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Visual orienting to emotion

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Abstract

The purpose of this thesis was to investigate whether the emotional content of the visual scene influences the inhibitory mechanisms subserving visual orienting. To achieve this aim, I employed a spatial cuing paradigm as the principal methodology. In this paradigm, an irrelevant visual cue is presented to a specific location just prior to the presentation of a target. When the interval between cue and target is sufficiently long (greater than approximately 300 ms), responses to the target are slower when the cue and target location are the same versus different, an effect referred to as inhibition of return (IOR). IOR was employed as a tool to investigate visual orienting in the presence of emotionally relevant stimuli presented as cues and targets in the spatial cuing paradigm. Further, whether the mechanism underlying IOR influenced the emotional evaluations of visual stimuli was also addressed. Adaptive accounts of IOR predict differential modulation of the effect dependent upon stimulus content (emotional, non-emotional). However, the proposed reflexive nature of IOR instead predicts insensitivity to the effect in the presence of emotion, rendering measures of IOR unchanged by the emotional content of cue and target stimuli. Evidence from across 16 experiments supported this latter reflexive hypothesis of IOR, indicating that the mechanisms underlying the effect are blind to the emotional content of the visual scene. However, in a final series of experiments I found affective consequences of IOR for stimulus evaluations, suggesting inhibitory mechanisms of visual orienting are not entirely independent from the emotion system.

Section 1: General Introduction

Chapter 1: Visual orienting of attention and inhibition of return

The ability to prioritise information is important in visual interactions. This can range from selecting the ripe apple from a basket of fruit, to rapidly applying the breaks whilst driving when an unknown object appears in the road ahead. Two apparently separate yet related systems work together to prioritise this visual processing. The first is an attentional system, which facilitates processing of task-relevant information, whilst inhibiting sources of task-irrelevant information. The second is an affective system, which codes and evaluates the emotional content of visual experiences. Reciprocity between these two systems benefits successful guidance of behaviour in response to current information in the visual surround. The purpose of this thesis was to investigate the relationship between these two systems by measuring overt behavioural responding under conditions when both systems may be engaged.

This Introduction is divided into four chapters. The present chapter addresses the role of the attention system, specifically, visual orienting and inhibition of return. Chapter 2 reviews visual responses to emotional stimuli, with Chapter 3 integrating these two discussions and presenting the overarching hypotheses of this thesis and the experiments reported. Finally, Chapter 4 describes the General Methods of this thesis.

Orienting visual attention

The term visual attention does not describe a unitary phenomenon, and may instead be considered more of a construct, traditionally encompassing a series of processes that can be considered within one of three domains (Posner & Peterson, 1990):

first, orienting to visual objects and locations; second, maintenance of an alert state; and third, detection of external visual signals. It is this first domain of visual orienting that is of principal interest here.

Orienting attention is an elementary mechanism for interacting with the visual environment (Posner, Cohen, & Rafal, 1982). Visual orienting can be achieved via overt (movement of head and/or eyes) or covert (head and/or eyes remain stationary) means. The notion that attention is oriented to and moves through locations in space led to the development of a spotlight metaphor of visual attention, where only stimuli falling within the attended region receive visual examination (Posner, Snyder, & Davidson, 1980). However, visual attention may also be directed toward objects. When two spatially overlapping objects are briefly presented together, followed by a visual mask, subsequent perceptual judgements are worse when they involve an aspect of both objects in contrast to when these judgements concern two aspects of the same object (Duncan, 1984). If the allocation of attention were purely spatial in nature, performance would have been equivalent in both judgement conditions as both objects fall within the same region of space. However, this study instead suggests that attention is allocated on an object-by-object basis, with impairments observed in performance when judgements are required about two (or more) objects. Consequently, it has been proposed that visual attention may operate in both location- and object-based frames of reference.

The allocation of attention to locations or objects may be under exogenous or endogenous control. Exogenous orienting describes the reflexive shift of attention to locations and objects in response to a stimulus-driven signal such as the onset of light or sound. In contrast to this, voluntary allocation of attention to an object or location is termed endogenous. Its efficiency is influenced by cognitive load and expectancy, factors that do not affect exogenous orienting (Jonides, 1981). Both exogenous and endogenous orienting systems seem to have overlapping neural substrates (including dorsal premotor and parietal regions), although overall neural activity has been reported as significantly greater during endogenous tasks (Rosen et al., 1999). Typically, the spatial cuing methodology is used to probe the nature of visual orienting under exogenous and endogenous conditions. A typical spatial cuing task is presented in Figure 1.

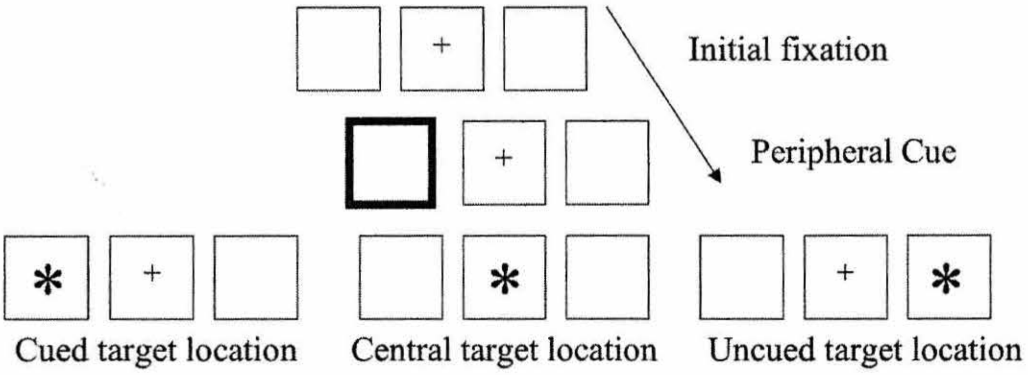

Figure 1. An example of a trial sequence typically used in a spatial cuing task. Note the target to be detected is an asterisk.

Participants fixate centrally at the beginning of each trial, and are instructed to maintain fixation throughout the trial. A peripheral cue is then presented, illustrated here as the brightening of one of the outer boxes. This peripheral cue is thought to automatically attract attention, consistent with attentional attraction by abrupt onsets

(Yantis & Jonides, 1984). Following this cue is a target, which is presented either in a peripheral location or at fixation, requiring detection. The time between cue and target onset, the *stimulus onset asynchrony* (SOA), is manipulated to explore the consequences of cuing attention on target detection. In Posner and Cohen's (1984) seminal paper, the probability of target onset location was manipulated, with targets presented in the centre being the most probable location. This manipulation ensured that participants would maintain their attention to centre, even after peripheral cuing. In a subsequent experiment, targets were presented only in the periphery with central fixation brightening (termed a second or re-orienting cue) prior to target onset. This procedure of encouraging the withdrawal of attention from cued locations back to centre using an additional cue was as effective as manipulating the probability of potential target locations.

There are two reasons why the spatial cuing task is advantageous when investigating visual orienting. First, the paradigm can be easily adapted to incorporate a variety of stimuli as cues and targets, and mode of response can also be easily manipulated. Second, spatial cuing paradigms enable examination of the three component processes underlying visual orienting: engagement, disengagement, and shifting (Posner & Peterson, 1990). Engagement describes the movement of attention to a location or object of interest, which is accompanied by subsequent disengagement that involves the removal of attention from that object or location. Shifting simply refers to the movement of attention in the visual field. These three processes were believed to be subserved by distinct anatomical locations, with disengagement mediated by the posterior parietal lobe, engagement mediated by the thalamus and pulvinar, and midbrain regions (including the superior colliculus) underlying shifting (Posner & Peterson, 1990). More recently, additional regions including the temporal parietal junction and the superior temporal lobe have been implicated in both disengagement and shift components of visual orienting, which may be modulated by the neurotransmitter acetylcholine (see Posner & Fan, 2008, for a review).

This thesis principally concerns covert exogenous orienting (and the role of emotionality within this). To explore this mode of orienting in a spatial cuing paradigm, the peripheral cue is made non-predictive of target location because an unpredictable cue ensures that there is no tactical reason to maintain attention to the cue location to aid task performance. Maintaining central fixation is the most efficient strategy. Exogenous orienting of attention is characterised by a biphasic effect of prior cuing on response times. Cuing initially facilitates target detection when the cue and target are presented in the same (cued) location in contrast to when the cue and target are presented in different (uncued) locations. However, this pattern of responding is reversed with longer SOAs (greater than approximately 300 ms). Cuing a location now results in an inhibitory effect on performance when cue-target locations are the same: Response times are slower to targets presented at cued than uncued locations. This response time effect is called inhibition of return (IOR; Posner et al., 1985).

Posner and Cohen (1984) proposed that facilitation and inhibitory effects measured in exogenous orienting tasks evolved to meet the demands of interactions in the visual environment. Attentional facilitation (as the term implies) promotes efficient processing of visual information present at an attended location. In contrast to this, inhibition reduces the efficiency of processing previously attended locations, preventing perseverative processing and encouraging shifts (covertly and overtly) of attention toward novel locations in the visual environment. Indeed, these benefits and costs of visual orienting to potential target locations are consistent with an attentional spotlight that progresses through visual space (Posner et al., 1980; c.f., Duncan, 1984), and the spotlight metaphor provides parsimony when interpreting data from spatial cuing studies.

Finally, it also worth noting that by employing a peripheral cue that is predictive of target location, within the same task parameters, enables the measurement of endogenous orienting. There is now reason to monitor the cue location because it predicts the likely target location. Moreover, predictive cues can also be presented centrally, which are typically arrows indicating the likely target location. Unlike exogenous orienting, facilitation effects of cuing are seen in response times regardless of SOA with no later IOR effect (Posner & Cohen, 1984). However, if participants endogenously saccade toward (Posner et al., 1985), or prepare an eye movement to (Rafal, Calabresi, Brennan, & Sciolto, 1989), a cue location, IOR is observed.

Inhibition of return (IOR)

In the experiments reported in this thesis, the generation and measurement of IOR was used as a tool to explore the effects of emotionality on visual orienting, with some experiments also examining modulation of attentional facilitation by emotion. The inhibitory and facilitatory consequences of spatial cuing are often conceived as sharing a common underlying mechanism, principally because they are generated and measured within the same methodological parameters, separable only temporally with facilitation occurring early and IOR occurring late. However, Danziger and Kingstone (1999) demonstrated that IOR could be generated with very short cue-target intervals. In their study, a predictive cue was used to direct attention endogenously away from its location to another spatial location where the target stimulus was likely to occur. If the target was then presented at that cued location, IOR was observed even when the SOA was 50 ms. Finding inhibitory effects of spatial cuing with this short SOA suggests that IOR may appear earlier, and be masked by attentional facilitation at cued locations. By directing attention away from these cued locations, earlier measures of IOR are obtained. Danziger and Kingstone's (1999) study is important because it demonstrates that IOR effects may co-occur with attentional facilitation effects, suggesting that these two processes may be manifested through different neural mechanisms within visual orienting.

IOR may be expressed as either an attentional or motoric phenomenon (e.g., Hunt & Kingstone, 2003; Kingstone & Pratt, 1999; Sumner, 2006; Sumner, Nachev, Vora, Husain, & Kennard, 2004; Taylor & Klein, 2000). Attentional IOR represents the traditional view of the inhibitory effect of spatial cuing, where re-orienting of attention is slowed to previously examined locations and objects. Onset of the peripheral cue attracts attention to its location, and the futility of the cue in predicting target location results in the withdrawal of attention to fixation (either endogenously or exogenously by the onset of a re-orienting cue). IOR as an attentional effect has received support from a number of sources, including studies demonstrating the generation of IOR in non-spatial tasks (Lupiáñez, Milán, Tornay, Madrid, Tudela, 1997; Pratt, Kingstone, & Khoe, 1997) as well as in tasks requiring no speeded responding but accuracy measures instead (Handy, Jha, & Mangun, 1999; Klein & Dick, 2002). Furthermore, the sensitivity of IOR to target intensity and target modality, properties which also affect attentional facilitation (Reuter-Lorenz, Jha, & Rosenquist, 1996), has been used to support an attentional locus of IOR.

IOR can also be expressed as a manifestation of the motor system, rather than the attentional system (Klein & Taylor, 1994). One study that identified the importance of the motor system in the generation of IOR required participants to either prepare and / or execute an eye-movement response to potential target locations following an endogenous cue. In the critical condition, participants did not execute the prepared eye-movement, instead making a manual (key press) response. Nevertheless, IOR was measured in responding, suggesting that the mere preparation of an eye-movement to the cued location was sufficient to generate IOR effects on performance even in the absence of an exogenous cue. Interestingly, the same effect was not observed with manual response preparation, which perhaps is indicative that this finding is restricted to the oculomotor system (Rafal et al., 1989).

