-parietal neural network, a system associated with the control of spatial attention (Hopfinger et al., 2000). Enhanced activity in the amygdala and the extrastriate visual cortex following the CS+ was also observed, which will be discussed later.

To further investigate the modulatory effect of threat on attentional processes, several studies have used the Electro-encephalogram (EEG) to record electrical brain activity. This technique allows to find changes in activity on a millisecond basis and could provide more insight into the temporal dynamics of attention modulation by threat. Several studies have been conducted using an emotional-modified dot-probe task and different pairs of stimuli were compared to assess attentional bias, such as fearful and happy face pairs (Pourtois et al., 2004) and angry and neutral face pairs (Santesso et al., 2008). Faster responses and enhanced P1 amplitudes to the targets were seen on trials with valid threatening compared to invalid threatening cues. The P1 is a positive peak on the EEG 100 ms. after stimulus onset and is thought to reflect early visual processing of a stimulus (Hillyard & Anllo-Vento, 1998) and is localized in extrastriate cortical structures (Heinze et al., 1994; Martinez et al., 1999). An increased P1 amplitude is associated with enhanced visual processing of attended locations (Hillyard & Anllo-Vento, 1998). These results suggest that facilitated processing of a neutral stimulus is induced by the preceding presentation of a threat-related stimulus at the same spatial location. In a follow-up study, Pourtois and colleagues (2006), made an attempt to localise the source of this attentional modulation by threat. They analyzed the EEG-activity preceding the P1 and found differences in a period 40-80 ms. pre-target onset between valid and invalid trials in the threat condition which was localized in the parietal cortex. These two neural events also showed a significant correlation which suggest coupling between the early posterior parietal activity and the later target-locked P1 wave. The authors hypothesized that if the early parietal activity is associated with top-down modulation of ongoing processing in the visual cortex, than this is enhanced for targets appearing at valid locations and disrupted for stimuli at invalid locations following a threat-related stimulus. No such effects were found when happy faces were used as cue.

A more recent study (Fox et al., 2007) also found support for the idea that threat induces rapid orienting of spatial attention to its location. Enhanced P1 amplitudes to targets after presentation of an angry face on valid compared to invalid trials were observed at short

SOAs (350 ms.), but not at longer SOAs (750 ms.). The authors suggested that the presence of threat induces a relative brief period of enhanced sensory processing of stimuli presented at the same location. Although the experimenters looked for modulatory effects of trait anxiety on the P1, no significant modulations were found. There is however reason to believe that such differences may exist, because several behavioural studies have consistently found enhanced attentional biases for threatening stimuli in high anxious compared to low anxious subjects using the spatial-cueing task (Fox et al., 2001; Yiend and Mathews, 2001; Broomfield and Turpin, 2005). Li and colleagues (2005) specifically investigated differences in behavioural and neurophysiological measurements between high and low anxious people. They used a spatial-cueing task in which the cues were pictures of scenes with either a high threat-related or a neutral content. They found faster reaction times on valid threat compared to valid neutral trials and enhanced P1 amplitudes on valid threatening compared to valid non-threatening trials in high anxious subjects. This consistency in behavioural and electrophysiological data in the high-anxious group could indicate that speeded behavioural responses may be partly caused by enhanced visual processing (Luck et al., 2000). However, this consistency between ERP components and behavioural data was not found in subjects low in anxiety. Low anxious subjects did show differences in reaction times in threat compared to non-threat conditions, but no significant differences in the P1 amplitude were found. Surprisingly, low anxious subjects showed a decreased P1 amplitude to threatening compared to non-threatening cues.

Although ERPs locked to the targets provide insight into sensory processing of stimuli presented after an attention-capturing event and could be related to behavioural performance, it is based on the assumption that the stimulus preceding the target has attracted attention in the first place. If, for what reason, the cue fails to capture attention it may have consequences for processing of the following target and the behavioural response. ERPs locked to the cue could give more insight into how these processes might interact.

One study examined cue-locked ERPs in an exogenous attention paradigm (Chica et al., 2010). In this experiment a dot-probe paradigm was used to explore the relationship between conscious perception and exogenous attention. Target contrast was manipulated in such a way that target detection was difficult and some targets could not be detected consciously. ERPs locked to the cues were measured and compared for valid and invalid trials. Results showed an enhanced cue-locked P1 for consciously seen targets on valid trials and unseen targets on invalid trials. This suggests that if the cue is able to attract exogenous attention, represented by an enhanced P1, people are better at consciously detecting targets at

the same location and impaired in detecting targets presented at a different location. However, if the cue failed to attract attention, represented by a weaker P1, then detection of targets at the same location was impaired and detection of targets at a different location was improved. This modulatory effect of the P1 has been found in previous research on endogenous attention in which endogenously attending to the location of a peripheral cue is associated with a stronger cue-locked P1 (Hopfinger and West, 2006). Although these studies showed that it is possible to find a relationship between differences in cue processing and its relation to target detection using visual ERPs and behavioural data, it is still unclear how this could be modulated by emotional processes.

A study conducted by Bar-Haim and colleagues (2005) was aimed to investigate potential differences in the time-course and strength in processing of emotional cues between high and low anxious subjects and potential effects on behavioural responses. Cue-locked ERPs and reaction times were measured during a variant of Fox and colleagues (2001) attention shifting paradigm. A cue, either a fearful, angry, sad, happy or neutral face, appeared at the centre of fixation and was followed by the presentation of a target below or above the cue. Participants needed to discriminate between two targets as quickly and accurately as possible. Results indicated shortened latencies for the P1 and N1 components locked to the cues in high compared to low anxious subjects across all conditions and a significant stronger amplitude for the cue-locked P2 component was found in high compared to low anxious subjects for angry faces. These findings may indicate that threat-related stimuli mobilize more attentional resources in high compared to low anxious subjects. Also, high anxious participants showed a general slowing of reaction times for the targets in all conditions. The authors argued that perhaps this general slowing in responses is due to increased processing of the cues which interferes with target discrimination. Because the cue and the target appear at relatively short time intervals between each other, they may use the same resources available for processing (Isreal et al., 1980; Wickens et al., 1983). If more resources are directed to the cue, than less is available for target processing which may result in slower responses, which has been shown by other researchers (Muller et al., 1998).

In a more recent study (Eldar et al., 2010) using the dot-probe paradigm a stronger cue-locked P2 was found in high compared to low anxious subjects, but not exclusively to the threatening condition, but also in the happy and neutral condition. The authors did not attempt to explain this discrepancy and suggested that more research is required to shed light on this issue. They did, however, find a modulatory effect of anxiety on the C1 component locked to the cue in the threatening condition. This ERP component is the earliest recordable ERP (60-

90 ms post stimulus) that arises in the primary visual cortex near the calcarine sulcus (Di Russo et al., 2002; Pourtois et al., 2004). The C1 represents the initial response of the visual cortex to a stimulus (Di Russo et al., 2003) and the C1 amplitude was enhanced for the threatening cue in high compared to low anxious subjects (Eldar et al., 2010). This is consistent with previous findings by Pourtois (2004) who also used a dot-probe paradigm, but did not compare high and low anxious subjects. In this study an enhanced C1 to fearful face-cues compared to neutral face-cues was observed, suggesting increased visual processing of a threat-related event. Interestingly, a positive correlation was found between the strength of the cue-locked C1 and the magnitude of the validity effect of the target-locked P1 in the left hemisphere. However, no such relation was found in the right hemisphere. The authors suggested that this supports the idea that direct feedback from the amygdala on the visual cortex could induce a sustained boosting of sensory processing and attention to visual stimuli. Further support comes from a study previously discussed using fMRI and the dot-probe task during which aversive-conditioning was applied (Armony & Dolan, 2002). Results indicated increased activity in the amygdala and extrastriate visual cortex in response to the conditioned stimulus. This is consistent with previous findings that show that increased visual processing of fear-inducing stimuli in the extrastriate visual cortex can be enhanced by the amygdala (Morris et al., 1998; Anderson & Phelps, 2000) and provides further support for the theory that the amygdala processes the emotional information and sends signals to other response systems that should be sensitive to this kind of information. This could result in increased vigilance of systems, such as the extrastriate visual cortex, after exposure to a visual emotional stimulus. However, some inconsistencies remain. For instance, Santesso and colleagues (2008) did not find modulatory effects of the cue-locked C1 component for emotional valence nor did the strength of the C1 to the cue correlate with the magnitude of the validity effects of the target-locked P1. Both effects were observed in the study by Pourtois and colleagues (2004). Santesso (2008) suggested that perhaps the differences in cues could be responsible for this discrepancy, since Pourtois used fearful and Santesso used angry faces. However, Eldar and colleagues (2010) used angry faces and did observe an increased C1 to these cues in high anxious subjects.

In the preceding studies the main focus was aimed at attentional modulation of visual processing in the visual cortex by emotional processes. However, besides purely visual processes another region of interest and relevance to this study is the Medial Frontal Cortex (MFC), including the Anterior Cingulate Cortex (ACC). Evidence suggests that the ACC plays a critical role in error detection (Miltner et al., 1997), response conflict monitoring

(Carter et al., 1998), response-selection or selection for action (Holroyd and Coles, 2002) and evaluations of reward signals and motivational significance (Gehring and Willoughby, 2002).

Gehring and Willoughby (2002) found that when participants' choices resulted in losses, even when the participant's response was the best available option, a stronger negative deflection on the EEG originating from the MFC, the Medial Frontal Negativity (MFN), was observed. Yeung and colleagues (2005) showed that the MFN was also present in a passive task in which the participant took no overt actions but merely observed the outcome of a computer-generated choice that resulted in monetary loss. Based on these findings the authors proposed that the medial frontal cortex contains a general motivational evaluation system not tied explicitly to the motor system. The evaluative role of the medial frontal cortex in reward expectation violations was examined in a study by Potts and colleagues (2006). In a passive task requiring no response from the participants the effects of reward expectation violations were assessed on two ERP components localized to the MFC. A positive deflection, the P2a, was observed after the presentation of an unexpected reward and a negative deflection, the MFN, was observed after the presentation of an unexpected non-reward. A model was proposed in which this difference in polarity is caused by different firing rates of neurons involved in reward processing in the ventral tegmental area (VTA) from which projections are sent to medial frontal areas. These dopaminergic neurons change their firing rate according to violations of reward expectations, increasing their firing rate to unexpected rewards and decreasing their firing rate to unexpected non-rewards (Shultz, Dayan, & Montague, 1997).

Positive deflections occurring approximately 200-300 ms. post-stimulus originating from the medial frontal cortex have also been associated with an attention selection mechanism of task relevant stimulus features, showing a larger amplitude to task-relevant stimuli compared to task-irrelevant stimuli (Kenemans et al., 1993; Potts et al., 1996; Potts et al., 2004a; Potts, 2004b). This sensitivity to the relevance of the item to the current task is observed in tasks requiring a motor response (Potts, 2004b) or no motor response but silent counting (Potts et al., 1996; Potts, 2004b).

Based on these studies the MFC is thought to play an evaluative role in motivational significant events, such as the experience of losses or reward expectation violations, and is involved in an attention selection of task-relevant stimuli. The MFC can also be associated with anticipation of motivational relevant events. In a study conducted by Baas and colleagues (2001) grating patterns were presented of either high or low spatial frequency and were sometimes followed by the administration of an electric shock. One of the gratings would sometimes be followed by the electric shock and served as a threat cue while the other

grating would never be followed by the aversive stimulus and served as a safe cue. Participants were explicitly instructed which cue would be paired to the shock. Results showed a frontal negative slow wave, probably originating from medial frontal areas, which developed 500 ms. after the offset of the threat stimulus and may reflect anticipation of the possible occurrence of the aversive electric shock. In another study by Pizzagalli and colleagues (2003) subjects passively observed fearful face pairs and aversive-conditioning was used to modulate the level of threat. One face pair (CS+) would be followed by the UCS (loud noise) on 50% of the trials while another face pair would serve as a control condition (CS-). Subjects had no control over the occurrence of the aversive-event and over time the cue gained predictive value whether or not an aversive event was likely to occur, making it motivational significant. Results showed a stronger negativity over anterior ventral frontal regions that significantly increased over time from 240-464 ms. after the onset of the CS+. The authors suggested that this negative wave over frontal regions represents anticipatory processes related to the occurrence of arousing stimuli, in this case the UCS. These findings are in line with earlier results that showed an increase in negativity at 100-400 ms. post-CS+ during the conditioning phase in which the CS+ was presented outside awareness (Wong et al., 1997).

Based on these results that indicate the involvement of the medial frontal cortex in evaluation, anticipation and attention selection of motivationally relevant events, it could be hypothesized to find a modulatory effect of the MFC in an emotional-modified spatial cueing task using instructed aversive conditioning. In such a paradigm the cue gains predictive value whether a negative event is likely to occur, thereby making it motivational relevant. This may influence attentional processes allocated to the cue and have an impact on evaluative and anticipatory processes. Although the presentation of the cue and the presentation of the aversive event is not related to action choices made by the participants, a motor response does not seem to be a prerequisite for processing in the MFC to occur (e.g. Yeung et al., 2005).

The aim of this study is twofold. The first goal is to investigate threat induced modulations of attentional processes and its effect on behaviour and neurophysiological processes. Participants conducted an emotional modified spatial cueing paradigm, based on the study by Massar (in press), while EEG activity was recorded and reaction time and accuracy was measured. An instructed aversive conditioning procedure was applied to modulate the level of threat. Neutral faces were paired to either an aversive auditory stimulus or a neutral tone. To our knowledge no such experiment has been conducted thus far, combining a emotional modified spatial cueing paradigm, instructed aversive conditioning

and EEG measurements. On a behavioural level a cue-validity effect and an emotion and validity interaction is expected, specifically slower reaction times to invalid targets following the threat cue compared to the neutral cue, as has been previously found by Massar (in press) using the same kind of paradigm. This would indicate difficulties in attentional disengagement from threat. The primary goal of this study is to investigate potential differences in cue- and target-locked ERPs between the threat and neutral condition. In this study the main focus is aimed at the cue and target-locked P1 and MFC activity following the cue. We hypothesize to find threat modulation of the P1 to both cue and target and on MFC activity in response to the cue. Also, potential emotional modulatory effects on the C1 and the P2 will be explored. Because of the exploratory nature concerning the C1 and P2 in this task, only significant effects and interactions between ERP components and behavioural measurements will be mentioned if found in this study. Significant modulatory effects of behavioural and neurophysiological processes will be correlated to self-reported anxiety measured by the BIS-BAS and STAI questionnaire .

The second goal of this study is methodological in nature. As has been shown in previous studies in a variety of tasks, the MFC activity of interest occurs in a time window 200-400 ms. post stimulus. As a consequence of examining MFC activity in response to the cue at these latencies, it is necessary to use a relatively long time-interval between the onset of the cue and the onset of the target in order to prevent contamination of EEG-measurements of cue-related processes due to the presentation of the target. However, an increase in this time-interval increases the likelihood of the appearance of the Inhibition Of Return (IOR) effect, first observed by Posner and Cohen (1984) during a spatial cueing task. IOR results in the opposite behavioural patterns that are characteristic of the *Cue Validity Effect*. It is associated with slower reaction times to validly cued targets and faster reaction times to invalidly cued targets. IOR was observed for SOAs longer than 300 ms., but at shorter SOAs the cue validity effect was present. Klein (1988) reasoned about the functional significance of this mechanism and hypothesized that orienting away from a previously attended location and inhibition of reorienting to the same spot can aid visual search. It prevents orienting repeatedly to an already inspected location. Although the IOR effect was observed at SOAs longer than 300 ms. using a detection task, IOR began at SOA of 700-1000 ms. when a discrimination task was used (Lupianez, Milan, Tornay, Madrid, & Tudela, 1997). These effects were replicated and extended in a study conducted by Lupianez and colleagues (2001) using colour and letter discrimination tasks. IOR was found at longer SOAs (700-1000 ms.), but not at shorter SOAs (400 ms.), while IOR was already present at this shorter SOA in

detection tasks. These results are explained by the theory that when performing a discrimination task, an attentional set may be adopted that favours the integration of information within a single representation rather than the detection of new information from different areas in the visual field. The maintenance of the attentional focus on the cued location favours integration and therefore delays the IOR effect in discrimination tasks (Lupianez et al., 2001).

In our study a localization and a discrimination variant of the spatial cueing task will be used between subjects to assess its effect on the occurrence of IOR. Trials with short (200 ms.) and long SOAs (400 ms.) will be presented within subjects to measure whether IOR is present at these task parameters. Based on previous research (e.g. Lupianez, 1997) we hypothesize that IOR is more likely to occur at longer SOAs in the localization compared to the discrimination task and we do not expect to find IOR at the shorter SOAs during both the localization and the discrimination variant of the spatial cueing task. However, this experiment differs in an important aspect from the experiments of Lupianez. In the latter experiments a detection task was used in which participants had to press one button if a target was detected irrespectively of the target's location. In this study a localization task will be used instead in which participants respond by pressing one of two buttons to indicate the location of the target, either left or right. The decision to use a localization task was based on the study by Massar and colleagues (in press) in which a reliable cue-validity and threat modulation of this validity effect was found. It is this effect we attempt to replicate so the task parameters were kept as similar as possible. Besides, it has been shown that IOR is present at the same SOA in detection and localization tasks (Klein & Taylor, 1994), this in contrast to the different onset of IOR in discrimination tasks. Based on a theory proposed by Lupianez (1999) to explain differences in the onset of IOR between detection and discrimination task, it is hypothesized that this can also be generalized to a localization task. Detection and localization tasks both emphasize the detection of the target and not integration of information, resulting in similar attentional sets. Finally, the difference in the onset of IOR between a detection and a discrimination task seems to be due to differences in perceptual demands instead of differences in response selection (Lupianez et al., 1999). Since there is no difference in perceptual demand in a localization compared to a detection task, but only a difference in response selection, it is unlikely that cueing effects will be affected differently by a detection compared to a localization task.

Because there are some differences in the tasks being used in this study compared to the experiment conducted by Lupianez (1997; 1999), we can not rule out the occurrence of

IOR. However, if IOR is present it may also be modulated by threat. Fox et al. (2002) was the first to report modulations in the magnitude of IOR in response to angry schematic faces in an emotional-modified spatial cueing task. It was argued that delayed disengagement to the threat-cue resulted in less IOR. If attention has not yet disengaged, inhibition of the return of attention to the previously cued location can not yet take place. However, attempts to replicate these findings have not yet been successful (Stoyanova, Pratt & Anderson, 2007; Lange et al., 2008). These authors suggest that IOR is a blind mechanism and can not be influenced by the valance of objects. If IOR is present in this study, most likely in the long SOA condition in the localization task, possible modulations of the magnitude of IOR by threat will be examined and can be correlated with STAI and BIS/BAS scores.

Methods

Participants

All participants had normal or corrected-to-normal vision and participation was on a voluntary basis. Subjects could earn either 13,- Euro's or credits by participating. All subjects were naïve as to the purpose of the experiment.

Apparatus

In this study the visual stimuli were presented using E-prime 1.1 (SP3) software (Psychological Software Tools) on a CRT monitor using a refresh rate of 75 Hz. The experiment was conducted in a dark room while participants were seated in a comfortable chair. A chin support was used and participants watched the monitor from a distance of 60 cm. The sounds were presented to the participants via foam tipped earplugs. Responses could be given by pressing the <v> and the <m> button on a QWERTY keyboard.

Stimuli and Task

The task is based on a paradigm previously used in a study conducted by Massar (in press) in which a spatial cueing task and an instructed threat procedure was combined. A recording of a human scream, (duration 300 ms.; 100 dB) was used as the aversive US, adopted from work by Lissek et al. (2005). The neutral US was a 1000 Hz sine wave (300 ms.; 70 dB). The cues consisted of pictures of two male faces with a neutral facial expression. To increase the discriminability between the two cues, one face was coloured blue and the other yellow and which cue served as the CS+ was randomized between subjects. A white fixation cross (1 x 1° visual angle) was presented during the task at the centre of the screen. Two white boxes (height 6.5°, width 4.8°) were presented laterally on left and right side of the fixation cross. Distance between the fixation cross and the centre of the box was 9.2°. See figure 1 for an illustration of the sequence of events and temporal parameters during a single trial. After a trial began a cue was presented in one of the boxes. Two different cue presentation times were used within subjects, either 200 (randomized between 174, 187, 200, 213 and 226) or 400 ms (randomized between 374, 387, 400, 413, 426). After the presentation of the cue a cue-target interval of 13 ms. preceded the presentation of the target, which was presented for 106 ms. The trial ended after a response was given, which was followed by an inter-trial interval of either 800, 1000 or 1200 ms.

The targets were presented at the centre of the box. Gratings with spatial frequency of 5 cycles per degree of visual angle and a diameter of 2.4 cm served as targets. On 50% of the trials the grating were tilted 5 degrees to the left and on the other 50% of the trials the targets were tilted to the right. Two different conditions were used between subjects, either a localization or a discrimination paradigm. In the localization task subjects were instructed to press the <v> button in response to a grating appearing in the left box and the <m> button if the grating was presented in the right box. In the discrimination task subjects were instructed to press the <v> button in response to gratings oriented to the left and the <m> button for gratings oriented to the right. In both experiments subjects were encouraged to respond as quickly and as accurately as possible. On 50% of the trials the target appeared at the same location of the previously presented cue (valid trials). In the remaining half of the trials the target was presented in the opposite box (invalid trials). A semi-randomized procedure was used in which blocks of 4 trials were created. Each block consisted of 2 valid and 2 invalid trials and 2 CS+ and 2 CS- cues. Blocks were presented randomly as were the trials within blocks. This was done to prevent coincidental sequential presentation of several similar trials. Although participants received explicit instructions to keep their eyes fixated on the central fixation cross during the entire length of the experiment, digit trials were included to further stimulate subjects to keep their eyes fixed on the fixation cross. During a digit trial a number, from 0 to 9, was presented instead of the target. This number, presented for 100ms., replaced the fixation cross and subjects were instructed to name the number aloud as quickly as possible. 6,25% of the trials consisted of digit trials.

Three conditions were included in the experiment. First participants performed a short practise session of 34 trials (32 trials and 2 digit trials) to get acquainted with the task. Then participants performed the baseline phase consisting of 680 trials (640 trials and 40 digit trials) which was followed by the acquisition phase also consisting of 680 trials (640 trials and 40 digit trials) making up a total of 1360 trials in this experiment (practise session not included). Both the baseline and the acquisition phase were divided into 5 blocks of 136 trials (128 trials and 8 digit trials). Short breaks were included between the 5 blocks. Subjects were encouraged to take a short break of approximately 1 minute between blocks, but the duration of the break was up to the subject's own choosing.

During the baseline phase no auditory stimuli were presented. Auditory stimuli were presented during the acquisition phase only. The aversive and neutral stimuli were presented 200 ms. after a response was given on 25% of the trials (12.5% for both stimuli). Before the start of the acquisition session, subjects received explicit instructions about which face would

be associated with the aversive stimulus to make participants aware that if the aversive sound was presented it would only be following a specific cue, while the other cue would be associated with the neutral sound. Pairing of the cue and the aversive stimulus was alternated between subjects.

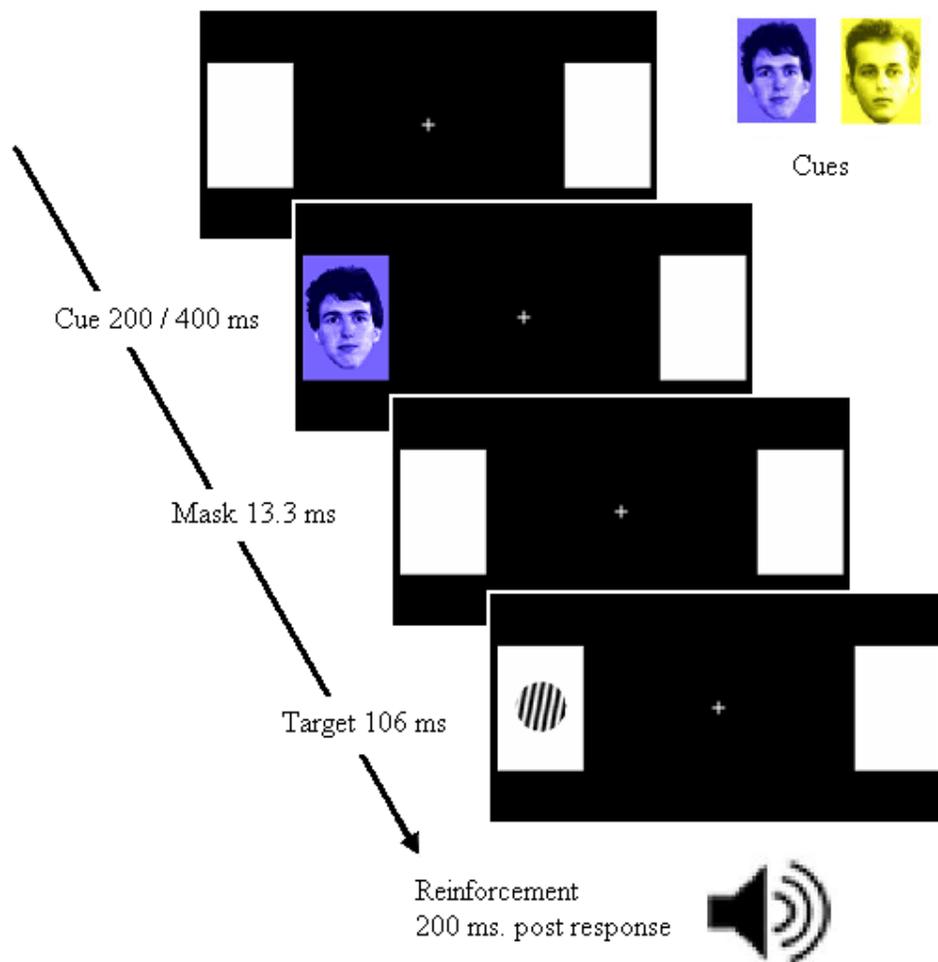


Figure 1: Trial Schedule in the Emotional Spatial Cueing Task. In the baseline phase no reinforcement were presented. The reinforcement was delivered on 25% of the trials in the acquisition phase.

HEOG recording

After completion of the experimental task, participants performed a short eye-movement check. The same facial stimuli that served as cues during the spatial cueing task were used and were randomly presented on the left or the right side for 1000 ms. with a 2000 ms. interval between presentation of subsequent stimuli in which no stimulus was presented.

Participants were instructed to fixate their eyes on the fixation cross, but to fixate and keep their eyes on the presented stimuli in either the left or the right box until the stimulus disappeared. Then participants had to relocate their eyes to the fixation cross until the next stimulus appeared. No responses were required and no digit trials were included. This task consisted of 16 trials during which horizontal eye-movements were recorded to measure the amplitude of the eye-movements towards the stimuli.

Subjective Questionnaires

Subjects completed the BIS/BAS questionnaire (Carver & White, 1984) and the Spielberger Trait Anxiety questionnaires (Spielberger, Gorusch, & Lushene, 1970; van der Ploeg, Defares, & Spielberger, 1980).

Procedure

After arrival participants signed an informed consent form and this was followed by the preparation of the EEG. First a baseline EEG was measured for 2x2 minutes. Participants were seated in a comfortable chair and were instructed to keep their eyes on the fixation cross in the centre of the screen for 2 minutes. This was followed by again 2 minutes of EEG recording while participants had their eyes closed.

After the baseline EEG recording participants were given instructions concerning the task they had to perform. They would start with a short practise phase during which no auditory stimulus would be presented. After the practise phase the aversive and neutral sound were presented once to the participants so they knew what kind of sounds would be presented during the acquisition phase. If subjects had no further questions concerning the experiment and if they and the experimenter felt that the subject had mastered the task, the experimental phase would begin starting with the baseline phase. Following the baseline phase participants went on to the acquisition phase. Before the acquisition phase began subjects got explicit instructions concerning which cue would be associated with the aversive and neutral sound. After completion of the task participants were subjected to a manipulation check to assess subjective experiences of the faces, expectancies concerning the UCS and the aversiveness of the auditory stimuli. This check consisted of 6 questions for which a 10-point Likert scale was used in which participants could rate how comfortable they felt watching the two face cues (0 = very uncomfortable, 9 = very comfortable), how strongly they expected to hear the aversive stimulus following presentation of the faces (0 = certainly not, 9 = certainly) and how aversive they rated the aversive and neutral UCS (0 = absolutely not aversive,

9 = highly aversive). Then participants performed an short eye-movement check and finally participants were asked to fill in the two questionnaires. Before the participants left they were debriefed and received their rewards.

EEG recording and Data Analysis

The Electroencephalogram (EEG) was recorded from 64 scalp Ag/AgCl electrodes with 2 reference electrodes placed on the left and the right mastoids. Vertical EOGs were measured using 2 facial electrodes placed in the superior and inferior areas of the left orbit and horizontal EOGs were recorded by 2 electrodes placed on the lateral aspect of the orbit of both eyes. All data were recorded with a 512 Hz low-pass filter at a sampling rate of 2048 Hz and stored for offline analysis.

Data were analysed using Brain Vision Analyzer (Brain Products GmbH, Germany). The EEG and EOG were digitally filtered with a 1-30 Hz bandpass filter before cue and target segmentation. Epoch periods of 600 ms., starting 100 ms. before cue or target onset and continuing to 500 ms. after cue or target onset. Segments containing EEG or EOG artifacts were removed using a $\pm 75 \mu\text{V}$ criterion. The waveforms to the cues were averaged separately for all relevant experimental conditions: Phase (baseline and acquisition), Location (left and right), Cue Duration (198 and 398 ms.) and Cue Type (Threat and Neutral). Waveforms in response to the targets were averaged separately for the following conditions: Phase (baseline and acquisition), targets following a short and long SOA, targets following a CS+ and CS-, valid and invalid targets, left and right targets.

The waveforms were visually inspected in order to determine the temporal time window around components of interest. The occipital P1 in response to the cue and target were strongest at PO7 and PO8 electrodes and at 100-130 ms. latency for the target-locked P1 and 90-120 ms. latency for the cue-locked P1. The P2a was strongest at medial frontal electrodes (FCz) during a 190-260 time interval post cue presentation. The mean amplitudes were calculated for every component in every condition. A repeated-measures analysis of variance with the above mentioned conditions was conducted for ERPs locked to the cue and target. Mean reaction times to the targets were also analyzed by using a repeated-measure analysis of variance with Phase (baseline and acquisition), SOA (short and long), Validity (valid and invalid), Cue Type (Threat and Neutral) and Location (left and right) as factors.

3. Results

3.1. Results Localization Task

3.1.1. Behavioural Analysis

Sample

The sample consisted of 10 participants, 5 males and 5 females, with a mean age of 21.9 years (SD = 4.01). Three participants were left handed and 7 were right handed. Questionnaire mean scores were 30.3 (SD = 4.74) for the STAI, 18.0 (SD = 3.02) for the BIS scale, 39.5 (SD = 4.30) for the BAS scale, 17.3 (SD = 1.57) for the BAS-reward scale, 10.9 (SD = 2.08) for the BAS-drive scale and 11.3 (SD = 2.54) for the BAS-fun scale.

Subjective Ratings

The aversiveness scores of the noise and the neutral sound were rated on a 10 point likert scale and showed a significant difference, $t(9) = 10.3$, $p < .001$, with higher aversiveness scores for the noise, Mean = 7.6 (SD = .97), compared to the neutral sound, Mean = 0.9 (SD = .16).

The expectancy rating, on a 0 to 9 scale, of the aversive sound presented after the threat cue was rated 7.2 (SD = 1.32) and 0.8 (SD = 1.39) after the neutral cue and was significantly higher for the threat cue, $t(9) = 9.1$, $p < .001$. The difference in ratings of how comfortable participants felt watching either the threat and the neutral face cue was significant, $t(9) = 3.3$, $p < .01$, indicating lower comfort scores for the threat cue, Mean = 4.2 (SD = .92) compared to the neutral cue, Mean = 6.4 (SD = 1.43).

Accuracy Scores

Mean accuracy scores in all conditions were between 97 and 100% and were not analyzed in further detail.

Reaction times

Reaction time data are displayed in figures 2 and 3. A 2 x 2 x 2 x 2 repeated measures ANOVA with Phase (baseline, acquisition), SOA (short, long), Validity (valid, invalid) and Cue Type (Threat, Neutral) as factors was conducted.

A significant Phase x Validity x Cue Type interaction was observed, $F(1, 9) = 11.26$, $p < .01$, $\eta^2 = .556$, indicating different validity effects for the neutral and the threat cue between the baseline and acquisition phase. Also, a significant SOA x Validity interaction was found $F(1, 9) = 52.05$, $p < .001$, $\eta^2 = .853$, indicating a difference in validity effects between the short and the long SOA.