A motoric account of IOR conceptualises the effect as a reluctance or inhibition of executing a motor action to a previously cued location or object. The onset of a spatial cue activates a motor response to that cued location, which is subsequently inhibited. This inhibition is generated within a visual map of spatial locations that guides action; therefore, IOR can be measured by both saccadic and manual responses (Klein & Taylor, 1994). Inhibition to respond raises the criteria to react to targets presented at cued locations, requiring greater accrual of evidence that a target is actually present there before response execution. Criterion shifts are not needed at uncued locations because no previous visual signal has been presented there (the target onset being the first).

Moreover, if IOR facilitates visual search (as discussed below), in addition to preventing re-examination of previously visited locations, efficient search would also be aided by preventing the execution of unnecessary responses to locations containing distractor stimuli (Ivanoff & Klein, 2006; Ivanoff & Taylor, 2006; Klein & Taylor, 1994). This would suggest that IOR may reduce false alarms, as well as slowing responding. Indeed, Ivanoff and Klein (2001) found slower response times and fewer false alarms to targets presented in cued locations than uncued locations, using a go / no-go task.

To dissociate between potential attentional and motor components underlying IOR, Hunt and Kingstone (2003) presented two tasks that were inherently attentional or motoric in nature. The attentional task required localisation of targets that varied in luminance (bright, dim). As described previously, Reuter-Lorenz et al. (1996) demonstrated that IOR was sensitive to target intensity (larger IOR was observed with more intense targets). The motoric task exploited the fixation offset effect (FOE), wherein removing the central fixation point prior to target presentation facilitates saccadic response times. Abrams and Dobkin (1994) had previously demonstrated that in conditions generating a FOE, the magnitude of IOR was larger than in conditions when fixation remained throughout the trial sequence. In Hunt and Kingstone's (2003) study, participants completed the attentional and motoric tasks, making manual and oculomotor responses. The results were striking. In the saccadic response condition, the magnitude of IOR was larger when the fixation remained (-35 ms) than when the fixation offset (-13 ms) during a trial sequence[1]. However, target luminance did not differentially affect the

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[1] Note that this modulation of IOR by the FOE is in the opposite direction to that previously reported in Abrams and Dobkin (1994). Hunt and Kingstone (2003) speculate this may be owing to different experimental procedures employed between the two studies, and perceptual confusion of cue, fixation and target information in the former study that contribute to the modulation of IOR there.

magnitude of IOR in this saccade condition (~ -24 ms). In the manual response condition, IOR was larger when responding to dim targets (-26 ms) than bright targets (-14 ms). However, IOR magnitude (~ -20 ms) was not modulated by the presence or absence of the FOE when making a manual response. These data suggest a clear dissociation between an attentional IOR effect and a motoric IOR effect at the level of response mode. When making a manual response, IOR is manifested through the attentional system; however, when making a saccadic response, IOR is instead manifested through the oculomotor system (Hunt & Kingstone, 2003; see also Kingstone & Pratt, 1999; Taylor & Klein, 2000).

Furthermore, attentional and oculomotor IOR has been dissociated at a neural level too. Using a traditional spatial cuing task, Sumner et al. (2004) presented peripheral cues that were either luminance changes or colour changes only visible to shortwave sensitive (S) cones. S-cone stimuli are invisible to the retinotectal pathway and superior colliculus but not retinogeniculate pathways. Consistent with Hunt and Kingstone (2003), participants made either a manual detection response to the target or a saccadic response to the target's location. Although luminance cues generated IOR in both response conditions, the S-cone cues resulted in IOR only in the manual condition, and *not* the saccade condition. This absence of IOR with S-cone cues when making saccade responses suggests that oculomotor IOR must be generated through the collicular pathway. It is likely that attentional IOR is instead generated through cortical pathways (although there may be some collicular contributions, Sumner et al., 2004).

The role of IOR in visual cognition

Regardless of the mechanism underlying IOR, its utility in promoting novelty in vision by preventing re-examination of locations and objects has been widely held. Moreover, this functional nature of IOR has been proposed to subserve visual foraging behaviour: An inhibitory tag placed at a previously attended location prevents its re-inspection during real-world search (Klein, 1988). Consequently, many studies have investigated the role of IOR in lab-based visual search (Hooge, Over, van Wezel, & Frens, 2005; Klein, 1988; Klein & MacInnes, 1999; Klein & Taylor, 1994; MacInnes & Klein, 2003; Müller & von Mühlenen, 2000; Thomas et al., 2007; Wolfe & Pokorny, 1990). For instance, Klein and MacInnes (1999) presented participants with scenes from the 'Where's Waldo?' series of books, where a target person (Waldo) is presented amongst a cartoon scene of a complex array of perceptually similar stimuli (other individuals wearing similar clothing, or objects of similar colouring). Participants had to search for Waldo until a target probe was presented, which they were instructed to immediately fixate. The probe was presented in locations that were either occupied by a previous fixation or determined by the current point of gaze. In the latter case, the probe could appear in one of six locations, which were equidistant from the current point of gaze, with these locations being near or far from the preceding fixation location as a consequence. Participants were slower to respond to probes presented in locations that had previously been fixated (or were close to these previously fixated locations) during the search trial, than new locations outside of the fixation region. However, this was only true for when the search scene remained on the screen during probe presentation. Furthermore, Klein and MacInnes (1999) noted that prior to probe onset, participants were more likely to saccade away from previously fixated locations than saccade back towards them (see also MacInnes & Klein, 2003). This study provides compelling evidence of IOR influencing visual orienting during search tasks, supporting the foraging facilitator hypothesis (c.f. Hooge et al., 2005).

In addition to biasing vision to novelty in search tasks, IOR may also prevent erroneous or unnecessary responses to previously examined locations or objects by delaying response execution processes to cued locations (c.f. Klein & Taylor, 1994). This would be advantageous, enabling cued locations to be monitored prior to target onset, and preventing unsuitable responses to undesirable targets. To test this, Ivanoff and Taylor (2006) combined a stop-signal task with a cuing task designed to generate IOR. Following the presentation of a target stimulus in the periphery of the display, a central cue signalled whether participants should localise the target (go signal) or withhold responding to the target (stop signal). When the target was presented at a previously cued location proceeded by a stop signal, the probability of successfully inhibiting a localisation response was greater than when the target was presented at an uncued location under the same conditions. Data obtained from erroneous execution of responses in stop trials and correct responding in go trials revealed evidence that IOR was present in both conditions, with slower responding in cued trials than uncued trials.

These results indicate that the mechanisms underlying IOR facilitated successful withholding of a motor response following the target onset. Extrapolating this apparent facilitation effect of inhibition, Ivanoff and Taylor (2006) propose that the slowed responding which characterises IOR enables adaptation of behavioural responding 'online' to meet the needs of interacting with dynamic environments, where delayed responding to one location allows accrual of information about other locations of interest.

IOR as an object-based effect

IOR is typically conceived as a location-based effect. However, an orienting mechanism that is specific only to the inhibition of locations may not necessarily serve all visual interactions well. This is particularly true considering that humans live in more dynamic visual environments, whereby not only do we search through locations, but we also search for particular objects, which may not have a fixed location. If we consider the task Klein and MacInnes (1999) employed, search for the character Waldo occurred in fixed, yet complex, visual scenes. Therefore participants were helped in their search because Waldo remained stationary in the search display. However, it is unlikely in real-world situations that Waldo (or any other person being searched for) will remain stationary. Thus a purely location-based inhibitory mechanism may not be sufficient to provide efficiency in search. A person wearing similar clothing to Waldo may move from an inhibited location and require re-examination, or Waldo himself may also move to an inhibited location and avoid detection. Tipper, Driver, and Weaver (1991) presented these problems of a purely location-based IOR mechanism, proposing an object-based frame of reference would be more suitable for facilitating search in dynamic visual environments.

The utility of an object-based frame of reference for IOR is very apparent considering that searcher, their targets, and search environments frequently change[2]. However, such a mechanism would require inhibition to be encoded and stored with a specific object, and move with that object to prevent its re-examination during the remainder of search. To test this notion, Tipper at al. (1991) presented moving displays consisting of two objects positioned either side of fixation. One of the objects was cued, and then both objects were presented at new locations either 90° or 180° from their original location. Response times to detect targets in previously cued objects were slower even though these objects were presented in novel locations. This finding was even more remarkable given that in the 180° movement condition, the uncued object was presented in the location where the cued object was initially presented and cued. Moreover, IOR was equivalent in both movement conditions, further suggesting that inhibition was primarily associated with the object rather than the cuing location. However, in a subsequent series of experiments, Tipper, Weaver, Jerreat, and Burak (1994) found IOR was larger and more robust for targets presented in objects moving 90° from their original location than for objects moving 180°, suggesting the additional influence of location-based IOR on responding. This latter study is important because it demonstrates object-based and location-based inhibitory effects occurring concurrently in guiding behaviour. Indeed the components of any cuing task may provide an additive effect of these two frames of reference, where both locations and objects are concurrently cued,

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[2] Object-based information is crucial to measuring IOR in visual search tasks. Klein (1988) measured IOR in a visual search task; however, subsequent replications of this effect were unsuccessful (Klein & Taylor, 1994; Wolfe & Pokorny, 1990). More recently, IOR has been measured in search, but this is dependent upon the maintenance of the search scene during probe presentation (Klein & MacInnes, 1999; Müller & von Mühlenen, 2000). Therefore, the previous failures to demonstrate IOR in search tasks are probably owing to the removal of this object-based information that is crucial to the manifestation of IOR in these studies.

resulting in cumulative impairments to performance in cued trials (Jordan & Tipper, 1998).

Subsequent research has demonstrated that object-based IOR is specific to an object's identity. If the cue and target are presented on the same object (an apple), IOR is larger than when cue and target are presented on different exemplars of objects belonging to the same semantic category (different types of apples), or on objects from different semantic categories (chest of drawers, container, plant; Morgan, Paul, & Tipper, 2005). Similar results were also found for cuing and presenting targets in same and different examples of meaningless stimuli (Morgan & Tipper, 2007). Furthermore, encoding an inhibited object's identity in memory promotes longevity to IOR, with re-presentation of the cued object producing IOR effects on target detection up to 13 minutes after initial cuing (Tipper, Grison, & Kessler, 2003).

Neuroanatomy of IOR

The initial exploration of the underlying neurophysiology of IOR was driven by the relative importance of the oculomotor system in the manifestation of the effect (e.g., Rafal et al., 1989). Therefore, the superior colliculus (SC) has been traditionally associated with IOR, and was originally believed to be the locus of the effect. The SC is a subcortical midbrain structure, situated on the apex of the brainstem. The superficial layers of the SC receive multisensory afferents that are transformed through a motor map into the intermediate and deep layers of the SC, which control visual orienting (King, 2004). The retinotectal pathway is the major visual afferent to the SC, and therefore the activity of this pathway was believed to influence IOR. There are stronger retinotectal projections to the SC representing the temporal hemifield than the projections representing the nasal hemifield. Under monocular viewing conditions, IOR was larger following cue-target presentations to the temporal hemifield than the nasal hemifield, presumably owing to these stronger retinotectal projections to the SC (Rafal et al., 1989). This IOR bias to temporal hemifield presentations has also been replicated in studies of newborn infants (Simion, Valenza, & Ulmita, 1995); further supporting collicular (and generally subcortical, see also Posner et al., 1985, and Danziger, Fendrich, & Rafal, 1997, the latter study reports evidence of IOR where visual cortex is compromised) generation of IOR. The SC-IOR hypothesis was also strengthened by measuring IOR in a patient with a unilateral lesion to the right SC. Under monocular cue-target presentations, IOR was only generated in the temporal and nasal hemifield projecting to the intact left SC. No IOR was seen for cue-target presentations to the impaired right SC (Sapir, Soroker, Berger, & Henik, 1999).

Although the SC seems to contribute to the manifestation of IOR, it may not be the site of inhibition. For instance, single cell recordings of the monkey SC reveal that activity in collicular neurons increases following cue onset and during the cue-target interval of cued trials relative to uncued trials, rather than any attenuation of activity (Dorris, Klein, Everling, & Munoz, 2002). Furthermore, IOR has been generated in the absence of SC involvement by presenting cue stimuli to which the SC is blind (Sumner et al., 2004). These studies suggest a more cortical contribution to the generation of IOR. Indeed Dorris et al. (2002) propose the parietal cortex as a possible candidate region in generating IOR, a region that may contain a spatial saliency map through which the mechanisms underlying IOR could operate (see also Vivas, Humphreys, & Fuentes, 2003; 2006). Although cortical manifestation of IOR may be consistent with an attentional locus of the effect (Sumner et al., 2004), in addition to increased activity in regions of the parietal cortex during IOR trials, fMRI studies have also revealed increased activation of the regions involved in oculomotor control, including the supplementary eye-field and frontal eye-field (FEF; see also Ro, Farnè, & Chang, 2003, for FEF contributions to IOR), as well as the ventrolateral nucleus of the thalamus (Lepsien & Pollman, 2002; Mayer, Seidenberg, Dorflinger, & Rao, 2004; Rosen et al., 1999). Interestingly, in these studies no differential activation of the SC was observed between IOR and non-IOR (control) trials, consistent with a cortical locus of the IOR effect[3].