Because the Phase x Validity x Cue Type interaction did not differ between the short and the long SOA conditions, both were taken together and a 2 x 2 repeated measures ANOVA with Validity and Cue Type as factors was conducted separately for the baseline and acquisition phase. A significant main effect for validity was observed in the baseline phase, $F(1, 9) = 47.84$, $p < .001$, $\eta^2 = .842$, indicating slower reaction times for valid compared to invalid targets, hence IOR. No significant Cue Type x Validity effect was found in the baseline phase, $F(1, 9) = 1.39$, $p = .27$, $\eta^2 = .134$, illustrating that IOR did not differ between the cues. A significant main effect for validity was also observed in the acquisition phase, $F(1, 9) = 34.53$, $p < .001$, $\eta^2 = .793$, indicating the presence of IOR, and a significant Cue Type x Validity effect was found, $F(1, 9) = 9.78$, $p < .05$, $\eta^2 = .521$. To further investigate the difference in validity effects between the neutral and the threat cue, difference scores were calculated by subtracting the invalid from the valid RT data for both cue types. A paired sample t-test showed a significant difference between the neutral cue compared to the threat cue, $t(9) = 3.13$, $p < .05$, showing a larger IOR effect for the neutral cue. Although the IOR effect is present in both cue type conditions, the amount of IOR is significantly reduced on trials with the threat compared to the neutral cue.

To assess the SOA x Validity interaction, a 2 x 2 repeated-measures ANOVA was conducted with SOA and validity as factors. Results showed a significant main effect for SOA, $F(1, 9) = 17.03$, $p < .01$, $\eta^2 = .65$, indicating a stronger IOR effect in the long compared to the short SOA condition.

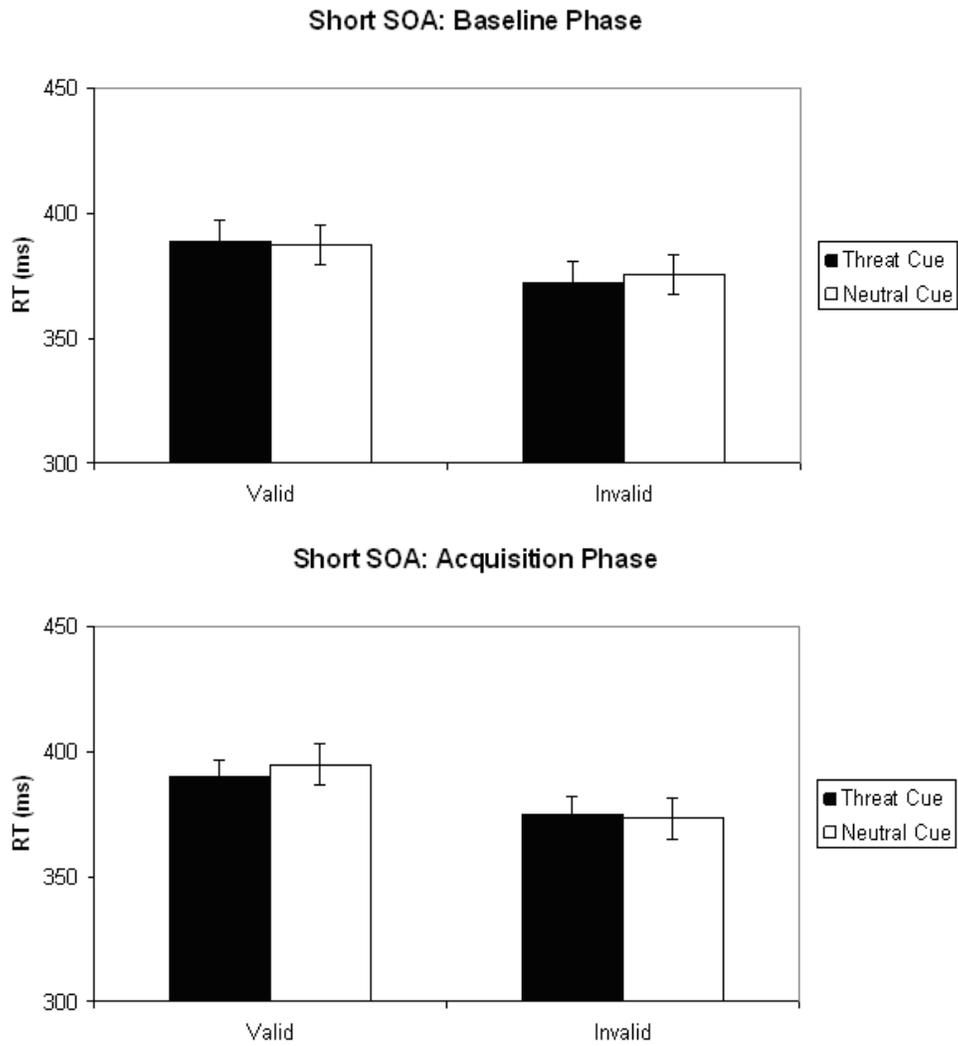


Figure 2: Mean RT and standard errors of the mean for targets following the Neutral and Threat cue in Valid and Invalid conditions after a short SOA (200 ms) for the Baseline and Acquisition phase.

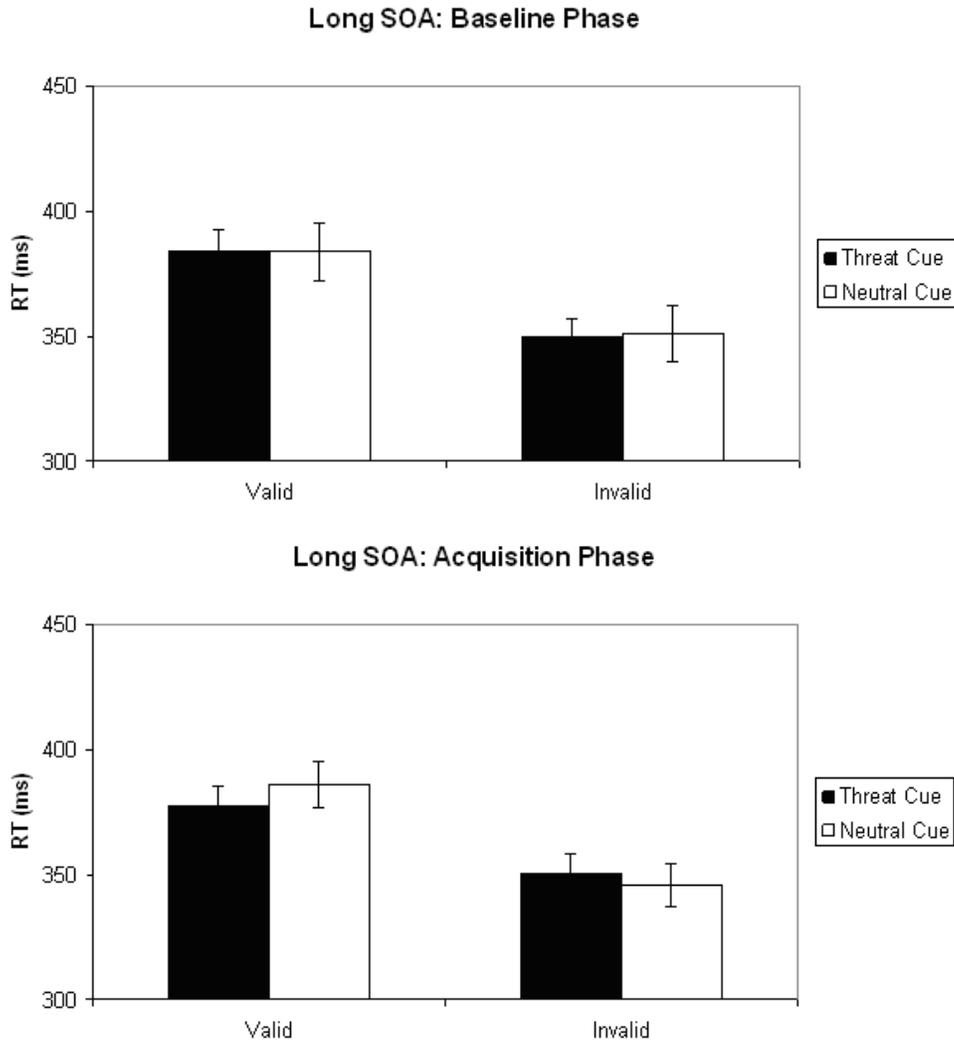


Figure 3: Mean RT and standard errors of the mean for targets following the Neutral and Threat cues in Valid and Invalid conditions after a long SOA (400 ms) for the Baseline and Acquisition phase.

3.1.2. ERP Measures

Cue

P1 (100-130 ms)

ERP waveforms of the cue-locked P1 are displayed in figure 4. A 2 x 2 x 2 x 2 Repeated measures ANOVA with Phase (Baseline and Acquisition), Location (left and right), SOA (short and long) and Cue Type (Threat or Neutral) as factors was conducted. Results showed a significant Phase x Location x SOA x Cue Type interaction, $F(1, 9) = 5.22$, $p < .05$, $\eta^2 = .37$.

To further investigate this interaction two separate Location x SOA x Cue Type repeated measures ANOVAs were conducted for the baseline and the acquisition phase.

In the baseline phase a significant main effect for SOA, $F(1, 9) = 7.23, p < .05, \eta^2 = .47$ and a significant main effect for Location, $F(1, 9) = 5.48, p < .05, \eta^2 = .38$ was found. These results indicated larger P1 amplitudes for left compared to right cues and larger P1 amplitudes to cues with long compared to short SOAs. No other significant main effects or interactions were observed.

In the Acquisition Phase only a main effect for SOA was found, $F(1, 9) = 6.42, p < .05, \eta^2 = .42$, indicating larger P1 amplitudes to targets with long compared to short SOAs.

No significant main effect for CS was found in the acquisition phase, $F(1, 9) = .00, p = .99, \eta^2 = .00$. This result showed that threat did not have a modulatory effect on the P1.

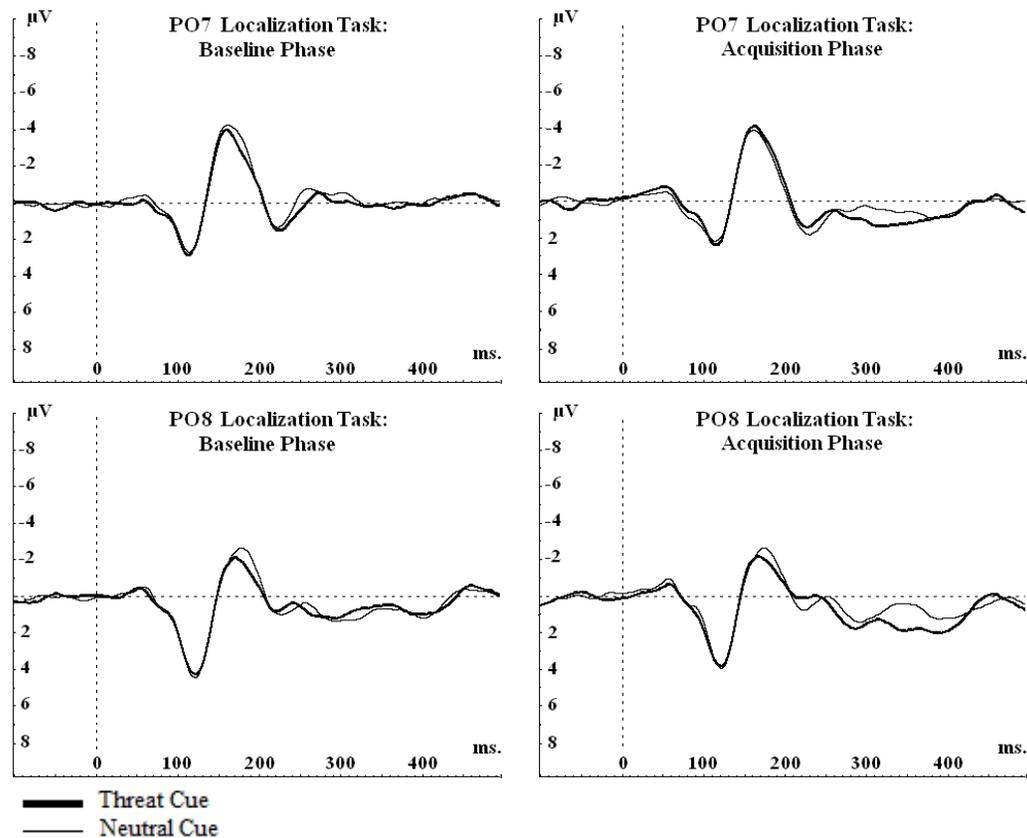


Figure 4: Grand-averaged cue-locked P1 waves at electrodes PO7 and PO8 for left and right cues respectively in the baseline and acquisition phase.

P2a (190-260 ms)

The P2a waveform to the cue is displayed in figure 5. A 2 x 2 x 2 repeated measures ANOVA with Phase (Baseline and Acquisition), Cue Type (threat and neutral) and Cue Location (left and right) as factors was conducted and a significant Phase x Cue Type interaction was found, $F(1, 9) = 17.86$, $p < .01$, $\eta^2 = .67$, showing different effects of the cues on the P2a amplitude between the baseline and acquisition phase. To further investigate this effect of Cue Type on the P2a amplitude, separate analysis for the baseline and acquisition phase were conducted. Because the Phase x Cue Type x Location interaction was not significant, both locations were taken together in this analysis. No significant main effect for Cue Type was found in the baseline phase, $F(1, 9) = .47$, $p = .51$, $\eta^2 = .05$. However, a significant effect of Cue Type was found in the acquisition phase, $F(1, 9) = 12.56$, $p < .01$, $\eta^2 = .58$, showing larger P2a amplitudes for the Threat compared to the Neutral Cue.

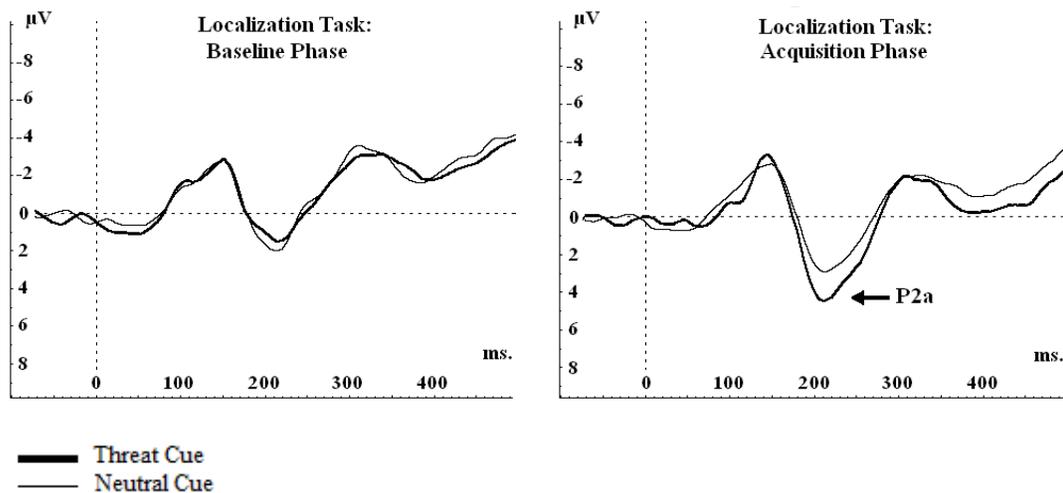


Figure 5: Grand-averaged P2a waveforms to the cue measured at FCz in the baseline and acquisition phase. Notice the stronger positive peak following the threat cue in the acquisition phase.

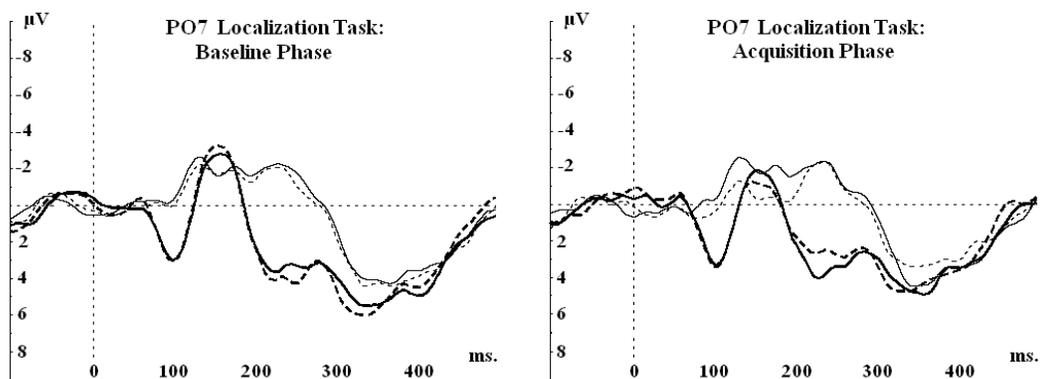
Target

P1 (90-120 ms)

The target-locked P1 waveforms are depicted in figure 6. A 2 x 2 x 2 x 2 x 2 repeated measures ANOVA was conducted with Target Side (Left and Right), Phase (Baseline and Acquisition), SOA (Short and Long), Cue Type (Threat and Neutral) and Validity (Valid and Invalid) as factors.

First, validity effects on the P1 amplitude were inspected, because a significant SOA x Validity effect was found, $F(1, 9) = 31.11$, $p < .001$, $\eta^2 = .78$ which indicated different validity effects of P1 in the short and the long SOA. Further analysis revealed a significant validity effect in the short SOA, $F(1, 9) = 15.44$, $p < .01$, $\eta^2 = .63$ and in the long SOA, $F(1, 9) = 73.99$, $p < .001$, $\eta^2 = .89$. These results confirmed that in both SOAs the P1 amplitude was significantly larger on invalid compared to valid trials and this validity difference was larger in the long compared to the short SOA condition.

The Phase x Cue Type x Validity interaction proved to be non-significant, $F(1, 9) = .11$, $p = .75$, $\eta^2 = .01$. Although different validity effects were found for the threat and neutral cues between the acquisition and the baseline phase in the behavioural analysis, no such interaction was present for the target-locked P1 amplitude. However, a significant Phase x SOA x Cue Type interaction was found, $F(1, 9) = 6.05$, $p < .05$, $\eta^2 = .40$, indicating different effects of the threat and the neutral cue on the amplitude of the P1 on trials with short and long SOAs between the baseline and the acquisition phase. To further test this interaction two SOA x Cue Type repeated measures ANOVAs were conducted for the baseline and the acquisition phase separately. In the baseline phase no significant main effects or interactions were found, although the main effect for SOA was marginally significant, $F(1, 9) = 4.67$, $p = .059$, $\eta^2 = .34$, indicating larger target-locked P1 amplitudes on trials with short compared to long SOAs. In the acquisition phase a significant main effect for SOA was observed, $F(1, 9) = 12.09$, $p < .01$, $\eta^2 = .57$, indicating larger P1 amplitudes to targets on trials with a short compared to a long SOA. Although a trend was observed for larger P1 amplitudes to targets following a threat cue compared to a neutral cue on trials with short SOAs compared to long SOAs in the acquisition phase, this interaction did not reach statistical significance, $F(1, 9) = 3.67$, $p = .09$, $\eta^2 = .29$.



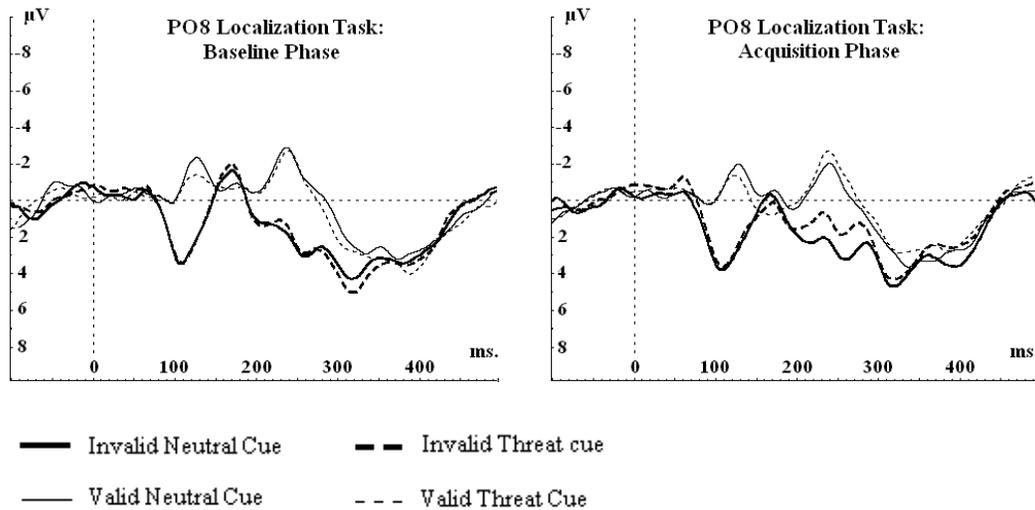


Figure 6: Grand-averaged target-locked P1 waves measured at PO7 and PO8 electrodes for left and right targets respectively. Notice the stronger P1 amplitude to invalid targets compared to valid targets.

3.1.3. Correlational Data

RT and Personality Traits

To investigate possible correlations between the STAI and BIS/BAS scores on the one hand and the effects of the cues on the validity effects on the other hand, the difference in IOR between threat and neutral cue was calculated by subtracting the difference RT (valid – invalid) of the threat cue from the difference RT (valid – invalid) of the neutral cue. In this way higher scores indicate a greater reduction in IOR compared to lower scores. However, no significant correlations between the STAI and any of the BIS/BAS components (BIS, BAS, BAS-reward, BAS-fun and BAS-drive) were found.

P2a, Personality Traits and Reduction IOR

The P2a could only be measured in the long SOA condition, so the following analysis was only applied to the long SOA condition. The increase in amplitude in response to the threat compared to the neutral cue in the acquisition phase was analyzed by first calculating the average amplitude of the CS+ and the CS- between the left and the right cue location. Then the average P2a amplitude CS- was subtracted from the average CS+ P2a amplitude. In this way higher scores represent a larger increase in the amplitude of the P2a for the threat cue

compared to the neutral cue. These scores were correlated with STAI, BIS, BAS, BAS-fun, BAS-reward and BAS-drive, but no significant correlations were found.

The increase in the P2a in response to the threat cue in the acquisition phase did not show a significant correlation with the amount of reduction in IOR, $r = -.08$, $p = .835$.

3.2. Results Discrimination Task

3.2.1. Behavioural Analysis

Sample

The sample consisted of 10 participants, 4 males and 6 females, with a mean age of 22.2 (SD = .39). All were right handed. Questionnaire mean scores were 36.9 (SD = 6.49) for the STAI, 18.5 (SD = 2.99) for the BIS scale, 37.1 (SD = 2.28) for the BAS scale, 15.8 (SD = 1.40) for the BAS-reward scale, 10.5 (SD = 1.78) for the BAS-drive scale and 10.8 (SD = 1.55) for the BAS-fun scale.

Subjective Ratings

The aversiveness scores of the noise and the neutral sound were rated on a scale from 0 to 9 and differed significantly, $t(9) = 17.493$, $p < .001$, with higher aversiveness scores for the noise, Mean = 7.9 (SD = .74), compared to the neutral sound, Mean = 1.1 (SD = .88).

The expectancy rating, on a 0 to 9 scale, of the aversive sound presented after the threat cue was rated 7.4 (SD = 1.26) and 1.8 (SD = 2.29) after the neutral cue and was significantly higher for the threat cue, $t(9) = 6.836$, $p < .001$. The difference in ratings of how comfortable participants felt watching either the threat and the neutral face cue was marginally significant, $t(9) = -2.17$, $p = .058$, indicating lower comfort scores for the threat cue, Mean = 4.2 (SD = 1.99) compared to the neutral cue, Mean = 5.4 (SD = 2.17).

Accuracy

Mean accuracy scores in all conditions were between 89 and 93% and were not analyzed in further detail.

Reaction times

The reaction time data are displayed in figure 7 and 8. A 2 x 2 x 2 x 2 repeated measures ANOVA with Phase (baseline, acquisition), SOA (short, long), Validity (valid, invalid) and

Cue Type (Threat, Neutral) as factors was conducted. A significant Phase x SOA x Validity x Cue Type interaction was found, $F(1, 9) = 6.67, p < .05, \eta^2 = .425$, indicating that between the baseline and acquisition phase, there are different validity effects for the neutral and threat cue between the short and the long SOA. To further investigate this interaction separate $2 \times 2 \times 2$ repeated measures ANOVAs with SOA, Validity and Cue Type as factors were conducted for the baseline and acquisition phase.

For the baseline phase a significant SOA x Validity effect was observed, $F(1, 9) = 5.59, p < .05, \eta^2 = .383$. To further investigate the difference in validity effects between the two SOAs (short, long) two 2×2 repeated measures ANOVAs with Validity and Cue Type as factors were conducted for the short and the long SOA, but no significant main effects or interactions were observed. Next, difference scores were calculated in both SOA conditions by subtracting the valid RT data from the invalid RT data and adding both cue conditions together. A paired-sample T-test showed significant longer RT for valid compared to invalid targets in the long SOA condition compared to the short SOA condition, $t(9) = 2.364, p < .05$, indicating an IOR effect in the long compared to the short SOA condition.

In the acquisition phase the SOA x Validity x Cue Type repeated measures ANOVA showed a significant SOA x Validity x Cue Type interaction, $F(1, 9) = 6.96, p < .05, \eta^2 = .436$. Also a significant SOA x Validity interaction was observed, $F(1, 9) = 6.01, p < .05, \eta^2 = .403$. Separate 2×2 repeated measures ANOVAs with Validity and Cue Type as factors for both SOAs were conducted and showed no significant main effects or interactions in the short SOA condition, but a significant Validity x Cue Type interaction, $F(1, 9) = 6.45, p < .05, \eta^2 = .418$ and a significant main effect for Validity, $F(1, 9) = 14.01, p < .01, \eta^2 = .610$, in the long SOA condition (see Figure 1 for RT data).

Paired-sample T-tests showed no significant validity effect for the Threat Cue, $t(9) = 3.6, p = .071$, but did show a significant validity effect for the Neutral Cue, $t(9) = 3.6, p < .01$, indicating slower RT for valid compared to invalid targets, hence IOR. To further investigate these validity differences between cues, paired sample T-tests were performed to compare reaction times between Cue Types for valid and invalid trials separately. No significant difference in RT was found in invalid trials between the threat and the neutral cue, $t(9) = -.13, p = .990$, but a significant difference in RT was found in valid trials between the threat and the neutral Cue, $t(9) = -2.32, p < .05$. This indicates that reaction times to targets are significantly faster on valid trials with threatening cues compared to neutral cues and results in the disappearance of IOR in the threat cue condition while IOR is present in the neutral cue condition.

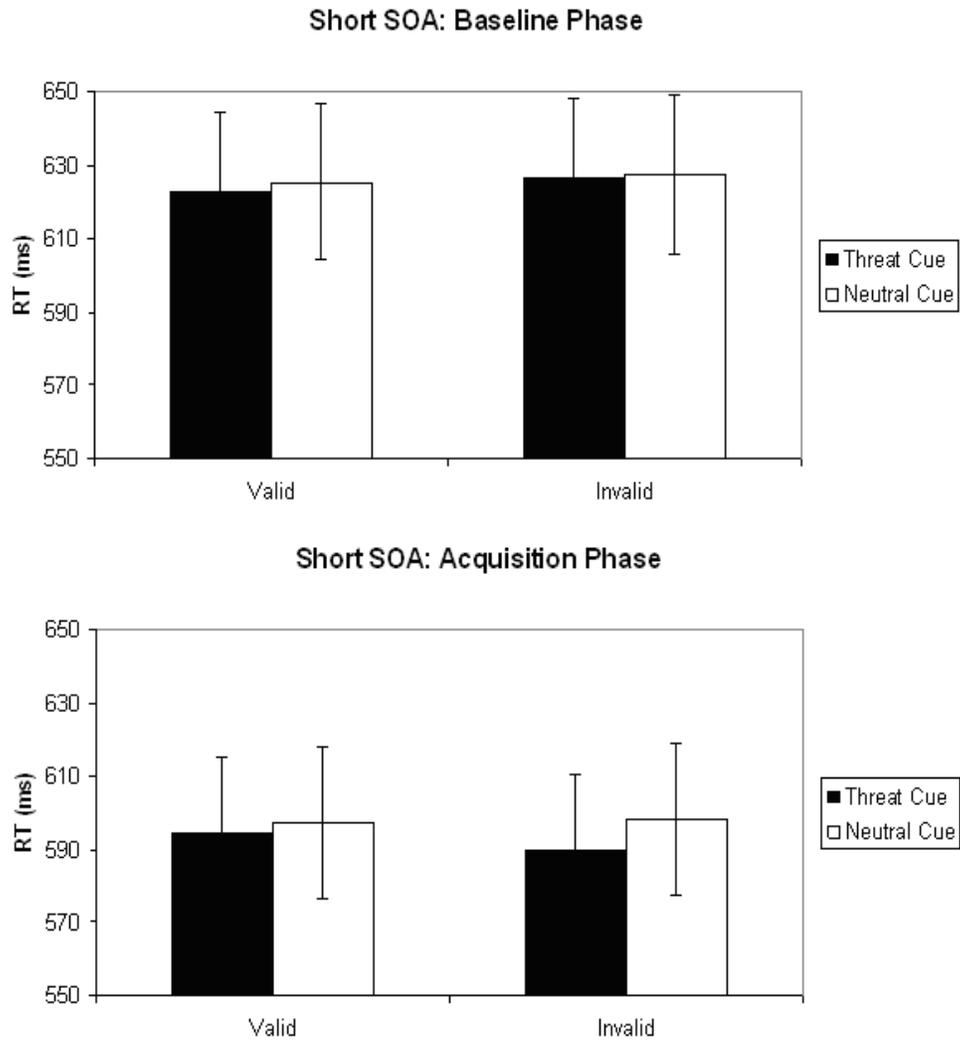


Figure 7: Mean RT and standard errors of the mean for targets following the Neutral and Threat cues in Valid and Invalid conditions after a short SOA (200 ms) for the Baseline and Acquisition phase.

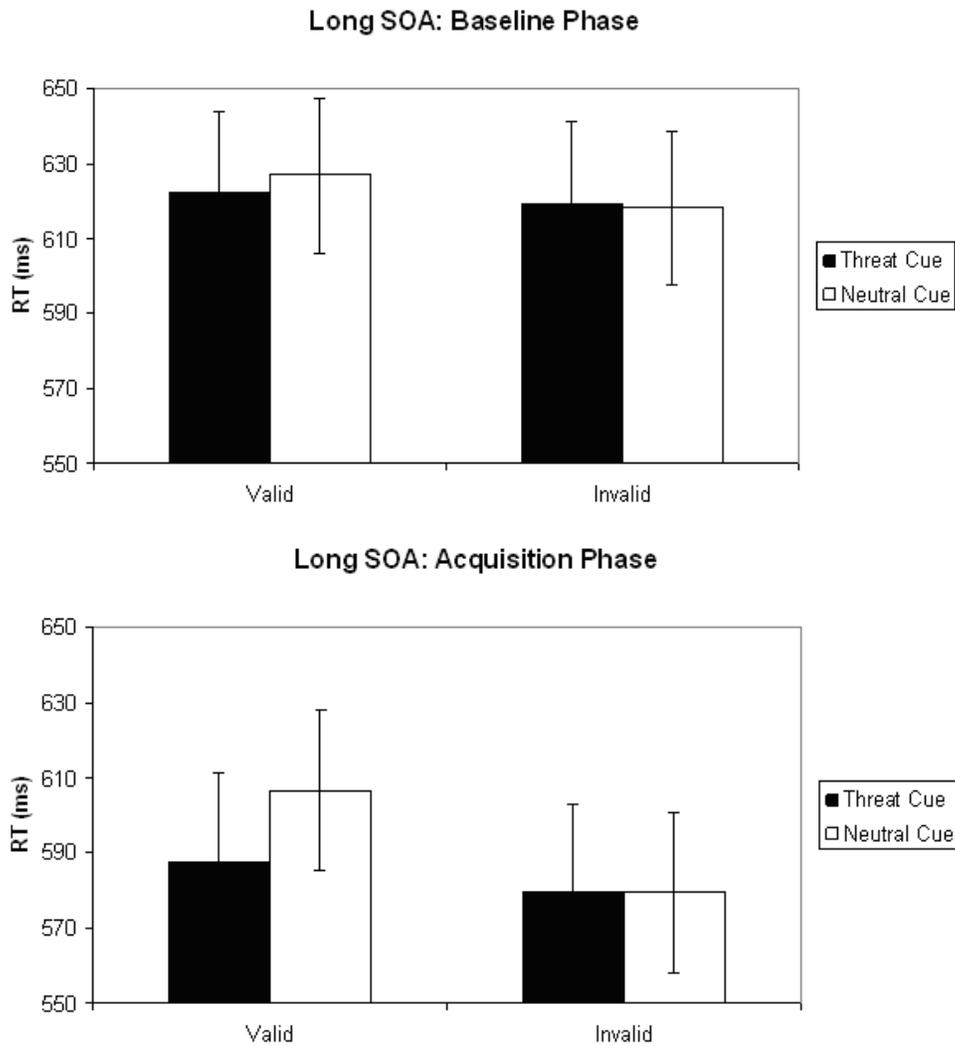


Figure 8: Mean RT and standard errors of the mean for targets following the Neutral and Threat cues in Valid and Invalid conditions after a long SOA (400 ms) for the Baseline and Acquisition phase.