Further evidence of cortical involvement to IOR was considered in the maintenance of object-based IOR. Split-brain patients (patients presenting a lesion sectioning their corpus callosum, preventing inter-hemispheric communication) showed normal object-based IOR when the cued object moved but remained within the same hemifield that it was initially cued. However, when the cued object moved through the midline into the opposite hemifield, no object-based IOR was observed. Lesion of the corpus callosum seemed to prevent the transfer of inhibitory information about an object between hemispheres, consistent with a cortical mediation of object-based IOR (Tipper et al., 1997).

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[3] Absence of SC may reflect its activation throughout the experimental conditions (facilitating maintenance of fixation) or owing to the absence of eye-movements that may be necessary for SC activation (Rosen et al., 1999). However, responding in these tasks was via a manual response with IOR occurring most likely as an attentional effect, therefore collicular involvement may not be expected (Sumner, 2006; Sumner et al., 2004).

Chapter Summary

IOR is a reflexive consequence of spatial cuing, and may reflect the activation of the attentional and oculomotor response systems. Although the precise neuroanatomy that subserves IOR is not yet fully understood, there are clearly cortical and subcortical mediators of the effect. IOR can be mediated by both location-based and object-based frames of reference, and is believed to bias vision to novelty, facilitating behaviour online to meet the demands of changing environments. IOR is a robust inhibitory effect, and is easily generated and measured using a standardised cuing procedure. Therefore, it makes an excellent tool to explore the effects of emotionality on visual orienting, and is the principal measure used in this thesis.

Chapter 2: Visual responses to emotional stimuli

Chapter 1 described how visual stimuli are prioritised under the guise of attention. A second approach is to consider the emotional content of a stimulus, and how this might facilitate its prioritisation in visual encounters. It is important to note that there are several dominant theoretical approaches to defining emotion (see LeDoux, 1998, for a review). For instance, the James-Lange theory of emotion posits that feeling an emotion is a consequence of changes in behaviour and physiology in response to an external stimulus or event. In contrast to this, is the Cannon-Bard theory, where it is the emotional feeling that is responsible for changing physiology and behaviour. In a more recent account, Schachter and Singer introduced the importance of cognition to interpreting physiological responses (i.e., arousal) and experiencing emotion. As a foreword here, these theories of emotion will not be considered any further in this thesis because the experiments presented here were specifically interested in the effects of visual representations of emotion on the generation and measurement of IOR. Consequently, this current chapter presents a review of visual responses to emotional stimuli organised within three domains. First, I will define what an emotional stimulus is in the context of this thesis, and then describe the various sources of emotional stimuli and the methodological issues that are encountered when they are employed in experimental paradigms. Second, I will describe emotional influences on visual perception, considering both the behavioural and the neurophysiological evidence supporting this association. Third, I will examine the evidence that demonstrates interactions between the visual attention and emotion systems.

Emotional stimuli

When describing the effects of emotion on perception and attention, I am referring to the specific emotional content of a particular stimulus. This definition of emotion does not incorporate emotional feelings (or mood states). Further, I also think it is useful to distinguish emotional feelings from emotional responses, the latter I use to describe specific neurophysiological consequences of visual exposure to emotion, consequences that are objective, and can be quantified and measured.

In the experiments conducted in this thesis, emotional stimuli were presented in the visual domain. Employing pictorial stimuli is advantageous, ensuring precise control over their temporal exposure and level of intensity (Lang, 1995). Emotional stimuli can be distinguished from non-emotional stimuli in respect of their valence (positive, negative) and their arousal level (high, low; Lang, 1995; Lang, Bradley, & Cuthbert, 1997). The latter dimension of arousal in particular may be crucial to determining emotional salience and stimulus prioritisation. As will be reviewed here, performance-related biases (in terms of accuracy and speed of responding) are frequently observed when participants are exposed to stimuli that are negatively valenced, with performance in conditions presenting positive and neutral (non-emotional) stimuli often being equivalent. These findings are typically interpreted as representing preferential processing of negative or threat-relevant information. However, this valence specific effect may instead be attributed to the greater levels of arousal associated with negative stimuli, rather than any specific response bias to negatively valenced information (e.g., Anderson, 2005; Anderson et al., 2003). Indeed, when positive and negative stimuli are equated in arousal level, performance-related biases are seen for both valence categories, in contrast to neutral stimuli (Anderson, 2005). Therefore, when reviewing effects of emotion on perception and attention, it is important to consider whether the effects are purely valence-based, or whether differences in arousal may instead be the critical factor.

Facial expressions of emotion have traditionally been used as sources of emotional stimuli in a variety of tasks. Models pose a series of expressions (e.g., angry, happy, disgust, surprise, no expression) that are then presented as stimuli in visual tasks. The Ekman and Friesen series (1976) is still one of the most widely used emotional face databases, although more recent emotional face databases have emerged from the Karolinska Institute and the MacBrain Organisation. Face stimuli are advantageous to use as a source of emotion in experimental procedures for three important reasons. Firstly, as social organisms, face stimuli are both biologically and motivationally relevant to humans, and are therefore uniquely salient to perceivers in contrast to other exemplars of emotional stimuli that may vary in salience. Secondly, face stimuli although expressing different emotions, consist of the same spatial arrangement of features, and therefore are comparable in terms of low-level visual information. This is especially important when investigating whether visual exemplars of emotion are perceived outside the focus of attention. Thirdly, facial emotions elicit unique emotional responses as well as communicating emotional information about the intention and motivation of an individual (Ruys & Stapel, 2008). Therefore, face stimuli provide a rich quantity of information in a single visual instance.

Pictures of animals and emotional scenes have also been employed as sources of emotional stimuli in visual tasks (Lang, Bradley, & Cuthbert, 1995; 2005). Images of snakes and spiders are typically used as sources of negative emotion. Moreover, these stimuli (along with angry facial expressions) are considered to be examples of ancestral threat, which humans may be biologically prepared for in visual encounters (Öhman & Mineka, 2001). However, more modern sources of threat (e.g., hypodermic needles, guns, knives) are also increasingly used in studies of emotion perception, finding comparable results to sources of ancestral threat (Brosch & Sharma, 2005; Fox, Griggs, & Mouchlianitis, 2007).

Although it is advantageous to have multiple sources of emotional stimuli, there are methodological issues that may confound or complicate the interpretation of many studies of emotion perception. I will now discuss three of the main issues: Stimulus salience, subjective relevance, and stimulus properties.

Stimulus salience. Typically, emotional stimuli are not pre-tested to determine their emotional value prior to their inclusion in experimental designs, which can be especially problematic when introducing stimuli that have not previously been used. Null performance effects in conditions containing emotional stimuli may occur if these stimuli are insufficiently emotional. Moreover, stimuli that are sufficiently emotional may vary in intensity, and item specific effects may drive performance in visual tasks. This poses a significant challenge to studies employing multiple exemplars of emotion (e.g., snakes, spiders, faces, scenes) instead of a category specific source of emotion (e.g., all spider stimuli). In an attempt to correct these issues, emotion researchers are now using standardised sources of emotional stimuli. One example is the International Affective Picture System (Lang et al., 1995; 2005), which contains multiple exemplars of emotional stimuli that have been pre-assessed and quantified in terms of their valence and arousal value.

Subjective relevance. Although salience can be controlled within a stimulus set, the salience of a stimulus can vary between perceivers in terms of the biological and motivational relevance of these stimuli, defining emotional content beyond controlled and quantified valence and arousal values. Therefore, it is necessary to control the subjective relevance of a stimulus, and this can be achieved in two ways. First, researchers can be careful in their sample selection to ensure *a priori* that participants do not have existing biases to the saliency of stimuli employed. For instance, when exploring perception of ancestral sources of threat, participants fearful of spider and snake stimuli should be excluded. A second approach involves artificially assigning emotional content to stimuli using the principals of classical conditioning. For instance, the repeated presentation of a neutral stimulus with an aversive stimulus (typically white noise), will result in the neutral stimulus becoming associated with aversion, and when presented alone, will generate an emotional response typically elicited to the aversive stimulus. Conditioning stimulus value is beneficial, enabling control over the emotional salience a stimulus affords by tailoring the level of aversion to the individual's threshold of sensitivity (Armony & Dolan, 2001). This issue will be further discussed in Section 4 of this thesis.

Stimulus properties. Properties of emotional stimuli (beyond their emotional value) may create significant difficulties in interpreting findings from studies of emotion perception. The frequency of encountering these stimuli may bias prioritisation processes, with more frequently encountered stimuli (emotional or otherwise) prioritised for processing, irrespective of their inherent emotional content. The low-level featural differences between emotional stimuli may also be problematic in determining whether emotional or visual dissimilarities are responsible for performance related differences between emotional and non-emotional stimuli. A good example of this was a claim made by Hansen and Hansen (1988) that angry face targets can be detected pre-attentively when presented amongst an array of other non-angry face distractors in a visual search task. Re-examination of the stimuli used in this experiment revealed this preferential detection of angry faces was owing to a low-level featural artefact absent in the non-angry faces, that was instead responsible for the benefits in target detection observed (Purcell, Stewart, & Skov, 1996).

Does emotion facilitate visual perception?

After describing the issues surrounding the use of emotional stimuli in experimental paradigms, I now want to consider whether emotion facilitates visual perception. This topic has been addressed at both a behavioural and a neurophysiological level, and I will discuss each in turn. A good starting point here is to describe the neuroanatomy of the visual system in processing stimuli in the absence of emotion. Figure 2 presents the main cortical and subcortical visual pathways to the brain responsible for stimulus processing. The retinogeniculate pathway transfers visual information from the retina to the lateral geniculate nucleus in the thalamus, which then projects to the striate cortex with visual information then transferred to the extrastriate cortex. The retinotectal pathway refers to the projections carrying visual information from the retina to the superior colliculus and then onto the pulvinar, with projections from the pulvinar to the extrastriate cortex. Visual information is then further processed by the temporal and parietal regions to determine the identity and location, respectively, of the source of the visual information.

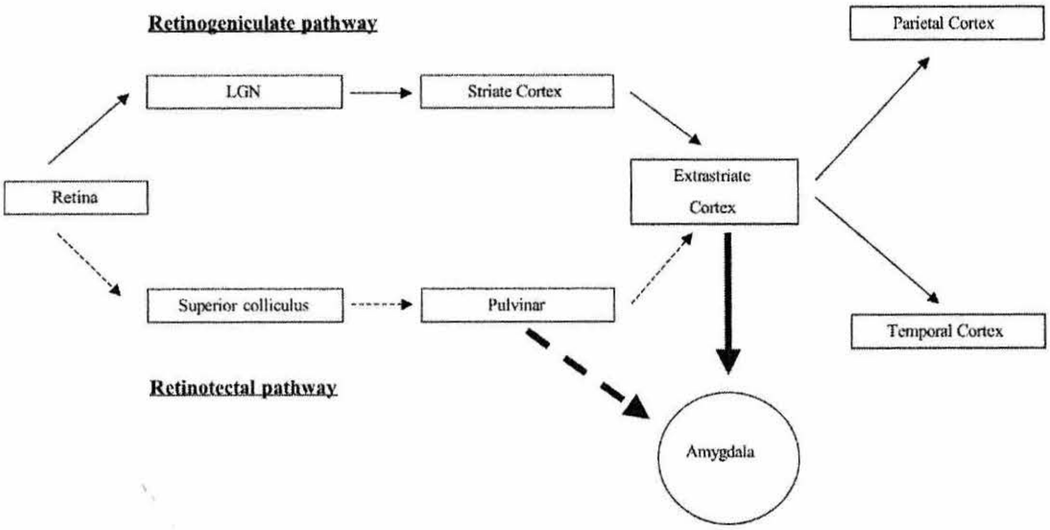

Figure 2. Schematic diagram of the cortical and subcortical pathways of the visual system. Note the dashed lines represent the subcortical pathway and the filled lines represent the cortical pathway. The thick black arrows indicate the proposed cortical and subcortical projections to the amygdala from these main visual pathways (LeDoux, 1998; Pessoa, 2005; Vuilleumier, 2005). Abbreviation: LGN, lateral geniculate nucleus.

The emotional content of a visual stimulus may also be processed through subcortical and cortical pathways, with both pathways converging on the amygdala (see Figure 2, LeDoux, 1998; Pessoa, 2005; Vuilleumier, 2005). The amygdala is a structure located in the anterior medial temporal lobe, believed crucial to the perception of emotion

(Davis & Whalen, 2001). It is proposed that the subcortical pathway projects to the amygdala through the colliculus and pulvinar (although note that in humans, the precise anatomy of this subcortical pathway is yet to be fully demonstrated, Pessoa, 2005). The cortical pathway instead projects to the amygdala once visual information pertaining to the emotional stimulus has initially been processed through the visual cortex. The cortical and subcortical emotion processing pathways may operate in parallel, being beneficial to rapid (with shorter neural tracts subcortically) and accurate (with precise stimulus representations cortically) responding to external visual events (LeDoux, 1998).