3.2.2. ERP Measures

Cue

P1 (100-130 ms)

The cue-locked P1 waveforms are displayed in figure 9. A 2 x 2 x 2 x 2 repeated measures ANOVA with Phase (Baseline and Acquisition), Location (Left and Right), SOA (Short and Long) and Cue Type (Threat and Neutral) as factors was conducted. Results showed a only a main effect for Cue Type, $F(1, 9) = 8.86$, $p < .05$, $\eta^2 = .50$. The amplitude for the CS+ was

larger compared to the CS- in both phases. The Phase x Cue Type interaction was non-significant, $F(1, 9) = .04$, $p = .84$, $\eta^2 = .01$.

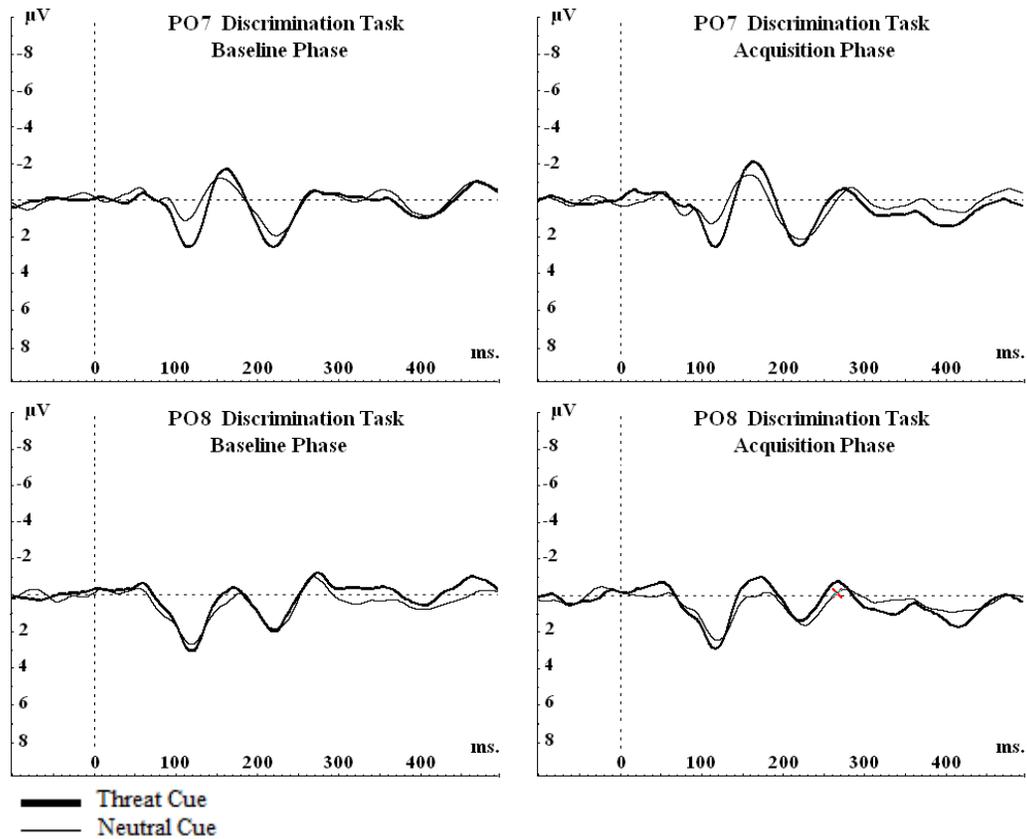


Figure 9: Grand-averaged cue-locked P1 waves at electrodes PO7 and PO8 for left and right cues respectively in the baseline and acquisition phase.

P2a (190-260 ms)

The waveform of the P2a is displayed in figure 10. A $2 \times 2 \times 2$ repeated measures ANOVA was conducted with Phase (Baseline and Acquisition), Cue Type (Threat and Neutral) and Cue Location (Left and Right) as factors and a significant Phase x Cue Type interaction was observed, $F(1, 9) = 8.42$, $p < .05$, $\eta^2 = .48$. Because this interaction did not differ between Cue Locations, the Cue Type effect was analyzed separately between the baseline and acquisition phase with both Cue Locations taken together. No significant difference between the threat and the neutral cue was found in the baseline phase, $F(1, 9) = .52$, $p = .49$, $\eta^2 = .05$, but a significantly greater P2a amplitude was found following the threat cue compared to the neutral cue, $F(1, 9) = 6.20$, $p < .05$, $\eta^2 = .41$ in the acquisition phase.

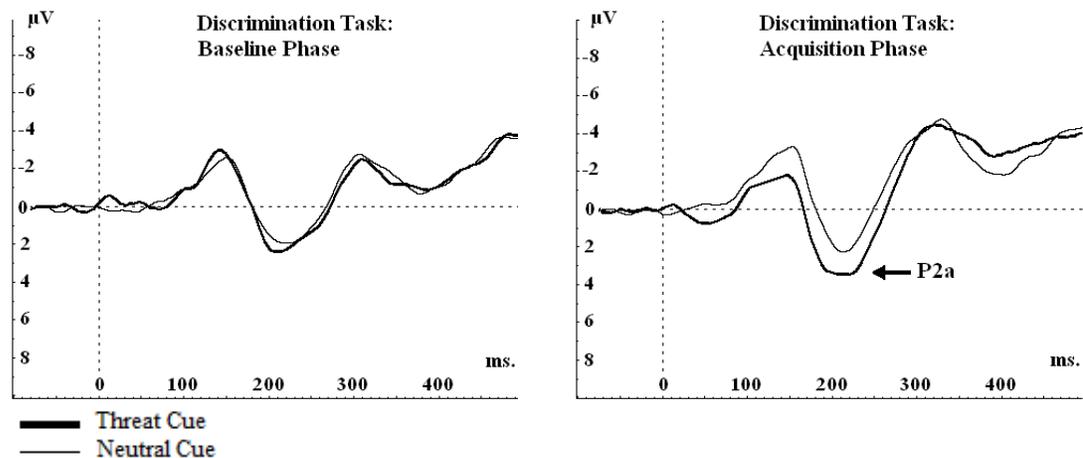


Figure 10: Grand-averaged P2a waveforms to the cue measured at FCz in the baseline and acquisition phase. Notice the stronger positive peak following the threat cue in the acquisition phase.

Target

P1 (90-120 ms)

The waveforms of the target-locked P1 are displayed in figure 12. A 2 x 2 x 2 x 2 x 2 repeated measures ANOVA was conducted with Target Side (Left and Right), Phase (Baseline and Acquisition), SOA (Short and Long), Cue Type (Threat and Neutral) and Validity (Valid and Invalid) as factors. A significant SOA x Validity interaction was found, $F(1, 9) = 5.96$, $p < .05$, $\eta^2 = .40$, indicating differences in P1 amplitude to valid and invalid targets between trials with short and long SOAs. Further testing revealed a marginally significant main effect for validity on trials with short SOAs, $F(1, 9) = 4.62$, $p = .06$, $\eta^2 = .34$, and a significant main effect for validity on trials with long SOAs, $F(1, 9) = 16.39$, $p < .01$, $\eta^2 = .65$. These results indicate that P1 amplitudes were larger to invalid compared to valid targets and this validity difference was larger on trials with long compared to short SOAs.

The Phase x Cue Type x Validity interaction was not significant, $F(1, 9) = .00$, $p = .98$, $\eta^2 = .00$. Differences in validity effects for the neutral and the threat cue between the baseline and acquisition phase, as was found in the behavioural data, were not present for the target-locked P1. This means that threat did not modulate the validity effects of P1 amplitude to the targets. Threat did however modulate differences in P1 in the baseline and acquisition differently between the short and the long SOA, because a significant Phase x SOA x Cue Type interaction was found, $F(1, 9) = 5.60$, $p < .05$, $\eta^2 = .38$. Two separate repeated measures ANOVAs were conducted for the baseline and acquisition phase with SOA and Cue Type as factors. In the baseline phase no significant main effects or interactions were found. A

marginally significant main effect for SOA was observed, $F(1, 9) = 4.51$, $p = .06$, $\eta^2 = .33$, indicating larger P1 amplitudes to targets on long compared to short SOAs. No significant main effects or interactions were found in the acquisition phase. To further examine what effects underlie the significant Phase x SOA x Cue Type interaction the mean amplitudes for SOA, Cue Type and SOA x Cue Type were examined. After inspection of the mean amplitudes the same patterns were found for SOA and Cue Type in the baseline and the acquisition phase, with larger amplitudes to targets on trials with long compared to short SOAs and no obvious differences in amplitudes between the threat and the neutral cue. However, the SOA x Cue Type interaction showed a difference between the baseline and the acquisition phase. In the baseline phase the amplitudes for targets in the threat condition and the neutral condition showed a similar pattern, that is larger target-locked P1 amplitudes on long compared to short SOAs. However, in the acquisition phase this pattern was only found for the neutral cue. In contrast, the P1 amplitude to targets following the threat cue was larger on trials with short compared to long SOAs.

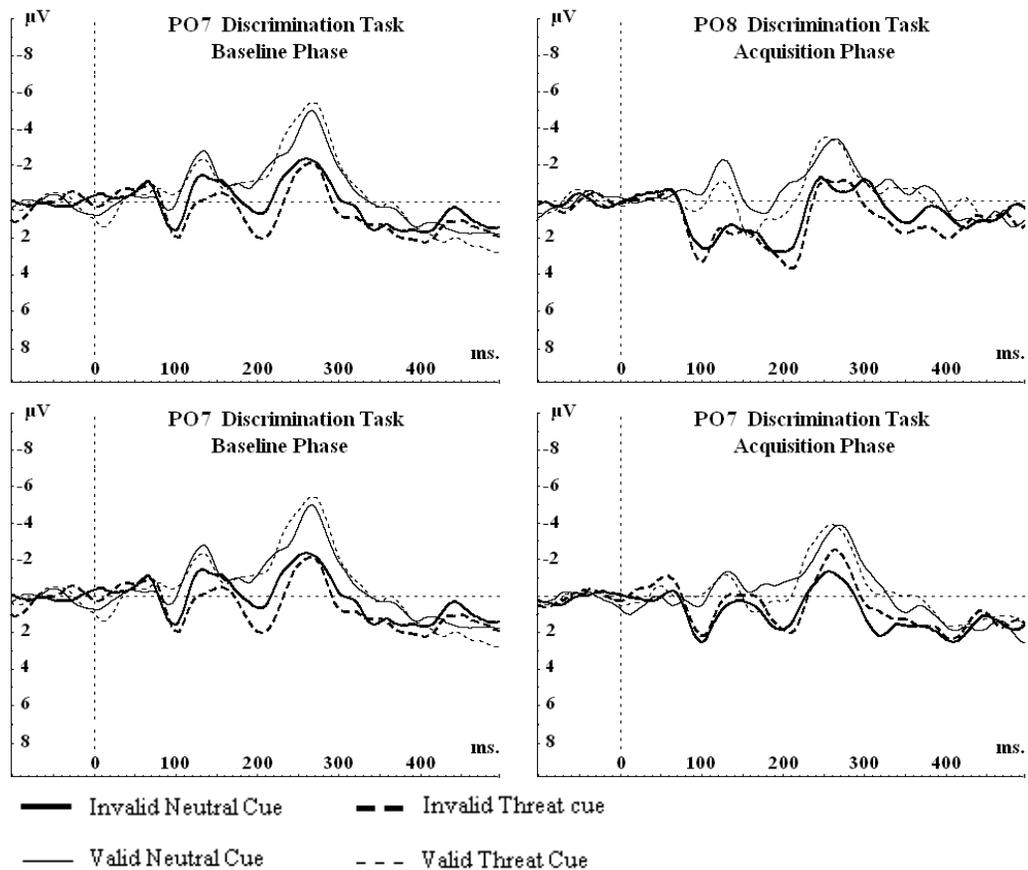


Figure 12: Grand-averaged target-locked P1 waves measured at PO7 and PO8 electrodes for left and right targets respectively. Notice the stronger P1 amplitude to invalid targets compared to valid targets.

3.2.2. Correlational Data

RT and Personality Traits

To analyze possible relations between personality characteristics and the reduction in IOR observed for the threat cue, difference scores were calculated by subtracting valid RT from invalid RT for both cues. These IOR scores of the Threat cue were then subtracted from the IOR score of the Neutral cue to assess the amount of change in IOR between the cues. Higher scores indicate a stronger decrease in the amount of IOR compared to lower scores. These scores were correlated with STAI, BIS, BAS, BAS-reward, BAS-fun and BAS-drive, but no significant correlations were found.

P2a, Personality Traits and Reduction IOR

The P2a could only be measured in the long SOA condition, so the following analysis was only applied to the long SOA condition. The increased P2a amplitude in response to the threat compared to the neutral cue in the acquisition phase was analyzed by first calculating the average amplitude of the CS+ and the CS- between the left and the right cue location. Then the average CS- P2a amplitude was subtracted from the average CS+ P2a amplitude. In this way higher scores represent a larger increase in the amplitude of the P2a for the threat cue compared to the neutral cue. These scores were correlated with STAI, BIS, BAS, BAS-fun, BAS-reward and BAS-drive. A significant correlation between BIS scores and the increase in the P2a to the threat cue was found, $r = -.89$, $p < .01$ (figure 11). Higher scores on the BIS are thus related to smaller increases in the P2a in response to the threat cue compared to the neutral cue. No other significant correlations were found.

The increase in the P2a in response to the threat cue in the acquisition phase did not show a significant correlation with the amount of reduction in IOR, $r = .49$, $p = .147$.

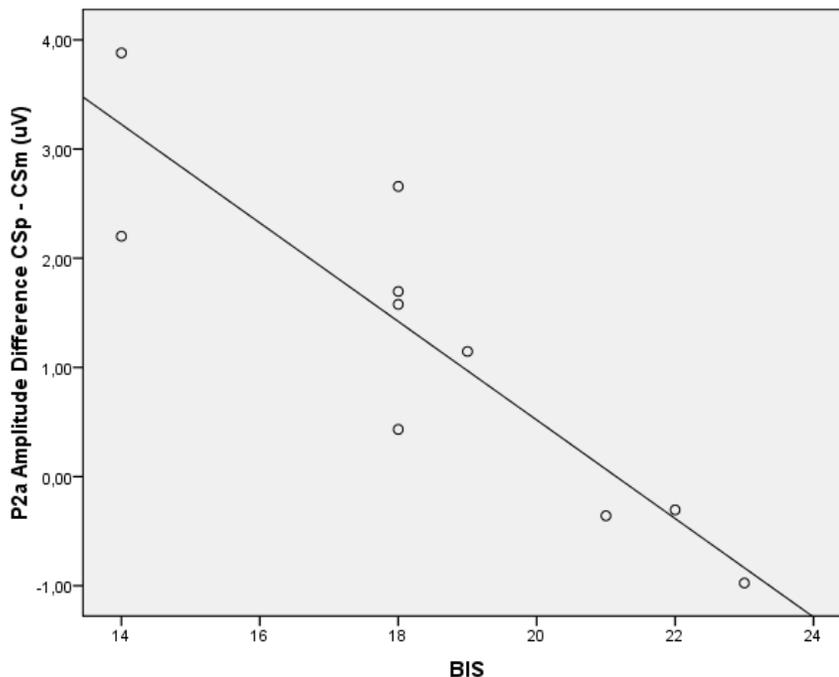


Figure 11: Correlation between BIS and the difference in the P2a amplitude to the threat compared to the neutral cue (CSp – CSm. $r = -.89$, $p < .01$, $r^2 = .79$).

Discussion

The main aim of this study was to investigate emotional modulation of exogenous attention and to gain insight into the neurophysiological mechanisms that underlie these processes. The existence of an association between attentional and emotional processes has been hypothesized based mainly on two ideas. First, one of the primary functions of attention is to facilitate rapid detection and processing of new objects appearing in the environment (Yantis, 1996). Second, the primary function of fear is to facilitate detection of potential dangers in the environment (LeDoux, 1996). A task that has been frequently used to assess attention modulation by emotional stimuli is Posner's exogenous covert orienting task (Posner, 1980) in which participants have to respond to either validly or invalidly cued targets. This led to the discovery of the *cue validity effect*, meaning faster reaction times to validly cued targets compared to invalidly cued targets when relatively short SOAs were used. This task has proven to be especially useful in distinguishing between different stages of attentional processes, namely attentional engagement, shift and disengagement (Posner & Peterson, 1990). By manipulating the emotional valence of the cues, the effect of the emotional content on these different stages of attention can be measured. Several studies have consistently shown significant effects of threat-related stimuli on attention. Both a stronger disengagement effect for emotional compared to neutral cues, reflecting slower reaction times to invalidly cued targets (Fox, 2001; Fox, Russo & Dutton, 2002; Yield & Matthews, 2001) and a stronger engagement effect for emotional cues (Koster et al., 2004; Koster et al., 2006), reflecting faster reaction times to validly cued targets, were found. These findings suggest that the attentional system is modulated by emotional processes resulting in enhanced allocation of attentional resources towards the location of the threatening cue and in a delay in disengaging attentional resources from a location previously occupied by threat.

In this study an emotional-modified exogenous spatial cueing paradigm was used based on the study by Massar (in press) in which an instructed conditioning procedure was applied to pair an aversive sound to one cue (CS+) and a neutral tone to the other cue (CS-). Pictures of neutral faces were used as cues. EEG activity was recorded to examine the temporal dynamics of spatial attention processes. Although several studies have already been conducted to investigate both emotion induced effects on attention and neurophysiological attentional processes by using EEG (e.g. Fox et al., 2007; Li et al., 2005; Pourtois et al., 2004; Santesso et al., 2008), results have not always been consistent and ERPs locked to the cues have not received much attention thus far. To our knowledge only a few studies addressed the issue of cue-locked ERPs (Pourtois et al., 2004; Santesso et al., 2008; Bar-Haim et al., 2005;

Eldar et al., 2010), but with some mixed results. Also, no such study has used a conditioning approach to manipulate the level of threat. Instead stimuli with intrinsic emotional value, such as angry faces or arousing pictures, have served as cues.

One of the main goals of this study was to address the effects of threat on the cue validity effect. Another main goal of this study was to measure potential differences in EEG activity to threat-related compared to neutral cues. However, because the cue-related MFC activity of interest occurs relatively late, 200-400 ms. post stimulus, specific measures had to be taken to prevent the occurrence of the Inhibition Of Return (IOR) effect. IOR was first observed by Posner and Cohen (1984) during a spatial cueing task when SOAs longer than 300 ms. were used. IOR showed the exact opposite behavioural effect compared to the cue validity effect, namely faster reaction times to invalidly compared to validly cued targets. However, in studies by Lupianez and colleagues (1997; 1999) it was discovered that the occurrence of IOR could be delayed to SOAs of 700-1000 ms. by switching to a discrimination task instead of a detection task. At shorter SOAs a facilitation effect for validly cued targets was found on trials with a 100 ms. SOA in both the detection and the discrimination task. Interestingly and relevant to this study, on trials with a 400 ms SOA this facilitation effect was still present in the discrimination task while IOR was observed in the detection task. Based on these results a spatial cueing task with target discrimination instead of target detection could be used to delay the IOR effect. In this way the IOR effect may not be present and EEG-activity measured at 200-400 ms. post-cue uncontaminated by the presentation of the target is possible.

In this study 4 conditions were included in an attempt to replicate and extend Lupianez's findings (1997). In our experiment subjects either performed a localization or a discrimination task in which half of the trials had short SOAs (200 ms) and the other half had long SOAs (400 ms). The reason to chose for a localization instead of a detection task was based on the fact that we attempted to replicate the results by Massar and colleagues (in press) who found an cue-validity effect and modulation of this validity effect by the CS+. We hypothesized to replicate Lupianez's findings with a localization instead of a detection task, based on three reasons. First, research has shown that IOR is present at the same SOA in detection and a localization task (Klein & Taylor, 1994). Second, in a study by Lupianez and colleagues (1999) it was shown that the difference in onset of between a detection and a discrimination task is due to differences in perceptual demands instead of differences in response selection. Because the only difference between a localization task and a detection task is a difference in response selection while the perceptual demands are similar, we

expected similar cueing effects in a localization compared to a detection task. Finally, we expected that the explanation postulated by Lupianez and colleagues (1999) for the discrepancy in cueing effects between a detection and a discrimination task could also be extended to localization tasks. This explanation states that a discrimination task favours an attentional set aimed at the integration of information over time within the same representation which facilitates making a discriminative judgement. In a detection task such integration is not required and an attentional set is adopted that is focused on the detection of new events. The attentional set favouring integration results in stronger attentional capture effects and later disengagement, especially when discrimination between targets is difficult. Increasing the difficulty accentuates the attentional set to integrate information. In this way the attentional set aimed at integration induced by the discrimination task results in a later onset of IOR compared to the attentional set that is adopted in response to a detection task. In a localization task one has a similar task as in a detection task and therefore a similar attentional set could be adopted, resulting in a similar onset of IOR.

The results of this study concerning the onset of IOR are consistent with our expectations. A delay in the IOR was found in the discrimination compared to the localization task, thereby replicating previous findings (Lupianez et al., 1997; Lupianez et al., 1999). While IOR was present at the 200 ms. SOA in the localization task, IOR was not yet present on trials with 200 ms. SOAs in the discrimination task. The role of different attentional sets between a detection or localization and a discrimination task has already been discussed and does provide a possible explanation for the difference in cueing effects that were found in this study. However, more processes may be involved. In a more recent article Lupianez and colleagues (2007) stated the importance of three different processes. Two of these processes are based on two hypotheses related to differences in attentional sets, but the authors suggested the role of a third mechanism. However, before discussing this third mechanism, the two hypotheses will be explained first. The “bigger capture hypothesis”, suggested by Klein (2000), states that a discrimination task is more demanding compared to target detection, which results in the preparation of more resources that are allocated to the cue. This causes a stronger facilitation effect to the cue and a later appearance of IOR. In this case the facilitation effect to validly cued targets gradually weakens over time after cue presentation and results in a decrease in the facilitation of responses to valid targets when SOAs become progressively longer. Eventually the facilitation of responses becomes negative, thus resulting in IOR. The “later disengagement hypothesis” stresses the importance of different disengagement and re-orienting strategies that occur in a discrimination and a detection task.

Although, according to this hypothesis, the facilitation effect is the same in both tasks, the disengagement process occurs later in the discrimination task, because an attentional set is adopted that emphasises integration of information instead of detecting new events in the environment (Lupianez et al., 2001). In this case the facilitation effect in the discrimination task remains as strong when the SOA increases up until a particular point in which there is a rapid decline in the facilitation effect and a quick transition to IOR takes place. Based on the results of the study by Lupianez (1997) this transition point was suggested to be around the 400 ms. SOA in their experiment.

Lupianez and Colleagues (2007) argued that both hypothesis focus on processes that occur prior to target onset and do not take into account processes that may occur at or after target presentation. In a series of experiments they showed that different cueing effects can be caused by processes that take place at or after target onset. A model was proposed in which differences in cueing effects cannot be directly attributed to the size of the attentional capture effect or to the speed of disengagement of attention, without considering the role of task-related processes that are initiated in response to the target. The authors concluded that any difference in cueing effects between tasks should be examined in light of these three processes. It is therefore reasonable to assume that differences in attentional sets and/or differences in task-related processes initiated in response to the target between the localization and the discrimination task were present in our study.

This study may provide some neurophysiological support for the fact that different tasks induce different attentional sets. Although not all effects turned out to be significant, examination of the target-locked P1 in the localization and the discrimination task at short and long SOAs revealed an interesting trend. The amplitude of the target-locked P1 was larger on trials with short compared to long trials in the localization task, while the amplitude of the P1 to targets in the discrimination task was larger on long compared to short SOAs. Perhaps the attentional set adopted in the localization task, which favours detection of new events, is especially strong in the early phases shortly after presentation of the cue, resulting in larger P1 amplitudes to targets on short compared to long SOAs. In the discrimination task the attentional set emphasizes integration of new and past events within the same representation by updating the old event. Perhaps as more time passes after presentation of the first event, the cue, more attentional resources are deployed to make it possible to integrate new information with the past event. Therefore, when the target is presented after a longer SOA, processing of the target is facilitated resulting in larger P1 amplitudes. More research is required to test whether the trend observed in this study becomes significant when more

subjects are tested. If these effects of the target-locked P1 can be modulated by attentional sets that are induced by the different tasks, changing the difficulty of the discrimination task and thereby the strength of the attentional set can be used to examine potential modulatory effects on the amplitude of the target-locked P1. Also, by using multiple SOAs one could examine how the strength of the P1 changes from short to longer SOAs.

Concerning the behavioural effects in this study, we replicated the delay in the onset of IOR induced by the discrimination task compared to the localization task. However, the results of our study did show several important differences compared to the results obtained by Lupianez and colleagues (1997). First, a difference in the onset of IOR in this study compared to the studies by Lupianez and colleagues (1997; 1999) was found. In these studies IOR was not present at the 100 and 400 ms. SOA in the discrimination task and at the 400 ms. SOA in the detection task, but only at the 100 ms. SOA in the detection task. Based on these results we expected to find IOR only in the localization task on trials with 400 ms. SOA. However, significant IOR was found on trials with a 400 ms. SOA in the localization and the discrimination task and on trials with 200 ms. SOA in the localization task. Only on trials with short SOAs in the discrimination task no significant IOR was observed and a slight cue validity effect was found in the baseline phase, but it did not reach statistical significance. This is a crucial difference in light of the goal of this study, since we attempted to eliminate the IOR effect in most conditions. Besides this difference in the onset of IOR, two more differences were found. A second difference is that in the study by Lupianez (1997) no difference was found concerning the magnitude of the IOR effect at the 700 ms. SOA between the detection and the discrimination task. Although no 700 ms. SOA was used in this study, IOR was present in both tasks at the 400 ms. SOA, but the amount of IOR differed. A stronger IOR effect was present on trials with a 400 ms. SOA in the localization compared to the discrimination task. The third difference is related to the two hypothesis, the 'bigger capture hypothesis' and the 'later disengagement hypothesis'. Using 100 and 400 ms. SOAs Lupianez (1997) found evidence in favour of the latter, which is a transition from facilitation to IOR in the detection task from 100 to 400 ms. SOAs while the facilitation effect remained as strong on trials with a 400 ms. compared to a 100 ms. SOA in the discrimination task. In this study results more consistent with the 'bigger capture hypothesis' were found. In both tasks stronger IOR was observed at the 400 ms. SOA compared to the 200 ms. SOA indicating a transition to stronger IOR effects in both tasks. These discrepancies between our results and the results in experiment conducted by Lupianez and colleagues (1997; 1999) must be explained by differences between task parameters that were used. Although we did use the

same general cue-target paradigm, several differences were present that may have contributed to the difference in the onset of IOR between Lupianez's and this study.

An important difference between our and Lupianez's discrimination task concerned the presentation time of the cue, which was longer in our compared to Lupianez's experiment, 200 or 400 versus 50 ms. respectively. As a consequence, perhaps people had a tendency to disengage more quickly from a location that does not show any further change after the presentation of a stimulus compared to a location in which a change does occur, namely the disappearance of the stimulus. In the latter situation the occurrence of IOR may be delayed as a result. Another difference was the kind of cue being used, a face vs. a flicker of light. It has been shown that a face readily captures attention (Mack et al., 2002; Ro et al., 2001; Theeuwes et al., in press). If the onset of disengagement depends on the onset of attentional engagement, then a more rapid allocation of attention to the cued location may result in earlier disengagement and thus an earlier onset of IOR. However, faces also have been shown to retain attention and delay the disengagement process (Bindemann et al., 2005). Although potential differences in attentional capture and disengagement between a face and a light flicker could have contributed to the differences in the onset of IOR, it is not clear how and what kind of an effect this may have had. It is however unlikely that the differences in the onset of IOR can be explained by the fact that different SOAs within subjects have been used in this study, because in the study by Lupianez and colleagues (1997) this was the case as well. Also, in the study by Lupianez and colleagues (1999) the different SOAs were presented between sessions, but similar results concerning the onset of IOR were found. Besides differences in the duration of the SOA, in our study the temporal uncertainty of the onset of the target was increased to reduce expectancy effects. This increased temporal uncertainty was established by using different SOA durations, 174, 187, 200, 213 and 226 ms. for the short SOA and 374, 387, 400, 413, 426 ms. for the long SOA condition. This was not the case in Lupianez's studies. The rationale behind this approach was that increased temporal uncertainty would increase the difficulty of the task, thereby delaying the IOR as has been shown by Gabay and Henik (2010). It therefore seems unlikely that this difference in temporal uncertainty between our and Lupianez's task design can be used to explain the earlier occurrence in IOR in our study.

Besides differences related to the cue, perhaps differences in the targets being used played a role in the earlier onset of IOR in our experiment. Using a letter discrimination task in which subjects had to discriminate between an 'O' and a 'X', IOR did not occur at 400 ms SOAs, but at the 700 ms SOA (Lupianez; 1997). IOR was not observed at all, even during the

1000 ms. SOA, when a more difficult letter discrimination task with the letters 'M' and 'N' was used. In our study the targets were spatial gratings with different orientations. Although we used a different kind of target, it can be argued that our task is quite difficult since only a 10 degree difference in orientation was used. Still, IOR at the 400 ms SOA was observed. Perhaps discriminating between letters compared to spatial gratings requires more thorough integration of information or the involvement of higher-cognitive processes and the activation of semantic representations before a response can be made, thus resulting in later disengagement from the cue and no IOR at the 400 ms. SOA.

To summarize, it is likely that the differences in task parameters have contributed to the difference in the onset of IOR between this and the study by Lupianez and colleagues (1997). Several cue and target related differences may be involved. The earlier onset of IOR in this study may be due to longer cue-presentation times or because of the different cues that were used compared to the study by Lupianez (1997). Also, the difference in targets, letters vs. spatial gratings, may have played a role. Besides the important difference in the onset of IOR, two other differences were mentioned. The amount of IOR was not similar between the two tasks at the 400 ms SOA while this was the case in the study by Lupianez (1997) at the 700 ms SOA. Also, our results seem to be more consistent with the bigger capture hypothesis in which the IOR effect is stronger in the localization compared to the discrimination task, but is weaker at shorter SOAs. The results at 100 and 400 ms SOAs obtained by Lupianez (1997) resemble the later disengagement hypothesis better. However, considering the fact that IOR occurred sooner in our study and was not present at the 400 ms SOA in the discrimination task in Lupianez's study, it becomes difficult to compare these results. Perhaps a better comparison would be between SOAs that induce IOR, which is the 700 ms SOA in Lupianez's study. Considering longer SOAs, an increase in the strength of IOR was observed for both tasks at the 700 SOA compared to the 400 SOA. Although the SOAs are different compared to our study, this increase in the strength of IOR is consistent with our results. Thus, it could be that the difference in how the amount of IOR changes from shorter to longer SOAs between the two tasks can be explained by the difference in the onset of IOR. Also, the amount of IOR may become more similar between the discrimination and the localization tasks at longer SOAs as was found in Lupianez's study at the 700 ms SOA. It is important to note that because several task parameters were different between Lupianez's and our study, it can not be determined how much each individual factor has contributed or if it has contributed at all to the different results. More research in which task parameters are systematically

altered is required to shed light on this issue. Suffice to say is that the onset of IOR seems to be easily influenced by task parameters.

Because the attempt to eliminate the IOR effect failed, the potential emotional modulations on the cue-validity effect could not be examined. Instead, emotional modulation of IOR was assessed. Results showed that in all three conditions in which IOR was observed, a significant reduction in the magnitude in IOR was present for targets following the threat compared to the neutral cue in the acquisition phase. Only in the short SOA discrimination condition no effect of threat on reaction times was observed. This null finding may be explained by the absence of neither an IOR or a cue validity effect in the baseline and acquisition phase. With the task parameters used in this condition it probably operated on the boundaries of IOR and cue validity effects, making it difficult to observe an effect of threat on one of these mechanisms. It could very well be that such effects cancelled each other out, since the IOR and cue-validity effect result in opposite behavioural results.

Concerning the emotional modulation of IOR two important observations can be made in this study. Most importantly, the amount of IOR is reduced in the threat compared to the neutral condition. Secondly, it seems that the magnitude of IOR is reduced differently in the localization compared to the discrimination task. In the localization task IOR is reduced due to both faster response times to valid and slower response times to invalid targets, while in the discrimination task IOR is reduced only due to faster response times to invalid targets. These results raise two questions. First, what mechanisms are involved in the reduction of IOR. Secondly, can these mechanisms be differently affected by the same threat-related stimulus in different tasks.