If visual pathways facilitate processing the emotional content of a stimulus (cortically and subcortically) through projections to the amygdala, it is plausible that this content may have processing consequences to prioritise the detection of an emotional stimulus. Indeed there is behavioural evidence to support such a notion. Dijksterhuis and Aarts (2003) presented either a positive word or a negative word as a subliminal cue preceded and followed by a visual mask, or no word at all and just the masks. Participants were asked to report whether a word was present or absent at the end of each trial. Word-present correct responses were higher for negative words than positive words. In a second task, valenced words were now presented on every trial (again masked), and participants instead categorised the word according to whether they thought it was positive or negative in valence. Again these affective category judgements were more accurate for negative than positive words. The authors interpreted these findings as evidence of the preferential processing of negative stimuli. However, Labiouse (2004) criticised this interpretation, proposing instead that the results could be explained in terms of a bias in decision criteria to report negatively valenced information. This differential interpretation is overcome if the experimental conditions are designed to measure both potential response biases and perceptual benefits of emotion within the same paradigm. This was achieved by Zeelenberg, Wagenmakers, and Rotteveel (2006), who employed a two-alternative forced choice identification task following the brief presentation of a masked word. The task was to select which word from the two (target, distractor) matched the masked word. The distractor varied in valence, and conditions where the target was neutral and the distractor was emotional were contrasted to conditions where the target and distractor were both neutral. The same comparisons were made when the target was emotional (i.e., accompanied by an emotional or a neutral distractor). When the target was neutral, performance was unaffected by the content (emotional, neutral) of the distractor, indicating that participants were not biased to select an emotional option when it was offered in this task. Further, performance was more accurate in the emotional target conditions (positive and negative) than the neutral target condition, suggesting emotional information (positive and negative) was preferentially detected in this task.

The two studies described above (Dijksterhuis & Aarts, 2003; Zeelenberg et al., 2006) suggest that when a stimulus is emotional, it is prioritised for detection. However, these tasks explored emotion effects on perception when emotion was inherent in the perceptual task. This raises an interesting question of whether perceptual processes would be enhanced by emotion when these processes are measured to visual events distinct from the initial exposure to emotion. I will now describe a study that explored this issue.

Phelps, Ling, and Carrasco (2006) presented either a brief (75 ms) emotional (fearful) or non-emotional (neutral) face at central fixation of a visual display. After a short interval (50 ms), four Gabor patch stimuli were then presented in the periphery, and the visual contrast of these patches varied at random during the experimental procedure. The task was to identify the orientation of an oddball target Gabor patch amongst the three remaining distractor patches. If emotion enhances perceptual processes, this would be indicated by an increase in sensitivity to contrast in the conditions preceded by the fearful face. Indeed, prior exposure to a fearful face significantly lowered the contrast sensitivity threshold required to discriminate the oddball target, relative to performance in conditions preceded by the neutral face. Therefore, these results suggest that prior exposure to an emotional stimulus enhances visual perception.

In a second experiment, neutral and emotional faces were either presented as single exogenous cues or as a group of four distributed cues (presented simultaneously with valence kept constant), prior to the presentation of the Gabor patch array as described before. This manipulation was designed to explore whether the relative benefits of attentional cuing *and* emotionality would reduce contrast sensitivity, or whether the benefit of emotion exposure would be an independent effect, modulating performance equivalently with and without the presence of the exogenous orienting cue. Contrast sensitivity was enhanced in the exogenous cue condition for both neutral and fearful face cues. This sensitivity was further enhanced when the exogenous cue was a fearful face rather than a neutral face. Moreover, the benefit to perception of emotion exposure was greater when fearful faces were presented as exogenous cues than when they were distributed in the periphery, demonstrating a significant attention and emotion interaction in this data. Taken together, these two experiments by Phelps et al. (2006) strongly suggest that prior exposure to emotional stimuli facilitates perceptual processes, and combining an attentional manipulation with this exposure to emotion, further enhances this effect.

A subsequent replication of this study incorporated fearful, neutral, and happy facial expressions prior to the contrast sensitivity task. Increased sensitivity to contrast was limited to the condition where trials were preceded by fearful faces, consistent with Phelps et al. (2006). Contrast sensitivity instead was comparable in the happy and neutral expression condition (Tipples, Skarratt, & Hulleman, 2007). Although these studies suggest that emotion benefits to perception are limited to negative facial expressions, an alternative interpretation may be related to the arousing nature of the fearful face stimuli. As described previously, negative stimuli are associated with greater levels of arousal than positive stimuli (Anderson, 2005; Anderson et al., 2003); therefore, the absence of a positivity benefit on measures of perception may be symptomatic of the insufficiently arousing nature of these happy facial expressions. The two studies reported here (Phelps et al., 2006; Tipples et al., 2007) cannot resolve this issue as neither study considered arousal as a variable of interest. Nevertheless it will be an important point of future research to determine the contribution of arousal, as well as valence, to the enhancement of visual perception.

Although these behavioural studies (Dijksterhuis & Aarts, 2003; Phelps et al., 2006; Tipples et al., 2007; Zeelenberg et al., 2003), are useful in determining and quantifying the effects of emotion (or indeed arousal) on stimulus processing, these studies can only speculate as to the neural mechanisms which may underlie these behavioural effects. Therefore, it is necessary to employ cognitive neuroscience techniques to provide a window into the brain to probe the nature of emotion-perception interactions. This can be achieved by systematically comparing the neural activity of cortical areas known to be involved in visual processes whilst participants view emotional and non-emotional stimuli.

Lang et al. (1998) measured functional activity of brain areas using functional magnetic resonance imaging (fMRI) whilst participants viewed pleasant, unpleasant, and neutral images. When viewing emotional images, hemodynamic activity was greater in the right hemisphere compared to the left hemisphere. Moreover, there was also an increase in hemodynamic activity in the visual cortex, specifically occipital and occipital-parietal regions, when participants viewed both the pleasant and unpleasant images in contrast to the neutral images. This increase in visual cortical activity whilst viewing emotional pictures suggests that exposure to emotion heightens the activity of the visual system, and may be a plausible neurophysiological explanation of the behavioural findings that emotional stimuli enhance visual perception (Phelps et al., 2006; Tipples et al., 2007).

Although the emotion-induced enhancement of visual cortical activity reported by Lang et al. (1998) may be the consequence of a cortically driven response to emotion, recent evidence suggests that it is more likely to be a subcortically mediated response, driven by afferent projections from the amygdala to the visual cortex (Morris et al., 1998; Vuilleumier et al., 2004). Indeed, neurophysiological evidence indicates that the amygdala has strong projections to early visual cortical regions (Amaral & Price, 1984).

Therefore, it is entirely plausible that these projections from the amygdala may modulate visual cortex activity, and a number of neuroimaging studies have explored this possibility. For instance, Morris et al. (1998) measured changes in regional cerebral blood flow in the amygdala and visual cortex whilst participants viewed a series of emotionally expressive faces (fearful or happy). The novel finding here was that activity in the amygdala predicted activity in extrastriate regions as a function of the emotional expression of the face stimuli viewed by participants. Increases in amygdala activity were related to increases in extrastriate activity in response to viewing fearful faces. However, decreases in amygdala activity were related to decreases in activity in the extrastriate cortex when viewing happy faces.

The potential relationship between amygdala and visual cortex activity in response to emotion has been further studied by combining lesion analysis and fMRI, again measuring changes in hemodynamic activity whilst participants view emotional (fearful) and non-emotional (neutral) facial stimuli. Vuilleumier and colleagues (2004) demonstrated that the integrity of the amygdala was crucial for increases in activity in visual cortex in response to emotional stimuli. Although healthy controls showed a bilateral increase in activation in fusiform and extrastriate cortex in response to fearful faces, patients with amygdala damage failed to show any such pattern of functional activation in these visual areas. Moreover, the degree of amygdala atrophy negatively correlated with activity in the fusiform region in response to emotional faces: The greater the extent of amygdala atrophy, the less functional activation measured in the fusiform face region. This combination of lesion analysis and fMRI is advantageous, providing a degree of causality to the notion that the amygdala modulates visual cortical activity

(Adolphs, 2004). Moreover, emotion and visual cortex interactions have also been supported by single cell recording research; for example, in macaque monkeys, temporal visual cortex activity is heightened in response to presentations of emotional images (Sugase, Yamane, Ueno, & Kawano, 1999)[4].

Although the studies described above illustrate the effects of emotion on neuroanatomical function, fMRI is somewhat limited as a tool in respect to the temporal information it can provide. The visual cortex response to emotional stimuli may reflect very early sensory processing responses to emotional stimuli, or alternatively later allocation of processing resources once the examination of visual input is complete (Schupp, Junghöfer, Weike, & Hamm, 2003). Indeed there have been several studies citing evidence for the latter hypothesis. When viewing emotional and non-emotional stimuli, approximately 400 ms post-stimulus onset an enhanced positive potential of the visual event-related potential (ERP) component is observed in response to emotional images (Cuthbert et al., 2000; Lang et al., 1997; O'Brien, Rutherford, & Raymond, 2008; Schupp et al., 2000; 2003). This modulation of the *late positive potential* (LPP) is believed to reflect the motivational relevance of the visual stimulus, wherein additional resources are allocated to their processing (Lang et al., 1997). More arousing images elicit larger LPPs, consistent with this hypothesis (Schupp et al., 2000), and again indicates the importance of stimulus arousal level in the generation of emotional responses.

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[4] Note that the modulation of cortical activity by emotionality does not seem to be limited to the visual domain, with some evidence that emotional prosody in voices increases activation of the auditory cortex too (Grandjean et al., 2005).

More recent research has also demonstrated earlier sensitivity to emotional stimuli using ERPs. Schupp et al. (2003) demonstrated that early posterior negativity or EPN (appearing around 100 ms post-stimulus onset) of the visual ERP component is more enhanced whilst viewing emotional pictures. Source localisation of this enhanced EPN identified visual cortical areas, consistent with the neuroimaging literature of converging visual-emotion interactions (Morris et al., 1998; Vuilleumier et al., 2004). Taken together, the findings from ERP, neuroimaging, and behavioural studies support the notion that the emotional content of a stimulus can significantly influence visual perception, and the underlying neural mechanism of this effect is likely to be the enhancement of cortical activity, driven by amygdala projections.

Attention and emotion

The literature described above strongly suggests that emotional stimuli modulate perceptual processes. I now want to move on to considering whether emotional stimuli modulate visual attention, and how this has been empirically measured.

Attention and emotion are conceptualised as two independent systems that both anatomically overlap (in regions including the prefrontal cortex and anterior cingulate), and functionally interact (Vuilleumier, Armony & Dolan, 2003). Whether attention is required to process emotion, or if emotion can be processed in the absence of attention (and even awareness), is still an issue of debate (e.g., Okon-Singer, Tzelgov, & Henik, 2007; Pessoa, 2005; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002; Silvert et al., 2007; Vuilleumier, Armony, Driver, & Dolan, 2001). Nevertheless, attention and emotion systems promote prioritisation of visual information, and therefore a large body of research has explored how these two systems interact. In this final section, I will discuss the main methodologies that are employed to investigate attention-emotion interactions. These are the emotional stroop task, visual search paradigm, dot-probe task, lesion studies, attentional blink task, and the spatial cuing task. Particular attention will be paid to the data obtained from spatial cuing studies because it is the methodology employed in this thesis. Where appropriate, I will also describe how these paradigms have furthered our understanding of the neural correlates of attention-emotion interactions.

Emotional Stroop. In standard stroop tasks (Stroop, 1935), participants name the ink colour of visually presented words that are colour names. Incongruency between the ink colour and word meaning (e.g., BLUE written in yellow ink) slows ink colour naming in this task, in contrast to when the ink colour is congruent (e.g., YELLOW written in yellow ink) or when a non-word is used (XXXX presented in yellow ink). These results are typically attributed to participants attending to the meaning of the word, which creates conflict when the task is to report the ink colour. To explore whether emotional stimuli create similar conflicts, the word list is altered to instead consist of emotional and non-emotional words, with speed to name ink colour remaining as the dependent measure. Pratto and John (1991) found participants were slower to name ink colours of words that represented undesirable personality traits (e.g., hostile) in contrast to desirable personality traits (e.g., kind). High anxious participants are slower than low anxious participants to name the ink colours of threatening (e.g., fatal) versus non-threatening (e.g., carefree) words (Mathews & MacLeod, 1985). Similarly, participants scoring higher in measures of depression are also slower to name the colour of negative words than positive words in these tasks (Williams & Nulty, 1996).

The stroop task has been advantageous, providing both a behavioural measure of attention-emotion conflict, but also being successfully employed to probe the neural correlates of these effects. A meta-analysis of neuroimaging studies employing emotional and non-emotional stroop tasks revealed an interesting dissociation of activity in the anterior cingulate cortex (ACC). Non-emotional stroop tasks activated the dorsal aspect of the ACC, deactivating the ventral aspect of the ACC. However, emotional stroop tasks produced the opposite pattern of results, activating the ventral ACC and deactivating the dorsal ACC. These results suggest that the ACC may reflect a cortical region of convergence for attentional and emotional processes (Bush, Luu, & Posner, 2000). This notion is consistent with a more recent study employing a non-stroop task, which also suggested integration of attention and emotion processes in the ACC (Yamasaki, LaBar, & McCarthy, 2002).

Visual search. Visual search paradigms have been widely used to explore whether emotion guides the focus of attention and to what extent this may be a pre-attentive process. An influential study by Öhman, Flykt, and Esteves (2001) demonstrated participants were faster to detect threat-relevant (snakes, spiders) target stimuli than non-threat-relevant (flowers, mushrooms) target stimuli. Moreover, this speeded threat detection did not change when the number of distractor stimuli in the search array was increased, indicative of pre-attentive processing of threat in this task. This *threat superiority effect* in visual search has been replicated a number of times using a range of modern and ancestral threat-relevant stimuli (e.g., Brosch & Sharma, 2005; Eastwood, Smilek, & Merikle, 2001; Fox & Damjanovic, 2006; Fox et al., 2000; Fox et al., 2007; Flykt, 2005).

Although visual search tasks have been widely used to explore attention-emotion effects, they may not be the most suitable methodology to explore attention-emotion interactions for two critical reasons. Firstly, the preferential detection of threat-relevant targets in visual search tasks is not a reliable observation. Some studies have failed to find any modulation by threat, despite extensive investigations (e.g., Lipp, Derakshan, Waters, & Logies, 2004; Tipples, Young, Quinlan, Broks, & Ellis, 2002). Secondly, visual search tasks are especially sensitive to low-level featural information present in search arrays that may modulate performance in the absence of any emotion specific effects (Cave & Batty, 2006; Purcell et al., 1996; Tipples et al., 2002).

Dot-probe tasks. Demonstrations of attention-emotion interactions have also been shown by studies employing a dot-probe methodology. Typically, two cue items are presented simultaneously on either side of fixation. After a brief delay, a target (usually a dot) is presented in one of the locations previously occupied by a cue item. Faster response times to detect the target at one of the cued locations suggests attentional capture by the cue at that location. Armony and Dolan (2002) presented two face stimuli as cues, one conditioned (CS+) with aversive white noise, the other remaining unconditioned (CS-), with both presented simultaneously prior to the onset of a target to be detected. Response times were greatly facilitated when the target was presented in the same location previously occupied by the CS+ than the CS-, suggesting that spatial attention was attracted toward the location of the conditioned stimulus, facilitating target detection there. Moreover, this attentional capture by the CS+ was accompanied by increasing hemodynamic activity in frontal and parietal regions, activity that was being recorded during the dot-probe task. These areas included the bilateral supplementary motor area / anterior cingulate, left parietal cortex, frontal eye-fields, and lateral orbitofrontal cortex. Therefore, the dot-probe methodology can provide a useful measure of attention capture by emotion, and can be used to understand the underlying the neurophysiology of these attention-emotion effects (note that the ACC was again activated during an attention-emotion task). However, no firm conclusions can be made using this paradigm as to whether emotional stimuli are affecting attentional engagement or disengagement processes. This is an important distinction to be made as to whether emotional stimuli attract attention differently to non-emotional stimuli, or whether emotional stimuli hold attention for longer than non-emotional stimuli. The effects of emotion on these two processes cannot be dissociated in dot-probe tasks.

Patient studies. Capture of spatial attention by emotion has been shown in patients with impairments to their normal attentional processes, an effect absent when non-emotional stimuli are presented. For example, patients with unilateral spatial neglect show a loss of awareness to their contralesional field of space, typically following lesions to right parietal cortex. Often accompanying neglect is visual extinction, a disorder characterised by an awareness of stimuli in the contralesional field, but loss of this contralesional awareness when stimuli are presented bilaterally in both visual fields with awareness instead shifting to stimuli presented in the ipsilesional field (i.e., the contralesional stimulus becomes extinct; Ellis & Young, 1996). Patients with neglect and extinction represent a unique population to explore whether the content of a stimulus (emotional, non-emotional) can influence its detection when a person would be unaware of its presence under normal circumstances. Indeed, these patients show a reduced extinction for emotional faces (happy and angry) and threat-related stimuli (spiders) when presented bilaterally with neutral control stimuli (Fox, 2002; Vuilleumier & Schwartz, 2001a; 2001b). These patient studies strongly support the notion of pre-attentive processing of emotion-relevant information, guiding vision towards locations that the patient would otherwise be unaware.

Attentional blink tasks. A similar approach to patient studies of neglect and extinction is to use a task where healthy participants are made temporarily 'unaware' of the presence of a visual stimulus, and then measure their awareness of that stimulus when it is emotionally charged. This is possible by presenting a rapid stream of visual stimuli and asking participants to identify two targets (T1, T2) within that stream. When the time between the targets is less than about 500 ms, T2 processing is impaired, with T1 identification engaging all available resources. This impairment in T2 identification has been analogised to normal attentional mechanisms 'blinking', with sparing of T2 identity with longer durations (or lags) between the two targets (Raymond, Shapiro, & Arnell, 1992). This attentional blink (AB) paradigm has been crucial in furthering our understanding of whether stimuli can be differentially perceived on the basis of their emotional value.

Anderson and Phelps (2001; see also Anderson, 2005) presented participants with an emotional variant of the AB task, with aversive words as T2 targets to be detected. Healthy control participants showed an attenuated blink for these negative words at the shorter lags, in contrast to neutral words. However, when the same task was administered to a patient with bi-lateral amygdala damage, no T2 sparing for emotional words was observed. Furthermore, patients with left unilateral amygdala damage also failed to show this emotion benefit. However, patients with right unilateral amygdala damage did show the same benefit as healthy controls and correctly reported the emotional T2. These findings are informative because they demonstrate that emotional information can be extracted under limited capacity conditions, and again, the neural circuitry of the amygdala being crucial in mediating this function. More recently, Anderson (2005) established that it was the arousal value of these stimuli rather than the valence, which modulated AB performance. Increasing the arousal value of the T2 stimuli (positive and negative stimuli) attenuated the magnitude of the AB.

An interesting emotional variant of the AB task was recently developed by Most and colleagues (2005) where T2 performance impairments were induced by the presentation of an emotional stimulus, rather than by engaging in a T1 task as traditionally used. Participants viewed a rapid stream of pictures, responding to the orientation of a target image (rotated 90° to the left or right). Preceding the onset of the target was a threatening image, presented either two lags or eight lags before target onset. Accuracy was significantly worse when the target followed in close proximity (lag 2) to the emotional image than when the target appeared later on in the stream (lag 8). Similar results were obtained when the emotional image was positively arousing (Most, Smith, Cooter, Levy, & Zald, 2007), and when non-emotional stimuli were conditioned with an aversive noise (Smith, Most, Newsome, & Zald, 2006). These results suggest that the emotional pictures captured and held attention in this task, impairing target discrimination performance when the target follows the source of emotion in close temporal succession.

Spatial cuing tasks. The spatial cuing paradigm is the main methodology of this thesis (see Figure 1)[5]. It has been extensively used to understand attentional biases toward emotional stimuli and is extremely advantageous because it can be used to determine whether emotional stimuli modulate attentional engagement, disengagement, or both types of processes. Typically, an emotional stimulus is presented as a peripheral cue, and after a short cue-target interval, a neutral target is presented at either the cued or the uncued location. Although a measure of attentional facilitation can be obtained (uncued – cued response times), it is the relative difference in mean response times at each location (cued, uncued) determined by preceding cue valence that is the main variable of interest in these tasks. This cuing methodology is advantageous because previous approaches exploring attention-emotion effects, including the emotional stroop and dot-probe tasks, fail to determine whether emotional stimuli attract attention differently to neutral stimuli (an engagement effect; indexed by performance on cued trials), or whether attention capture processes are the same regardless of stimulus value, but emotional stimuli instead hold attention (a disengagement effect; indexed by performance on uncued trials).

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[5] Note that only studies employing short SOAs and measuring cuing benefits are discussed here. Studies exploring IOR and emotion in this paradigm are reported in the next chapter.

This notion was highlighted by Fox and colleagues (2001; 2002), who used a spatial cuing task to investigate whether attentional biases to threat-relevant information in anxiety disorders reflected an attentional engagement or disengagement deficit. High and low anxious participants completed a cuing task where the cue presented was either an emotional (angry, happy) or neutral schematic face. High anxious participants were slower to respond to targets presented at uncued locations following an emotional cue, an effect absent in the low anxious participants. However, the valence of the cue did not affect responding to targets at cued locations in either the high or low anxious group. This slowed responding of the anxious participants in uncued trials reflects a deficit in disengaging attention from the emotional cues. Note that emotional cues speeding responses on cued trials would be consistent with an attentional capture hypothesis of emotionality acting in anxiety. Instead, presentation of the cue and its subsequent processing resulted in a delay in the disengagement of attention from the cue to the subsequent target location (Fox et al., 2002). Converging disengagement deficits to emotional cues in anxiety were also reported by Yiend and Mathews (2001) when employing more complex emotional scenes as cue stimuli.

Subsequent experiments employing threat-relevant stimuli as cues have not shown deficits limited to attentional disengagement in normal populations (although the contribution of anxiety was not explicitly measured here). Koster et al. (2004) presented spatial cues that were associated with either an aversive noise (CS+) or a neutral noise (CS-) following their onset. Note that this conditioning did not occur on every trial though; instead a partial conditioning strategy was adopted. Consistent with a disengagement deficit (Fox et al., 2001; 2002; Yiend & Mathews, 2001), target localisation responses were slower in uncued trials when the target was preceded by the CS+ than when the target was preceded by the CS-, indicating that these stimuli held attention to their location. However, unlike Fox et al. (2001; 2002), localisation responses were also faster following CS+ than CS- cues on cued trials, indicating attentional capture by these stimuli. This apparent capture and holding effect of attention by CS+ stimuli was replicated by the same research group (Koster et al., 2005), with the additional observation that the engagement and disengagement deficits declined over subsequent extinction phases.

The results presented by Koster et al. (2004) are inconsistent with a purely disengagement deficit account of attentional orienting in response to emotional cues (Fox et al., 2001; 2002; Yiend & Mathews, 2001). However, there are obvious differences between the two methodologies that may explain the differences in the results obtained. Principally, the role of anxiety was not considered by Koster et al. (2004; 2005), and therefore cannot be ruled out as influencing the nature of the attentional biases described above. Furthermore, the nature of the stimuli (visual-auditory, partial conditioning of emotional value) in the experiments by Koster et al. (2004; 2005) may also produce very different alerting effects in contrast to the stimuli used in previous studies (words, schematic faces, photographs of faces, and scenes). Moreover, in the Koster et al. (2004; 2005) studies the aversive conditioning followed the onset of the cue rather than occurring simultaneously with the cue. Therefore it is plausible that the aversive conditioning may have instead been associated with the onset of the target, explaining the possible source of the differential results reported here.

Nevertheless, despite the contrasting findings of the studies presented here, the utility of the spatial cuing paradigm to explore the effects of emotional stimuli on spatial attention is very clear. Measuring both the general differences in cue validity effects, as well as the consequences of cue valence on response times at cued and uncued locations, provides a wealth of information about the effects of emotion on visual orienting. Moreover, these measures can be obtained for cue-target intervals where both attentional facilitation and IOR effects can be measured.

Chapter Summary

Here I have described a series of studies demonstrating that the emotional content of a stimulus can enhance perceptual processes, driven by enhanced activation of visual cortical areas by afferent amygdala projections. Further, evidence drawn from a variety of methodologies indicates that the mechanisms underlying visual attention are also sensitive to this emotional content. Therefore, visually presented emotional stimuli were used in the experiments reported throughout this thesis to explore their influence on the generation and measurement of IOR.

Chapter 3: Inhibition of return and emotion

In this final introductory chapter, I want to draw together the literature on IOR and emotional stimuli, and present the main research hypotheses of this thesis. I will draw on the literature conceptualising the mechanisms and functions of IOR, and what they predict for visual orienting in the presence of emotional stimuli. I will then describe the potential neuroanatomy that may underlie emotional influences on the generation and measurement of IOR. Finally, I will provide an overview of the existing research that has begun to address whether IOR is affected by the emotional content of visual stimuli. Note that this research will be discussed in more detail in the relevant experimental sections, but an introduction to this literature is provided here.

Theories of IOR relevant to emotion

Adaptive accounts of IOR predict that inhibition of orienting to previously examined locations may not always be advantageous, or even reflect naturally occurring behaviour. Instead it may be more adaptive to monitor locations rather than suppressing responses to them altogether (Ivanoff & Taylor, 2006; Terry, Valdes, & Neill, 1994). For instance, it would be maladaptive *not* to return to a source of food or shelter that has previously yielded success, or monitor a location where a predator had formally been detected.