In order to comprehend why IOR may be reduced in certain situations it is important to consider its function from an evolutionary perspective and discuss the mechanisms that underlie IOR. After the discovery of the IOR phenomenon researchers suggested that its function is to enhance visual search by inhibiting relocation of attentional resources to previous attended locations (Posner et al., 1984; Klein, 1988). Although it may be adaptive to reflexively orient attention towards new objects in the environment, evolution seems to have limited the duration of attention towards these stimuli to maintain the organism's ability to scan the remainder of the environment for potential important stimuli (Sapir et al., 1999). This view on the functionality of IOR emphasises perceptual and attentional mechanisms. However, motor-related processes have also been suggested to be involved in IOR. Zhou (2008) suggested that response inhibition to validly cued targets contributes to the IOR effect. Further evidence is provided by Pastötter and colleagues (2008). These researchers examined

the neural correlates of response inhibitions by looking at event-related beta oscillations. Oscillations of beta activity have been related to motor activity (Jurkiewicz et al., 2006). Event-related desynchronization (ERD) is assumed to represent cortical activation and reduced ERD thus suggests cortical deactivation, hence response inhibition. In a cue-target paradigm that induced IOR, less event-related desynchronization (ERD) was found on valid compared to invalid trials which is indicative for response inhibition. Other evidence for motor-related processes involved in IOR comes from studies by Prime and Ward (2004; 2006) in which the motor-related Lateralized Readiness Potential (LRP) in relationship to IOR was examined. In both studies a delay in the onset of the target-locked LRP to valid compared to invalid targets was found when IOR was present. This delay in onset of the LRP after presentation of the target may represent the delayed duration of processes responsible for stimulus evaluation and response selection. However, no differences in the onset of the response-locked LRP was found, indicating that IOR is not caused by inhibition of motor planning or execution suggesting that only premotor effects are involved in IOR. Although these results may not be consistent with findings from Zhou (2008) and Pastötter and colleagues (2008) who both emphasized the role of response inhibition in IOR, both studies indicate that motor-related processes may play a role in IOR. A response-oriented hypothesis was proposed (Klein & Taylor, 1998; 2002) that states that when subjects are asked to detect or localize a target, they try to withhold responding to the cue to prevent a wrong response. This motor inhibition to the cue induces delayed responses to subsequent targets at the same spatial location, because of their shared spatial location and the requirement of location based responses to the targets.

Although IOR has been studied intensively, there is still much debate about the roles of attentional, perceptual and motor-related processes involved in IOR. In a study by Zhou (2008) the contributions of perceptual, attentional and motor processes were examined to the IOR effect. In a series of experiments results showed that IOR is caused by facilitation of allocating attentional resources to the uncued location and by response inhibition of the cued location. Interestingly, perceptual processing did not differ between cued and uncued locations. This latter finding is explained by the fact that it is not adaptive to greatly inhibit perceptual processing of cued locations in the real world. Potential dangerous objects, e.g. a predator, can occur anywhere irrespectively of previous distracters and inhibited perceptual processing could be disadvantageous to the organism. However, it could be argued that inhibited attentional allocation to cued relative to uncued locations and inhibited responses to cued locations is maladaptive when faced with a potential dangerous stimulus. It would make

evolutionary sense if the mechanisms involved in IOR can be modulated by the emotional valence by the cue in such a way that IOR can be reduced, thereby facilitation processing of and responding to validly cued targets.

Recently some studies have addressed this issue, but there is still much debate whether the mechanisms of IOR are affected by biologically relevant and emotionally significant information. Some researchers have suggested that IOR is insensitive to the nature of the cues that initially attracted attention and is blind to biologically relevant information (Taylor and Therrien, 2006). Several studies in which the IOR effect was equivalent in magnitude following emotional and neutral cues support this view (Stoyanova, Pratt & Anderson, 2007; Lange et al., 2008). However, other studies did find that IOR could be affected by emotional stimuli, such as angry faces (Fox et al., 2002) and sad faces in depressed patients (Dai & Feng, 2009). Interestingly, in the study by Fox and colleagues (2002) a discrepancy between high and low anxious subjects was found. Subjects with higher self-reports of state anxiety compared to low-anxious subjects showed a stronger reduction in the amount of IOR following an angry cue. It could be hypothesized that the IOR effect can be affected by mood-related and emotionally salient stimuli, such as a sad face for a depressed and an angry face for an anxious person. However, in our study no significant correlations between the magnitude of the reduction of IOR and state anxiety and BIS/BAS scales were found. This may be attributed to several factors, such as a lack of power due to the small sample size. Another reason could be that the SOAs used were too short to find differences between subjects. At these relatively short SOAs perhaps everyone, irrespectively of their level of anxiety, would experience the same amount of IOR. Considering the severity of the level of threat imposed by the cue, which is supported by the higher discomfort scores given to the CS+ compared to the CS-, this seems a plausible explanation. It would be interesting to see whether reductions in the magnitude of IOR are correlated with personality traits when longer SOAs are used. Perhaps at longer latencies differences in the amount of IOR between high and low anxious subjects emerge.

Although a reduction in IOR has not been found consistently, in this and some previous studies significant reductions in IOR have been observed. Research has shown that both perceptual-attentional (Posner & Cohen; Reuter-Lorenz et al., 1996) and the motor-related processes (Fuentes et al., 1999; Tassinari et al., 1987; Klein & Taylor, 1994; Godijn & Theeuwes, 2002; Pastötter et al., 2008; Zhou, 2008) are involved in IOR and these processes may be involved in the reduction in IOR. Fox and colleagues (2002) suggested that the reduction in IOR observed in their study may be attributed to delayed attentional

disengagement in response to the threat-related cue resulting in longer dwell time at the cued location and therefore a delay in the onset of IOR. However, based on the reaction time data obtained by Fox and colleagues (2002) and the results in this study, delayed attentional engagement may not be able to explain the reduction in IOR entirely. Delayed attentional disengagement may account for the faster reaction times to valid targets, but it would also have an impact on response times on invalid targets. In a study by Massar and colleagues (in press) delayed attentional disengagement by the threat compared to the neutral cue resulted in slower reaction times to invalidly cued targets in the threat condition. However, although IOR was reduced in the study by Fox and colleagues (2002) and in the discrimination task in this study, reaction times to invalid targets did not differ between the threat and the neutral cue. If attentional disengagement is delayed one would expect to find slower reaction times to invalid targets following a threatening cue compared to a neutral cue. Instead, reaction times were similar suggesting that some other processes may be involved in the reduction of IOR. One way to gain more insight into what mechanisms may have contributed to the reduction of IOR are neurophysiological measurements, especially when they interact with behavioural results.

Interactions between behavioural and neurophysiological measures have been reported in previous studies in the context of the cue-validity effect. In a study by Pourtois and colleagues (2004) increased accuracy and P1 amplitude to targets following an fearful facial expression was found. Also, faster reaction times to targets following an angry compared to a neutral face were observed, but only for targets appearing in the left visual field. Facilitated reaction times and P1 amplitudes to target following an angry face compared to a happy face were found in a study by Santesso and colleagues (2008) and in a study by Li and colleagues (2005), using IAPS pictures, in high but not in low anxious subjects. These results suggest that involuntary spatial orienting to a location of a threat-related stimulus enhances sensory processing of visual inputs occurring at the same location and contributes to the mobilization of cerebral and somatic resources that contribute to the organism's ability to cope with biological relevant events (Halgren & Marinkovic, 1995). This may result in enhanced reaction times and accuracy when subjects respond to targets.

Based on these results we explored the possibility of behavioural and neurophysiological consistencies in the context of IOR, especially the reduction of the amount of IOR in the threat condition. A main ERP component of interest was the P1. The P1 component represents an early stage of visual processing which is modulated by both voluntary spatial attention (Heinze et al., 1994; Mangun, 1995; Mangun & Hillyard, 1991) and reflexive attention (Hopfinger & Mangun, 2001). In the IOR literature it has been shown

that the P1 amplitude is larger to invalidly cued compared to validly cued targets (see Prime & Ward, 2006 for an overview). In this study an IOR effect on an early visual processing level was found as well, represented by larger P1 amplitudes to invalid compared to valid targets. Interestingly, this study showed that a stronger IOR effect on a behavioural level is associated with a stronger IOR effect on an early visual processing level. This holds true for the localization as well as the discrimination task, providing further support for the hypothesis that perceptual and attentional processes play a role in IOR. According to the inhibition-of-attention hypothesis postulated by Posner and colleagues (1984) the discrepancy in P1 amplitudes arises because attention is inhibited from returning to the previously cued location relative to a novel location. It could be argued that the longer the time between cue and target, the more disengaged the subject is from the cued location. As a result, it would be more difficult to allocate attentional resources towards a previously attended location compared to a new location and respond to a target, resulting in a stronger IOR effect on a behavioural and an early visual processing level. It is important to note that although no behavioural IOR effect was found in the discrimination task in the short SOA condition, a marginally significant IOR effect for the P1 was found. This discrepancy between behavioural and sensory processing IOR effects has been found before (Hopfinger & Mangun, 1998; Eimer et al., 1994) and also in the opposite direction, that is significant IOR on a behavioural level but no IOR effect on a sensory processing level (Hopfinger & Mangun, 2001). These findings are indicative for the involvement of other factors besides inhibition of sensory processes (Posner & Cohen, 1984) or perceptual processes (Reuter-Lorenz et al., 1996) in IOR, such as inhibition of response selection (Fuentes et al., 1999) or inhibition of motor processes (Tassinary et al., 1987; Klein & Taylor, 1994; Godijn & Theeuwes, 2002). Perhaps inhibition of motor-related processes did not take place in the short SOA discrimination condition, resulting in the absence of a behavioural IOR effect, although the visual system was already sensitive to the delay between cue and target.

Considering the reduction of IOR observed in this study two important observations can be made. First, the reduction in IOR on a behavioural level is not associated with a change in the IOR effect on an early visual processing level. Although IOR on a behavioural level was still present on short and long SOAs in the localization task for both cue types, IOR was not present in the acquisition phase at long SOAs in the discrimination task when a threatening cue was presented. Still, in all these conditions a significant IOR effect on a visual processing level was observed that did not change between the threat and the neutral condition. A second observation concerns the presence of a trend concerning a general

modulatory effect of the threat cue on the target-locked P1. In previous studies a significant larger P1 to validly cued targets was observed (Pourtois et al., 2004; Santesso et al., 2008; Li et al., 2005). In this study not all results were significant, which may be due to the small sample size, but an interesting trend in the data was found. As already discussed, a trend was observed concerning the amplitude of the target-locked P1 with larger amplitudes on trials with short compared to long SOAs in the localization task and larger amplitudes on trials with long compared to short SOAs in the discrimination task. The threat cue induced an increase in the target-locked P1 in the localization and the discrimination task on trials with short SOAs compared to long SOAs. In the discrimination task, the target-locked P1 became even larger on trials with short compared to long SOAs, while this was the other way around in the neutral condition. This indicates that the threat cue may have facilitated target processing at shorter intervals which resulted in larger P1 amplitudes on trials with short compared to long SOAs. An important notion is that all of the above mentioned effects did not differ between validly and invalidly cued targets. It may represent a general effect that operates irrespectively of target location. These differences in emotional modulation of P1 amplitudes between targets in trials with short and long SOAs have been found before. In a study by Fox and colleagues (2008) using angry facial expressions increased target-locked P1 amplitudes were found following angry faces in trials with short SOAs (300 ms.), but not at longer SOAs (750 ms.). This suggests that the presentation of a threat-related stimulus, being an angry face or a neutral face that has acquired threat-related valance through instructed conditioning, can result in a brief enhancement of sensory targets. This facilitation disappeared in the long SOA condition, resulting in no effect of threat on the target-locked P1. However, in contrary to this study in which this effect was not significantly different for valid and invalid targets and thus more general in nature, the study by Fox and colleagues (2008) found this effect only to valid targets. Because the trend observed in this study on how the P1 is modulated by the threat cue, with larger P1 amplitudes to target on trials with short compared to long SOAs in the threat condition, its role in the reduction of IOR is unclear. IOR was reduced at short and long SOAs in the localization task, but the facilitation of the target-locked P1 by the threat cue was only observed in the short SOA condition. The target-locked P1 in the discrimination task was stronger on trials with long compared to long SOAs, but the threat cue only facilitated the P1 in the short SOA condition and no such effect seemed to be present for the long SOA condition. However, reduction in IOR was present at the long SOA condition in the discrimination task. Therefore, although a trend in emotional modulation of the P1 was found, it is not clear whether this effect did play a role in the reduction of IOR.

Taken together, in contrary to other studies in the context of emotional modulation of the cue-validity effect, this study can not provide evidence that the reduction in the IOR effect on a behavioural level is associated with changes in the IOR effect on an early visual processing level. Perhaps attentional and perceptual processes at later stages are modulated and contribute to the reduction in IOR. Besides emotional modulation of perceptual and attentional, it has been shown that motor-related processes can also be modulated by emotional stimuli. In a study by Huang and Luo (2006) the onset of the response-locked LRP was shorter after presentation of IAPS pictures with a negative emotional valance compared to positive and neutral pictures. These results indicate that emotional stimuli can affect reaction readiness. Although more research is needed, based on research showing a role of motor-related processes in IOR we hypothesize that motor related processes could have played a role in the reduction of IOR.

Besides the reduction of IOR in response to the threat cue, another interesting finding concerns the way how IOR is reduced in the localization compared to the discrimination task. In the localization task, although IOR is still present, the amount of IOR is reduced due to faster reaction times to valid and slower reaction times to invalid targets. However, in the discrimination task on trials with long SOAs, IOR seemed to be reduced entirely because of faster reaction times to valid targets while no difference in reaction times to invalid targets was observed. Also, reaction times to invalid targets did not differ between the neutral and the threat condition. To our knowledge this is the first time that differences in how IOR is reduced between different task are reported. Assuming that this difference in how IOR is reduced between the two tasks is valid and can be replicated in future studies, two possible explanations can be provided that may contribute to this discrepancy. First, the difference in the attentional sets adopted in the context of a localization compared to the discrimination task may have played a role. Secondly, differences in response-related processes could have played a role.

The differences in attentional sets between a localization and a discrimination task has been discussed before in the context of different cueing effects between tasks (see Lupianez et al., 1999), but could also be considered in an attempt to explain the differences between the two tasks in how the IOR effect is reduced. The attentional set in the detection task favors encoding of new event representations. If the threat cue is able to hold on to the allocation of attention to that spatial location for a longer time period than the neutral cue, than the detection of new events would be expected to show the behavioral results observed in this study. A bias for attention to valid targets would result in a facilitation in response times to

valid targets and slower reaction times to invalid targets following the threatening compared to the neutral cue and thereby reducing IOR. The attentional set in the discrimination task favors integration of present and past information. It thus favors processing of cued targets. When a person has adopted this attentional set, the presence of a threat may accentuate the need to integrate new information with past and potential dangerous events that occurred at the same spatial location. However, IOR might interfere with the ability to integrate past and new events that occurred at similar spatial locations, because it inhibits orienting to the previously attended location compared to a new location. Perhaps the threat cue activates processes that selectively inhibits IOR in order to make the integration of past and present events within the same representation possible, while not interfering with allocating attention to uncued spatial locations. In this way, there is no reason for response times to differ between invalidly cued targets following a threatening and a neutral cue. Also, response times may not differ between invalidly and validly cued targets in the threat condition. Both effects were found in the discrimination task. Following this reasoning, a critical assumption in order to explain how IOR is reduced in the discrimination task is that people do not experience the same amount of delay in disengagement induced by the threat cue in the discrimination compared to the localization task. Because if this is the case, one would expect dissimilarities in response times to invalidly cued targets following a neutral compared to a threat cue, and this is not the case in the discrimination task. Perhaps the attentional set induced by the discrimination task already delays disengagement to such an extent that it can not be delayed for much longer, not even by a threatening stimulus. Disengagement in a detection task normally occurs sooner in order to facilitate detection of new events and may therefore be more susceptible to a delay in disengagement of attention induced by a threatening stimulus. It is, however, unclear why this has not influenced early visual processing as represented by the P1. Based on the P1 amplitudes IOR did take place in the discrimination task and no delay in disengagement on an early visual processing level was found in the detection task. Perhaps these early visual processes are not susceptible to attentional and perceptual processes that take place at later latencies that may be responsible for the reduction in the amount of IOR.