This adaptive account of IOR suggests that the mechanisms underlying the effect should be sensitive to stimulus value at both the level of the orienting cue, and at the level of the target to be detected. If IOR enables adaptive monitoring of information at previously attended locations, then meaningful, emotionally-relevant information should be prioritised for processing if presented in a target to be detected in a task designed to generate IOR, regardless of prior cue location. Similarly, emotional stimuli used as orienting cues may also influence the IOR effect, signalling the importance of a particular object or location in subsequent encounters. Therefore, this *adaptive hypothesis* of IOR predicts that the mechanisms underlying the effect will be sensitive to the emotional content of a visually presented stimulus.

However, in direct contrast with this adaptive hypothesis is the very nature of IOR, which is believed to be largely reflexive, initiated by the onset of a non-predictive spatial cue. Therefore, any peripheral onset is likely to generate IOR under the right temporal conditions. Furthermore, considering the parameters of a spatial cuing task used to generate IOR, there is no reason to attend to the cued location. The cue is non-predictive, and thus volitional orienting toward its location is an inefficient strategy to complete the task. Consequently, it would seem that visual orienting to the cue location is involuntary, with there being no target detection benefits in terms of spatial or temporal information provided by the cue (Tipper & Kingstone, 2005). This *reflexivity hypothesis* predicts that the mechanisms underlying IOR will be insensitive to the emotional content of a visual stimulus.

The experiments presented in this thesis serve to probe the reflexive and adaptive hypotheses of IOR in the presence of emotional stimuli. Support for a reflexive account would suggest that IOR is generated by blind mechanisms that subserve the orienting system in a ballistic fashion, regardless of the nature of the stimuli present in the visual environment. In contrast, finding support for an adaptive account of IOR would suggest that the mechanisms underlying the effect are sensitive to, and facilitate perception of, emotionally salient events in the visual surround. Therefore, the experiments presented in Sections 2 – 5 of this thesis explore the relative sensitivity of the mechanisms subserving IOR to emotion by manipulating the nature of the target, response mode, and cue used in a standard spatial cuing task. Of course additional hypotheses are considered within each section, and it may be over simplistic to consider interactions between IOR and emotion as either present or absent. Nevertheless, based on the functional accounts, and the very nature, of IOR, parsimony in these initial hypotheses is justified.

Potential neuroanatomy of IOR and emotion interactions

Although the adaptivity versus reflexivity hypotheses presented here are to be tested empirically in this thesis, it is useful to consider whether there is a neuroanatomical foundation to potential IOR and emotion interactions. As described in Chapter 1, IOR can be generated through both the occulomotor system and the attentional system. This provides both a subcortical and cortical locus wherein emotionality may modulate the IOR effect. I will consider each in turn.

The superior colliculus (SC) has been extensively linked to the manifestation of IOR (Posner et al., 1985; Rafal et al., 1989; Sapir et al., 1999; Simion et al., 1995; Sumner, 2006; Sumner et al., 2004), and the SC may also play an important role in the perception of emotion. Studies investigating patients with cortical blindsight have revealed that in the absence of intact visual cortex, accurate perceptual discrimination and accompanying amygdala activation still occurs in response to emotional (fearful) faces (Morris, DeGelder, Weiskrantz, & Dolan, 2001). This suggests that when cortical vision is compromised, a subcortical processing route maintains emotion perception. This proposed retino-collicular-pulvinar pathway to the amygdala is believed to facilitate rapid processing of emotion, suggesting a role for the SC in the perception of emotion. Indeed, when fear-conditioned face stimuli are masked such that they are not consciously reported by participants, collicular (and pulvinar) activity positively correlates with amygdala activity (Morris, Öhman, & Dolan, 1999). This finding would suggest that the SC is part of a subcortical pathway that is involved in emotion processing, at least under conditions where that emotion is threatening and unseen. Therefore it is plausible that emotion-collicular interactions may influence visual orienting and IOR.

However, it seems unlikely that the SC itself processes visual information to the depth that would be required for emotion processing. The superficial layers of the SC receive direct visual input from the retina, where single unit recordings have revealed neurons that are sensitive to the presence and absence, motion, and relative size of a stimulus; however, differential responding to stimulus features (including orientation and shape) was not observed (Dean, Redgrave, & Westby, 1989; Schiller & Koerner, 1971). This would suggest that the SC does not encode precise visual information regarding the nature of a stimulus, and is unlikely to respond to emotional stimuli any differently than neutral stimuli. It seems more likely instead that afferent projections from the visual cortex may serve to modulate the SC at a later stage, once stimulus processing has occurred and emotional meaning extracted (Vuilleumier, 2005).

An alternative neuroanatomical approach to IOR and emotion interactions is to consider the functions of the SC as a structure in its own right. The SC receives converging multisensory afferents that give rise to adaptive motoric responding, wherein visual and auditory inputs are transformed through a motor map that can exert control over gaze direction (King, 2004). Therefore, the sudden presence of a shadow accompanied by rustling noises can alert the organism to orient toward the source of the stimulation. However, the SC may have a more adaptive role beyond visual orienting toward a stimulus onset. Injection of GABA antagonists into the rodent SC results in the presentation of defensive behaviours (including freezing and enhanced startle reflexes), accompanied by the observation that otherwise non-threatening stimuli become threatening (Redgrave, Dean, Souki, & Lewis, 1981). This has led some researchers to propose that the SC has two response systems, which either (a) encourage orienting toward a stimulus, or (b) encourage avoidance away from a stimulus (Dean et al., 1989). This dual response system seems likely to be mediated by the intermediate and deep layers of the SC, and may facilitate flight/fight responding. Furthermore, whether the SC responds in an approach-avoidance orienting manner may depend upon an established criterion in responding. Indeed this may require an additional cortical (and subcortical) contribution, with contextual information being important to the outcome of response (Dean et al., 1989). This apparent criterion-based collicular responding may support the vigilance of the mechanisms underlying IOR in monitoring and determining stimulus selection (Ivanoff & Taylor, 2006; Terry et al., 1994), and suggests a possible role for top-down control of IOR by emotion. Furthermore, frequent encounters with emotional stimuli may modify response criteria, enabling the rapid detection of visual stimuli (emotional and non-emotional). If the mechanisms underlying IOR are indeed modulated by top-down consequences of emotion, then this may be an orthogonal factor occurring independently of any adaptive or reflexive effects of IOR in the presence of emotion.

Although the SC is heavily implicated in IOR, as described in Chapter 1, there is also a significant cortical component to IOR, which includes frontal and parietal regions (Lepsien & Pollman, 2002; Mayer et al., 2004; Rosen et al., 1999; Sapir, Hayes, Henik, Danziger, & Rafal, 2004; Vivas et al., 2004; 2006). Heightened sensitivity of these regions in response to emotional stimuli may modulate the mechanisms underlying IOR, and this change in cortical sensitivity may be a consequence of the afferent projections of the amygdala increasing the responsiveness of these regions in the presence of emotion. Previous research has indicated the crucial role of the amygdala in increasing activity in the visual cortex in response to emotion (Morris et al., 1998; Vuilleumier et al., 2004), and therefore it is plausible that similar effects could occur in other cortical sites too. Moreover, if the amygdala exerts its effects through increases in cortical arousal for instance (Davis & Whalen, 2001), this effect is unlikely to be limited to just the visual cortex. Indeed, increases in activity of both visual and parietal cortex in participants viewing emotional pictures have previously been reported (Lang et al., 1998). Furthermore, amygdala efferents to the intraparietal sulcus (IPS) have been described (Amaral & Price, 1984), with lesions to the IPS resulting in impairments to inhibitory tagging measured in IOR tasks (Sapir et al., 2004). Consideration of these studies suggests that heightened cortical responsiveness (perhaps via an arousal mechanism) to emotional stimuli may modulate the manifestation of IOR.

Direct investigations of IOR-emotion interactions

The theoretical and neuroanatomical literature described above is largely circumstantial evidence surrounding the present issue of whether emotional stimuli will influence IOR. However, a number of primarily behavioural studies have begun to address this issue more directly, and have explored whether IOR is affected by emotional stimuli in two main ways: Firstly, by manipulating the affective state of the participant (Avila, 1995; Compton, 2000; Compton, Wirtz, Pajoumand, Claus, & Heller, 2004); and secondly, by modulating the emotional content of the stimuli used in the spatial cuing task (Stoyanova, Pratt, & Anderson, 2007; with some studies manipulating both stimulus valence and affective state, Avila & Parcet, 2002; Fox et al., 2002; Lange et al., 2008; Moritz & Lauden, 2007; Waters, Nitz, Craske, & Johnson, 2007; Yiend & Mathews, 2001).

Early interest in whether there was a relationship between personality differences and attentional biases led Avila (1995) to explore whether individual differences mediated the facilitatory and inhibitory components of exogenous orienting. A standard cuing task was used, and participants were assessed across a number of personality traits including anxiety, impulsivity, extraversion, and neuroticism. Attentional facilitation did not differ as a function of personality trait. However, high anxious participants showed a larger magnitude of IOR than low anxious participants. Furthermore, this effect seemed to be driven by levels of neuroticism. Individuals showing higher levels of neuroticism showed an increased IOR effect in contrast to individuals with lower neuroticism scores. This exaggerated IOR effect in neurotics suggests a stronger bias to orient away from previously attended locations in these individuals (Avila, 1995). However, subsequent studies have found individual differences instead influence attentional facilitation rather than IOR (Compton, 2000; Compton et al., 2004). Although a key difference in these studies was the individual difference variable of interest: facilitation and IOR effects were correlated with scores on negative and positive affect in these latter studies, rather than personality traits *per se*. Therefore the current affective state of an individual (in respect of anxiety and neuroticism) may indeed modulate IOR in the absence of an emotional stimulus (Avila, 1995).

The second approach to exploring IOR and emotion interactions has been to change the nature of the stimuli used in spatial cuing tasks: The emotional content of both target and cue components can be manipulated to measure their effects on visual orienting.

Orienting to targets. Previously, in the absence of emotionality, Reuter-Lorenz et al. (1996) investigated whether IOR was sensitive to the modality and intensity of stimuli presented as targets in a spatial cuing task. When making both manual detection and saccadic localisation responses, IOR was larger when detecting visual versus auditory targets. IOR was also significantly greater when detecting low intensity target stimuli (in both visual and auditory modalities) than high intensity target stimuli using a manual response. This study demonstrated the sensitivity of IOR to stimulus properties (modality and intensity), factors that are known to affect attentional processes in general. Reuter-Lorenz et al. (1996) speculated that the differential sensitivity to target modality and intensity might reflect changes in response criterion to these attributes at cued locations, rather than a specific modulation of perceptual processes by IOR. Nevertheless, the adaptive nature attributed to IOR suggests that it should be sensitive to biologically significant events (or targets) present in the visual environment. Two previous studies (Taylor & Therrien, 2005; 2008) have addressed this notion using socially relevant stimuli (i.e., faces) as targets in a spatial cuing task, and will be further discussed in Section 2 where the emotional content of target stimuli was instead manipulated, and the effects on IOR were measured.

Response mode. More recent investigations of IOR have characterised the effect as being linked to response-related processes (Ivanoff & Klein, 2001; 2006; Ivanoff & Taylor, 2006; Klein & Taylor, 1994; Taylor & Klein, 1998). In Section 3, I probed whether IOR interacts with the emotional compatibility between stimulus and response. Speeded responding to emotional stimuli is greatly facilitated when the response mode used is emotionally compatible (Elliot & Covington, 2001). For instance, making an avoidance response to an image of a snake is faster than when making an avoidance response to an image of a cupcake. Therefore, in the experiments reported in Section 3, emotional stimuli were again presented as targets, and participants made emotionally compatible or emotionally incompatible localisation responses.

Orienting to cues. The majority of research investigating the sensitivity of IOR to emotion has manipulated the emotional content of the peripheral cue stimulus. If IOR is generated at the onset of the cue, the emotional content of this cue may influence the engagement and disengagement processes of visual orienting. Although some of these studies find IOR changes as a function of cue valence indicative of a disengagement deficit to the cue (Fox et al., 2002; Yiend & Mathews, 2001), null effects of cue valence on IOR have also been reported (Avila & Parcet, 2002; Lange et al., 2007; Moritz & Lauden, 2007; Stoyanova et al., 2007). These mixed findings may be reflected partly in the nature of the research question being asked, but the trial events used to generate IOR (e.g., single cue, double cue, variable cue, target, and SOA events), the different responses required (localisation, discrimination, detection), and the inclusion of a variety of emotional stimuli (schematic faces, face photographs, emotional scenes) have all added variability to the data obtained. The differences in these studies and the results obtained will be discussed in more detail in Section 4, where stimuli controlled in terms of their salience were employed as cues in a cuing task designed to measure their effects on attentional facilitation and IOR.

IOR and stimulus saliency

Although the research described above is primarily interested in the effects of emotion on IOR, a secondary interest of this thesis was whether the mechanisms underlying IOR may modulate the emotional quality of a stimulus. Computational models of visual attention have included IOR as a mechanism that functions to reduce the saliency of previously attended objects and locations in guiding the focus of attention (Itti & Koch, 2000; 2001; Itti, Koch, & Niebur, 1998). Indeed, the parietal cortex has been identified as a possible anatomical location of such a spatial saliency map. Unilateral lesions to this region result in deficits to IOR, and these deficits are believed to reflect the changes in the relative saliency of the representations of locations in space (Vivas et al., 2003; 2006). If IOR does function to reduce location (and indeed object) salience, response time and accuracy may not be the only measure of this. Indeed attentional inhibition has previously been demonstrated to reduce the emotional salience of visual stimuli in a number of tasks (Raymond & Fenske, 2006), and therefore it is plausible that IOR may influence emotional as well as behavioural responding. Furthermore, the proposed influence of IOR on stimulus selection (Ivanoff & Taylor, 2006) suggests stimuli presented at locations subject to IOR may be differentially valued, in contrast to stimuli presented in locations where IOR is absent (at novel locations for instance). Therefore, the experiments presented in Section 5 explored whether the mechanisms subserving IOR also reduced the emotional salience of visual stimuli. Participants completed a conventional spatial cuing task, and evaluated stimuli presented at either previously attended (i.e., inhibited) or novel (i.e., uninhibited) locations at the end of each trial.

Chapter Summary

Adaptive theories of IOR support potential IOR and emotion interactions, subserved by cortical and subcortical components. Recent behavioural studies have also provided some initial evidence to support the sensitivity of the mechanisms underlying IOR to emotion. However, the very nature of the IOR effect as a reflexive phenomenon must not be forgotten, and it is the purpose of this thesis to determine whether this presumed ballistic nature of IOR is fragile to emotion. Furthermore, whether IOR influences emotional evaluations was also investigated, allowing possible reciprocity between IOR and emotion interactions to be considered.

The spatial cuing paradigm was the main methodology used in the experiments reported here, and Chapter 4 describes the details of the paradigm, along with the General Methods of the thesis, prior to the beginning of the empirical sections.

Chapter 4: General Methods

This chapter describes the principle methodology that was used in the experiments presented in this thesis. Details of the stimuli are described in each experimental section, along with any changes to the methodology that does not adhere to the description below.

Participants

Participants were recruited from the Student and Community panels of Bangor University, and participated in exchange for either course credit or money. All reported normal or corrected-to-normal visual acuity, gave their informed consent, and were naïve to the purpose of the experiment.

Apparatus and Stimuli

All Experiments were conducted using a Pentium-IV computer controlling a 51 cm colour monitor (85-Hz, 1280x1024 resolution) running E-Prime 1.1 software (Schneider, Eshman, & Zuccolotto, 2002). Displays were viewed at an average distance of 60 cm in a small quiet room, with low ambient illumination.

All stimuli appeared on a uniform white field. All text and alphanumeric stimuli (i.e., "+") appeared in black 18-point Courier-New font. An open circle served as a cue (5.2° by 4.8°) in all conditions where target content was manipulated. Further cue and target stimuli details will be considered in the relevant experimental sections, with exemplars of each, where appropriate, presented in Appendix A.

Design and Procedure

A typical trial sequence is illustrated in Figure 3. Each trial began with a central fixation cross that was presented on a blank screen and remained on throughout the trial. After 1000 ms, a cue appeared at 3.53° degrees either to the left or right of fixation for 85 ms. After cue offset, a re-orienting cue was presented by brightening the central fixation cross for 15 ms. The target was then presented for 200 ms either to the left or right (3.5°) of fixation in either the previously cued or uncued location.

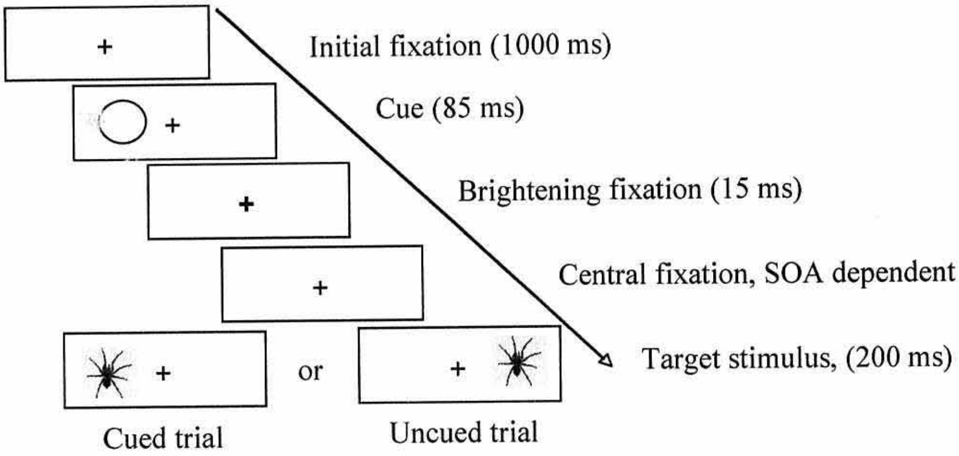

Figure 3. An illustration of a cued trial and an uncued trial in Experiment 1 (with a spider as the target). The task was to indicate the target's location (left or right) as quickly and as accurately as possible.

The interval between cue and target onset (stimulus onset asynchrony, SOA) was either brief (100 ms) or long (500, 1000, 1500, 2200, or 3200 ms). The brief SOA was principally included to ensure the experimental design was capable of generating both the facilitatory and inhibitory components of exogenous orienting (Posner & Cohen, 1984). Moreover, variable SOAs may also be advantageous in dissuading eye-movements to the cue location, increasing task difficulty and impairing performance if this strategy is adopted. Participants were instructed to indicate the target's location as quickly and accurately as possible using the "z" key (left index finger) and the "m" key (right index finger) to report left and right, respectively. Response time (RT) was defined as the interval between target onset and a key press response. After response, the fixation cross turned red, remaining so until the participant initiated the next trial by pressing the space bar.

The cue and target always appeared in randomly determined locations, with the sole constraint that on half of trials the target was validly cued (a cued trial) and on remaining trials the target was invalidly cued (an uncued trial). Each experimental session began with a series of practice trials prior to the experimental trials. On completion of the experimental session, participants were thanked for their time and fully debriefed.

Data Analysis

In all experiments, only RTs from trials with a correct target localisation response were analysed. RTs less than 200 ms were assumed to be anticipation response errors and were removed from the analysis, and responses slower than 1200 ms were also excluded. Mean RTs for each participant for each combination of target location (cued versus uncued) and SOA were calculated, and RTs greater than three standard deviations above or below the mean were excluded. IOR magnitude was calculated for each participant for each combination of SOA by subtracting the mean RT for cued trials from that for uncued trials. A criteria alpha value of .05 was used in all subsequent experiments unless otherwise stated.

Section 2: Visual orienting to emotional targets

Abstract

IOR refers to slower responding to a visual target appearing at a previously attended versus unattended location. In six experiments the sensitivity of IOR to the emotional content of target stimuli was investigated. Using a traditional spatial cuing task, participants reported the location of negative (spiders, angry faces), positive (sweet foods), or neutral (objects, neutral faces) targets that were presented in either previously cued or uncued locations. IOR was significantly smaller when detecting emotional targets compared to neutral targets, but only after repeated, successive exposures to these stimuli when presented in blocks of trials. This effect was eliminated when target type was randomised within blocks. By presenting emotional and neutral targets in short alternating blocks and examining IOR on the first trial of each new block, this emotional modulation of IOR was demonstrated as stemming from the affective context in place before visual orienting is initiated, not by perceptual processing of the target after cue offset.

Chapter 5: Section Introduction

The reflexivity in generating IOR predicts that the mechanisms mediating the effect should be insensitive to the meaning or emotional content of the visual object (i.e., the target) appearing after the initial onset of peripherally presented spatial cues (Tipper & Kingstone, 2005). However, this seems counterproductive for scenarios in which emotionally salient, particularly threat-relevant, stimuli are likely to appear at previously cued locations. Indeed, more adaptive accounts of IOR postulate that the neural mechanisms underlying the effect may prevent responding to previously cued locations, enabling behaviour to be modified to meet the needs of the environmental setting (Ivanoff & Taylor, 2006; Terry et al., 1994). This adaptive interpretation of IOR would suggest that the mechanisms subserving the effect should be sensitive to the presence of emotionality in the visual scene, facilitating rapid responding to emotional stimuli irrespective of prior cue location. The experiments presented here explored this proposed adaptivity of IOR by presenting emotional stimuli as targets in a conventional spatial cuing paradigm designed to generate IOR.

The majority of IOR studies have used simple meaningless stimuli as targets in spatial cuing paradigms. Early research probed whether IOR was sensitive to the modality and intensity of target stimuli, finding that IOR was larger for visual than auditory targets, with more intense (increased brightness, increased volume) targets reducing the magnitude of IOR obtained (Reuter-Lorenz et al., 1996; see also Hunt & Kingstone, 2003). Although these data were used to support an attentional account of IOR, these results may also represent a shift in the response criterion for target detection at the cued location. For instance, the IOR effect measured by Reuter-Lorenz et al. (1996) was greater for less intense targets, and this may reflect a greater response criterion threshold for target detection at cued versus uncued locations (Reuter-Lorenz et al., 1996).

Nevertheless, the adaptive nature attributed to IOR suggests that it should be sensitive to biologically significant events present in the visual environment. Taylor and Therrien (2005; Experiments 2 and 3; Taylor & Therrien, 2008; Experiment 4) explored this notion by presenting social stimuli (upright faces) and non-social stimuli (scrambled faces and pixilated image) as targets in a task designed to generate IOR. If the mechanisms subserving IOR are sensitive to socio-biological information, IOR should change as a function of the target content (face, non-face). Specifically, smaller IOR effects for face targets would suggest that the stimuli were prioritised for processing, overcoming the effects of IOR in comparison to non-face targets. However, this was not the case: When social and non-social targets were presented, IOR was equivalent regardless of target content. Although there was a trend for smaller IOR following face targets in Experiment 2, this effect was found to be inconsistent across participants, and was not replicated in a further experiment. This absence of sensitivity to target content by IOR suggests that the neural mechanisms underlying the effect are blind to stimulus content, at least when that content is socially relevant (Taylor & Therrien, 2005). However, the face stimuli presented in these tasks were affectively neutral, leaving open the question of whether emotionally salient targets could modulate the IOR effect. The goal of Experiments 1 – 6 was to investigate this issue.

As described in Chapter 1, the effectiveness of attentional control and responding in the presence of emotionally charged stimuli has attracted a great deal of interest. These studies are motivated by the need to gain ecological relevance in the understanding of visual attention, and by recent evidence from human neuroscience that attentional and emotional brain systems are heavily interconnected (e.g., Bush et al., 2000; Yamasaki, et al., 2002). Obvious emotionality in target stimuli reduces response times in tasks demanding voluntary control over attention orienting (e.g., Brosch & Sharma, 2005; Eastwood et al., 2001; Flykt, 2005; Fox et al., 2000; Öhman et al., 2001) and facilitates perceptual detection (e.g., Anderson & Phelps, 2001; Phelps et al., 2006; Vuilleumier & Schwartz, 2001a; 2001b). Furthermore, emotional distractor stimuli hinder responding to targets, capturing attention inappropriately (Eastwood et al., 2003; Fox et al., 2001; 2002). These findings provide a strong rationale for investigating whether emotionality in stimuli could modulate spatial attention mechanisms that may mediate IOR.

The question to be addressed by the current experiments was whether visual orienting, as measured with the spatial cuing paradigm, is affected by the emotional content of targets. Specifically, I was interested in whether threat-relevant stimuli would reduce IOR effects in contrast to neutral stimuli. This effect could occur in two different ways. Firstly, emotional content in a target could influence IOR late in processing, that is, after target onset but before initiation of response. Emotional content in a target could be processed on-the-fly (e.g., through the retino-collicular-pulvinar pathway to the amygdala, LeDoux, 1998) prior to response preparation. This would enable emotional information to modulate responding in this task by overcoming the inhibitory tag present at a cued location. However, arguing against the possibility of a late-acting emotional process is evidence that emotionality in briefly presented faces remains unprocessed (e.g., by the amygdala) when attention is directed elsewhere (Pessoa, 2005; Pessoa et al., 2002; Silvert et al., 2007; although see also Vuilleumier et al., 2001). Moreover, the previous work by Taylor and Therrien (2005; 2008) does not support this possibility. The absence of any effects of emotion on IOR would also be consistent with the assumed reflexivity of the effect (e.g., Rafal & Henik, 1994; Tipper & Kingstone, 2005). Second, if the context of the visual scene was such that emotional targets were frequently experienced and expected, then top-down contextual codes could modulate visual orienting mechanisms, adjusting their current level of responsiveness, even before cues and targets on any specific trial were presented. Such a context-sensitive mechanism, perhaps related to arousal, would be adaptive because it could prevent slowed returning of attention or responding to locations where potentially threatening stimuli had been frequently experienced and were expected to occur again.