Motor-related processes could also have played a role in the difference in how IOR is reduced between the localization and the discrimination task. Motor-related processes can also more easily account for the fact that no evidence for emotional modulation of early visual processing was found. A localization and a discrimination task differ not only in respect to attentional sets, but also in motor-related processes such as stimulus evaluation and response-selection operations, which have been shown to be involved in IOR (Prime & Ward, 2004;

2006). If motor-related processes are affected by the emotional valance of the cue and motor-related processes differ between a localization and a discrimination task, than this could contribute to differences in how IOR is reduced between tasks.

To summarize, in this study the threat cued induced a reduction of the IOR effect in both the localization and the discrimination task. Based on previous research perceptual, attentional and motor-related processes are involved in IOR and could be involved in the reduction of IOR observed in this and other studies (e.g. Fox et al., 2002, Dai & Feng, 2009). In this study no evidence was found for the involvement of early perceptual and attentional processes in the reduction of IOR. Perhaps emotional modulation of perceptual and attentional processes at later stages and motor-related processes have contributed to the reduction in the magnitude of IOR. More research is required to examine the relative roles of such processes in the reduction of IOR. The results of this study also suggest that IOR can be reduced in different ways depending on the task. Two possible factors, difference in attentional sets and different motor-related processes, have been suggested that might have contributed to the difference in how IOR is reduced between the localization and the discrimination task. More research in how IOR can be reduced and what factors may influence this process is required. A suggestion would be to investigate the effects of task difficulty on how IOR is reduced. As has been shown by Lupianez and colleagues (1999), the onset of IOR is delayed at longer SOAs when discrimination becomes more difficult. The authors suggested that the increased difficulty accentuates the attentional set to integrate information and therefore delays the onset of IOR even more. By varying the difficulty of the discrimination task and thereby the strength of the attentional set one could assess whether this has an impact on how IOR is reduced. The effect of task difficulty could also be investigated in relation to the spatial cueing effect. Several studies have highlighted the role of the disengagement process in the difference in response times to valid and invalid targets following threat-related compared to neutral cues. However, the spatial-cueing discrimination tasks that have been used thus far were relatively simple, such as discriminating between squares and circles (Fox et al., 2002) or horizontally and vertically oriented dots (Li et al., 2005). Perhaps this difference in disengagement following the threat-related compared to the neutral cue diminishes as discrimination becomes more difficult. Another suggestion would be to use different kinds of task with different motor-related processes and examine whether this has an impact on how IOR is reduced. By examining motor related brain activity, such as the LRP or beta-oscillations, more direct evidence for emotional modulations of motor-processes relevant to the reduction of IOR can be acquired. Taken together, this would not only provide more

insight in how IOR can be reduced, but also in what mechanisms are involved in IOR in general.

Several studies have shown emotional modulation of the P1 for emotional faces (e.g. Batty & Taylor, 2003). However, no such modulation has been found in this study. The P1 did not differ in amplitude between the threat and the neutral cue in the acquisition phase in both tasks, suggesting that early visual processing of the cues did not contribute to the reduction in IOR observed on a behavioural level. There were however several significant differences in amplitude strength, including differences between short and long SOAs and left and right location in the localization task. Also, cue type had a significant effect on the P1 in the discrimination task, showing larger cue-locked P1s to the CS+ compared to the CS- in both the baseline and the acquisition phase. These results were not expected and are difficult to explain. All SOAs were longer than the time-window in which the P1 was present (100-130 ms.) and cue type was alternated between subjects. Therefore, no explanation for the above mentioned effects can be given based on these task parameters and it seems likely that these results are coincidental.

A lack of finding an emotional modulatory effect on the cue-locked P1 has been observed before in a dot-probe paradigm using angry, happy and neutral face cues (Santesso et al., 2008). The absence of an effect of angry compared to neutral faces on the P1 was replicated by Eldar and colleagues (2010). However, Bar-Haim and colleagues (2005) reported reduced P1 amplitudes to fearful faces compared to neutral, sad, happy and angry faces. Based on these findings it seems that only fearful faces affect the amplitude of the P1 in spatial-attention tasks. In this study neutral faces and instructed fear conditioning was applied and no modulation of the cue-locked P1 was observed. Although a fearful and an angry face both signal the presence of a threat, they convey a different message. A fearful face signals the present of a danger somewhere else in the environment, while the angry face is itself the object of danger. It could be hypothesized that when instructed conditioning was used the neutral face acquired threat-related valence and most likely became the object to be afraid of, because it became a predictor of the aversive event. The threat cue in this study may therefore be more similar to an angry face compared to a fearful face and no P1 modulations would be expected, which is consistent with the results in this study. Another possible explanation is that the lack of a difference in stimulus properties between the threat and the neutral cue, both were neutral faces, contributed to the absence of an effect on the P1.

Besides examination of the cue-locked P1, one of the main goals of this study was to investigate EEG-activity related to medial frontal areas in response to the cue. In several

reward and attention tasks either positive or negative deflections on the EEG have been observed 200-400 ms. post-stimulus that are strongest over medio-frontal electrodes. These waves have been associated with evaluative processes (Yeung et al., 2005; Potts et al., 2006), anticipatory processes (Pizzagalli et al., 2003) and attention selection mechanisms (e.g. Kenemans, 1993; Potts et al., 1996). Based on these findings that indicate the potential role of medial frontal areas in evaluation, anticipation and attention selection, we hypothesized to find a modulatory effect of the threat cue on EEG-activity at medio-frontal regions in an emotional-modified spatial cueing task using instructed aversive conditioning. In this paradigm the cue gains motivational relevance, because it is predictive for the occurrence of an aversive event. This may influence attentional processes allocated to the cue and have an impact on evaluative and anticipatory processes. Although the presentation of the cue and the presentation of the aversive event is not related to action choices made by the participants, a motor response does not seem to be a prerequisite for processing in the MFC to occur, as has been shown in previous studies (e.g. Yeung et al., 2005).

In this study a significant stronger positive deflection peaking around 220 ms over medio-frontal electrodes following the threat cue compared to the neutral cue was found. Based on previous studies one might expect to find a negative wave, since a negative wave over frontal electrodes has been related to anticipation of an aversive event (Baas et al., 2001; Pizzagalli et al., 2003) and to reward expectation violation when an expected reward is not received (Yeung et al., 2005; Potts et al., 2006). Although these are two different processes, both indicate anticipation or evaluation of a negative event. Because the threat cue in this study serves as a predictor for the occurrence of an aversive event, a wave with a negative polarity in response to the CS+ might be expected. However, a positive deflection was observed. In the reward literature a positive wave with a similar latency and scalp distribution as the positive wave found in this study has been described. The wave is called the P2a and has been observed in gambling tasks when unexpected rewards were received (Potts et al., 2006). A negative wave, the medial frontal negativity (MFN), was observed when expected rewards were not received (Yeung et al., 2005; Potts et al., 2006). A model was proposed in which this difference in polarity is caused by different firing rates of neurons involved in reward processing in the ventral tegmental area (VTA) from which projections are sent to medial frontal areas. These dopaminergic neurons change their firing rate according to violations of reward expectations, increasing their firing rate to unexpected rewards and decreasing their firing rate to unexpected non-rewards (Schultz, Dayan, & Montague, 1997). Although this model provides a plausible explanation for the differentiation between these

two waves of opposite polarity in the reward literature, it seems unlikely that this mechanism can account for the finding in this study, namely a stronger P2a in response to a stimulus that serves as an indicator for the potential occurrence of an aversive event.

Interestingly, in the study by Baas and colleagues (2001) a positive wave originating from frontal areas was found at 160 ms. latency that was stronger for the CS+ compared to the CS-. The authors suggested that this wave may reflect an attention selection mechanism with similar properties as the Frontal Selection Positivity (FSP) (Kenemans et al., 1993). In the attention literature different names have been used to label these positive potentials such as the anterior P2 (P2a) (Potts and Tucker, 2001), the Frontal Polar (FP) (Guillem et al., 2001) or the Frontal Selection Positivity (FSP) (Kenemans et al., 1993). Although it is not certain whether these waves are the exact same components, the time-course and medio-frontal scalp distribution are very similar. From this point on we will refer to this positive wave as the P2a.

In studies focussing on attention selection mechanisms the P2a has been observed in target detection tasks and is associated with processes concerning attention selection of task-relevant stimulus features, showing larger P2a amplitudes to the task-relevant stimuli compared to task irrelevant stimuli (Kenemans et al., 1993; Potts et al., 2004a; Potts et al., 2004b). The P2a is more positive to stimuli that are instructed targets in the participants task and does not seem to vary between a variety of target stimuli, such as auditory (Potts et al., 1998) and visual (Potts et al., 2004a), and is present in a variety of response tasks, tasks requiring a motor response (Potts, 2004b) or no motor response but silent counting (Potts et al., 1996). The P2a is thus not sensitive to specific features of the stimulus, but to the relevance of the item to the current task (Potts, 2004a; Potts et al., 2004b; Potts & Tucker, 2001). This sensitivity to task relevant items is an important function, because the brain is a limited-capacity information processing system which can only process a subset of the available information at any given time. This is particularly true for systems involved in cognitive control, which help generate goal directed behaviours. Requiring access to this limited-capacity system should thus be limited to the most motivationally relevant information currently available. Attention is a mechanism which acts as a filter, selecting representations for preferential processing. In a model proposed by Posner and Dehaene (1994) and Posner and Peterson (1990) an anterior system located in the Anterior Cingulate Cortex (ACC) is responsible for the detection of task-relevant items, items that are targets in the context of the current task. The spatio-temporal distribution of the P2a and its cognitive-eliciting conditions are consistent with an index of attention selection in the MFC.

This selection mechanism for task-relevant items may extend to affective and motivationally relevant stimuli, because the amplitude of the P2a in this study was significantly more positive in response to the threat cue compared to the neutral cue. The CS+ did not contain any information relevant to the subject's task and no response to the cue was required. However, the CS+ did convey a message, namely the possibility of the occurrence of an aversive event. The cue did not have an intrinsic threat value, but through instructed conditioning an association between the cue and the aversive event was established. Because of this acquired threat valance, which is supported by the lower ratings by the participants for the pleasantness of the CS+ compared to the CS-, the cue did contain affective and motivationally relevant information about a potential threat. It would be adaptive to provide this kind of information access to limit-capacity cognitive control systems in the PFC for further processing and the selection and generation of goal-directed behaviours.

Based on previous findings (e.g. Baas et al., 2001) and this study we hypothesize that the attention selection processes represented by the P2a is not only influenced by task relevant events such as task-relevant items or reward-expectation violations, but also by affective properties of the stimulus, even when no response to the stimulus is required. It could be that if a stimulus is relevant, either because of task-related or more basic motivational and affective reasons, it is selected for further evaluation operations which results in a stronger P2a.

In the localization task no correlations between personality traits and the increase in the P2a were found, but in the discrimination task a negative correlation between the increase of the P2a amplitude in response to the threat cue and BIS scores was found. The Behavioural Inhibition System (BIS) is believed to underlie the emotion of anxiety and individuals high on BIS are hypersensitive to cues of punishments (Corr, 2004; Gray & McNaughton, 2000). Therefore, it could be expected that threatening stimuli are highly relevant to people with high BIS scores and larger P2a amplitudes could be anticipated compared to people with lower BIS scores. However, the opposite effect is observed in the discrimination task. The P2a amplitude becomes progressively smaller in people with higher BIS scores compared to people with lower BIS scores. For people with the highest BIS scores the P2a amplitude in response to the threat cue became even smaller compared to the P2a amplitude to the neutral cue. Based on behavioural and eye-tracking results from anxious patients the vigilance-avoidance hypothesis was proposed that states that anxious individuals show a rapid early response towards the aversive stimulus while at later stages they subsequently initiate attentional avoidance away from the aversive stimulus as an attempt to alleviate the fear reaction (Koster et al., 2005;

Mogg et al., 2004; Plfughshaupt et al., 2005). This effect has been observed in several ERP studies with high anxious subjects (Mercado et al., 2009) and patients with a social anxiety disorder (Mueller et al., 2009). Perhaps individuals with high BIS scores have a tendency to try to avoid severe threats, such as the threat cue in this study, which results in a weaker P2a amplitude. Although the P2a occurs relatively early compared to the later stage characterised by attentional avoidance referred to by the vigilance-avoidance hypothesis, the P2a did show a reduction compared to the neutral cue in people with the highest BIS scores. Perhaps this illustrates the early phase of an attention selection mechanism that results in attentional avoidance of the threat-related location.

The association between the P2a and relevance processing, whether it being task-related or based on motivational and affective factors, may suggest that medio-frontal areas are involved. The neural network involved in relevance processing involves several areas, such as the ventral striatum (Gray, 1999; Williams, Rolls, Leonard, & Stern, 1993), the amygdala and other limbic regions (Gray, 1999; Kalivas & Nakamura, 1999). Both the ventral striatum (Williams & Goldman-Rakic, 1993) and the amygdala (Vogt et al., 1992) have connections to the medial frontal cortex. The MFC also receives input from higher-order perceptual and motor cortices (Williams & Goldman-Rakic, 1993; Van Eden et al., 1992). The MFC seems thus highly qualified for relevance processing. For instance, by using both perceptual and motor representations and information about reward prediction, the MFC could identify perceptual objects and action plans associated with reward-prediction violations, which is a crucial step in understanding why the prediction was violated and how this can be avoided in the future. Also, the MFC could integrate perceptual and motor information together with signals concerning motivational relevance, either task-related or emotional relevance, such as the presence of a potential threat. When considering threat processing, it is thought that the amygdala and ACC play an important role. Activation of these areas has been found in response to threatening pictures of snakes and spiders (Carlsson et al., 2004; Carretie et al., 2005) and angry and fearful faces (Morris et al., 1996; Pissioti et al., 2003). The amygdala plays an important role in the evaluation of the motivational significance of sensory stimuli and it has been suggested that, because of their extensive reciprocal connections, the amygdala and ACC operate together to produce affective behaviours (Vogt et al., 1992).

As already described it is thought that the MFC receives information from multiple brain areas necessary to process relevant events, but how the MFC carries out this function has been not addressed. According to the Gate-control theory (Braver & Cohen, 2000), the

MFC may serve as a gate through which both perceptual and motor representations gain access to preferential processing by the PFC. Because the PFC is a limited-capacity system and can only process a limited amount, a selection process needs to take place to determine which information should gain access. This selection may be based on the relevance of these representations. Relevance can be signalled by the difference in the firing rate of neurons located in the VTA concerning reward-prediction violations. Another possible way for information to gain access through such a gate may be by signals from the amygdala concerning threat-detection, highlighting the relevance of the associated perceptual and motor representations. In this way the P2a may represent the same process, namely relevance processing, but is produced via different pathways, one from the VTA and one from regions involved in threat-detection, possibly the amygdala. Perhaps the negative correlation between P2a amplitudes and BIS scores in the discrimination task represents the process of trying to reduce the flow of information to the PFC for further processing, because the information may be considered to be too threatening by people with high BIS scores. By using techniques with stronger spatial resolutions compared to the electroencephalogram, such as functional magnetic resonance imaging (fMRI), the functional significance of these pathways and potential modulations by personality traits could be examined.

In conclusion, in this study an emotional-modified spatial cueing paradigm with instructed-conditioning to modulate the level of threat and EEG was used to examine emotional modulation of exogenous attention and its neurophysiological underpinnings. An attempt was made to delay the onset of IOR in order to measure relative late cue-locked EEG activity and emotional modulation of the cue-validity effect. Based on previous research in which IOR was delayed by using a discrimination task instead of a detection task, an attempt was made to replicate these findings. However, in this study a localization and a discrimination task was used. Although an effect of task on the onset of IOR was found, with an earlier onset of IOR in the localization compared to the discrimination task, the attempt to sufficiently delay the onset of IOR failed. Several task parameters most likely have been responsible for the fact that IOR was present in most conditions. Interestingly, the amount of IOR was reduced in the threat compared to the neutral condition. Based on previous research, several processes, including perceptual, attentional and motor-related, have been shown to be involved in the IOR effect. However, based on the P1 to cues and targets no evidence has been found in this study that early perceptual and attentional processes were involved in the reduction of IOR. Other processes, such as later perceptual and attentional processes and also motor-related processes may be involved, although more research is required to shed light on

this issue. An important goal of this study was to examine MFC-related activity in response to the cue, since the MFC has shown to be involved in evaluative, anticipatory and attentional selection processes. Based on the nature of the cue we hypothesized to find modulation of cue-related MFC-activity. Results showed emotional modulation of the P2a, a positive deflection on the EEG originating from medio-frontal electrodes. It is hypothesized that the P2a, which is associated with task-relevance processing, may also be involved in processing of motivational and affective relevant items.

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