To explore these two different modes (context sensitive versus on-the-fly processing) by which emotional content could influence IOR, two different experimental designs were used in the experiments reported here. First, to test the context-sensitive mode, I used a between-group design (Experiments 1 and 3), exposing participants only to threatening or neutral targets so that during the experiment a reliable affective context could be established, making the presentation of emotional or neutral targets fully predictable. Then, to test on-the-fly processing, I used a within-subjects design (Experiment 2 and 4), randomly varying the presentation of target type (emotional or neutral) from trial to trial. In a fifth experiment, I combined these two approaches using interleaved mini-blocks (short strings of same-target trials) to systematically contrast the effects of affective context with current target type. Experiment 6 used affectively positive targets and the data was included in a meta-analysis of IOR and emotion effects across all the between-group target conditions (positive, negative, neutral). All the experiments used a conventional spatial cuing paradigm that required participants to locate targets as quickly and as accurately as possible. A localisation response was employed to render the emotional content of the target as task-irrelevant. In Experiments 1 and 2, targets were either spiders or neutral objects and in Experiments 3, 4, and 5, targets were faces, displaying emotional (Experiments 3 and 5: angry; Experiment 4: angry, happy, fearful) or neutral expressions. Experiment 6 presented target stimuli that consisted of sweet foods, and to encourage a positive affective response, were presented after a fasting period. In all cases, cues were simple open circles.

Experiment 1

Experiment 1 was designed to determine whether IOR would have a different magnitude and/or time course when targets were naturally threatening images (spiders) or neutral objects. A between-subjects design was used such that half the participants were exposed to spider targets and half to neutral object targets.

Method

Participants

Fifty experimentally naïve adults (33 females; mean age = 23 years) were divided equally into two groups, with 25 in each target type condition.

Apparatus and Stimuli

The apparatus are described in Chapter 4. Thirty-six exemplars of each target type were used (see Appendix A), and images (objects and spiders) had a width ranging from 1.2° to 6.7° and height ranging from 1.8° to 7.0°. Neutral object targets consisted of different computer-generated, full colour images of everyday objects (e.g., a ruler, a shopping basket, a stapler). Spider images were grey-scaled and presented in isolation at different orientations to maximise ecological validity.

Design and Procedure

The procedure for these experiments is presented in Chapter 4. There were 14 trials for each of combination of SOA (six values), cue location (left, right), and target location (left, right), making 336 experimental trials. Each experimental session began with 12 practice trials and was run in two separate blocks of 168 trials each, separated by a brief rest period. The experimental session lasted no longer than 30 minutes.

Data Analysis

In this experiment, mixed effects ANOVAs using target location (cued, uncued) and SOA as within-subject factors and target type (object, spider) as a between-group factor were performed on the accuracy and RT data.

Results and Discussion

Error rates. Error rates were low (<1%). The mixed effects ANOVA revealed no modulation of accuracy by cue validity, *F*<1, target type, *F*(1,48) = 2.05, *p* = .16, and the cue validity and target type interaction was also non-significant, *F*(1,48) = 2.10, *p* = .15. No other main effects or interactions reached significance, *F*'s < 1.66, *p*'s > .14.

RTs. As shown in numerous previous studies and apparent in the data obtained here (see Figure 4), the global mixed effects ANOVA here demonstrated that differences in RT for targets appearing at uncued and cued locations (cue validity) were strongly affected by SOA, *F*(5,240) = 16.78, *p* < .001. Examining only data from the 100 ms SOA condition as a function of cue validity and target type revealed that target localisation was 17 ms faster for cued locations than for uncued locations, *F*(1,48) = 19.64, *p* < .001. Note that this attentional facilitation by cuing was unaffected by target content, *F* < 1. The magnitude of the facilitation effect for spiders was 23 ms, and the facilitation effect for objects was 15 ms.

Analysis of RT including data from only the longer SOAs (>100 ms) in the mixed effects ANOVA demonstrated spatial cuing slowed target detection by 14 ms on average, indicating IOR, *F*(1,48) = 76.12, *p* < .001. Note that the IOR effect is plotted for each target type in Figure 4c. Although target type did not modulate RTs, *F* < 1, the effect of target valence on RTs changed as a function of SOA, *F*(4,192) = 3.51, *p* < .01.

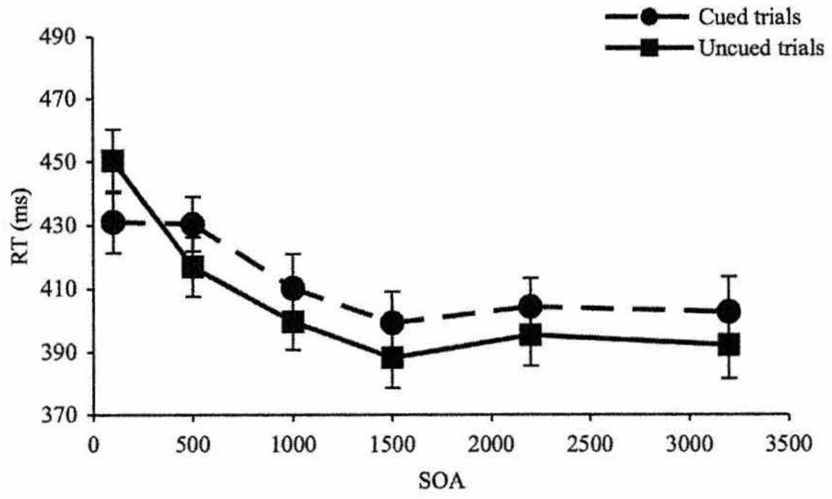

Figure 4a. Group mean RT obtained in Experiment 1 (target type blocked) for locating a spider target plotted as a function of SOA. Vertical bars indicate +/- 1 S.E.

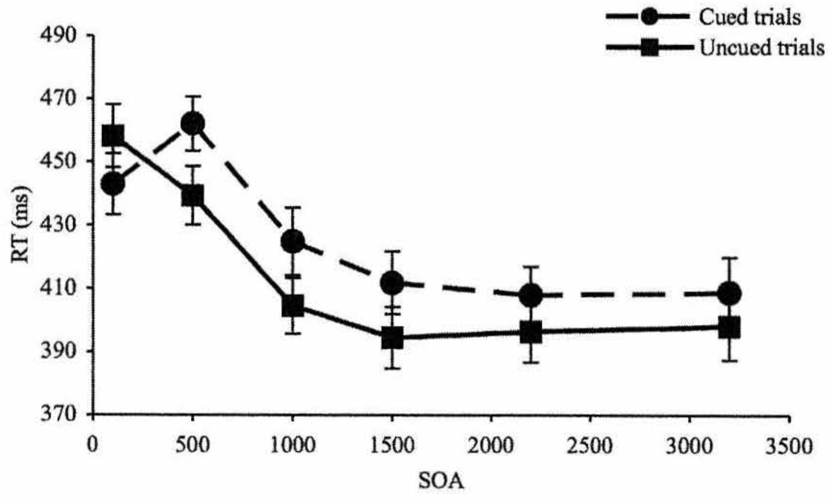

Figure 4b. Group mean RT obtained in Experiment 1 (target type blocked) for locating a neutral object target plotted as a function of SOA. Vertical bars indicate +/- 1 S.E.

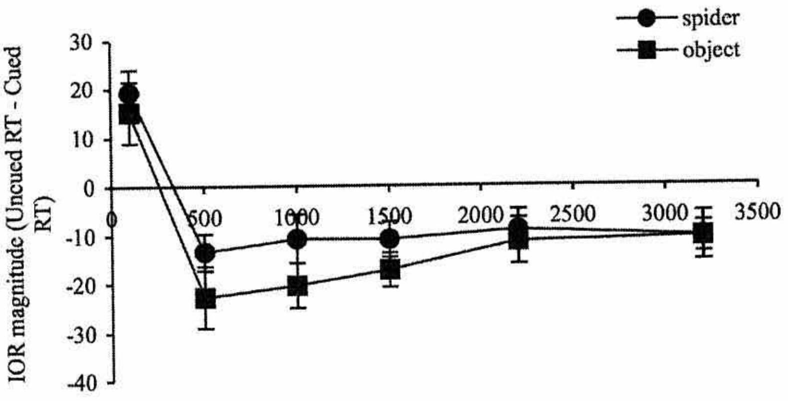

Figure 4c. IOR effect obtained in Experiment 1 (target type blocked) for locating a negative target or a neutral object target plotted as a function of SOA. Vertical bars indicate +/- 1 S.E.

Of particular interest here was the finding that cue validity marginally interacted with target valence, $F(1,48) = 3.11, p = .08$. To explore this effect in more detail, IOR magnitude (uncued RT – cued RT) obtained with 500, 1000, and 1500 ms SOAs was analysed, omitting data obtained with longer SOAs (>2200 ms). Not only has previous research indicated that IOR diminishes as SOA becomes greater than 2000 ms (e.g., Samuel & Kat, 2003), the data shown in Figure 4 suggest that any target content effects also collapse at this point. When IOR magnitude data obtained from this middle range of SOAs were analysed as a function of cue validity and target type, spider targets were found to significantly reduce IOR magnitude compared to that measured with object targets, $F(1,48) = 4.47, p < .05$. Mean IOR magnitude for spiders (-12 ms) was nearly half that for objects (-20 ms). Analysis of the longer SOA (>2200 ms) revealed no such modulation of IOR by target valence, $F < 1$.

A significant reduction in the IOR effect for mid-range SOAs for spiders versus neutral objects suggests that IOR may be modulated by emotional information in target stimuli. This would support the on-the-fly processing of emotion prior to response execution. Alternatively, this target content effect could have resulted because participants in the spider condition could predict accurately both the emotional nature of targets and their category (always spiders) on successive trials, whereas participants in the object group could not predict the object category (which changed from trial to trial), even though the emotional neutrality of targets was fully predictable. This raises the possibility that IOR may be reduced by expectation of negatively valenced images or by high predictability of the target category.

A third possible explanation for the target content effect observed in this experiment is that participants in the spider condition experienced a change in affective state (e.g., arousal, mood effects) that participants exposed to object images did not. Previous research (e.g., Bradley, Cuthbert & Lang, 1996; Smith, Bradley, & Lang, 2005) has shown that repeated exposure to negative stimuli can result in short-term physiological changes. Viewing unpleasant pictures decreased heart rate, increased electromyographical (EMG) activity of the facial corrugator muscles, and enhanced the magnitude of the startle reflex. The latter two effects persisted for some time even after unpleasant pictures were removed from view. It is possible then that a similar persistent affective state was induced in this experiment and that this served to mitigate IOR. However, in considering these different explanations (on-the-fly processing, expectancy, and affective state), it is curious why these effects are not consistent across all the SOA conditions. This point will be returned to in the Section Discussion.

To explore these issues, four further experiments were conducted. Experiment 2 used the same stimuli as Experiment 1 (spiders and objects) but employed a within-subjects design, pseudorandomly presenting either spiders or objects as targets on successive trials within each experimental block. This reduced the possibility of inducing a change in affective state in participants and enhanced the unpredictability of target stimuli category and emotional valence. Experiments 3 and 4 used a single category of stimuli (faces with angry or neutral expressions), thus eliminating object category uncertainty. These were presented in a between-design (to potentially induce state effects; Experiment 3) or in a within-subject randomised design (to reduce state effects and to test on-the-fly processing effects; Experiment 4), mirroring Experiments 1 and 2, respectively.

Experiment 2

In this experiment, targets on successive trials varied pseudorandomly between spiders and objects. If rapid perception of negative emotional content in targets could modulate IOR, then smaller IOR effects should be found with spider targets than neutral object targets. However, if the reduced IOR effect for spiders observed in Experiment 1 was due to state changes or greater predictability of target content, then no difference in IOR for spiders versus object targets should be found. An important procedural difference between this and Experiment 1 is that only one SOA (1000 ms) was used.

Method

Participants

Twenty-two naïve adults (18 females; mean age = 22 years) participated.

Apparatus and Stimuli

The apparatus and stimuli were the same as Experiment 1, except that object stimuli were now grey-scaled to match the spider stimuli from Experiment 1.

Design and Procedure

The procedure was the same as in Experiment 1 with the following exceptions. First, each trial began with a 4000 ms "get ready" prompt. Second, only the 1000 ms SOA was used, which was the SOA condition in Experiment 1 that yielded the greatest difference in IOR magnitude (-10 ms) between the emotional and neutral target condition. There were 42 trials for each combination of cue location (left, right), target location (left, right), and target type (spider, object), making 336 experimental trials. Each experimental session began with 16 practice trials and was conducted in two separate blocks of 168 trials each, separated by a brief rest period. The experimental session lasted no longer than 45 minutes.

Results and Discussion

Error rates. Error rates remained low (less than 1%) and did not differ by target type, $F<1$, cue validity, $F(1,21) = 1.97, p = .18$, and the interaction between target type and cue validity was also non-significant, $F<1$.

RTs. RTs were analysed using a repeated measures ANOVA specifying cue validity and target type as the within-subjects factors. As can be seen in Figure 5, participants were generally faster to detect spider targets than object targets, $F(1,21) = 49.35, p < .001$. A significant effect of cue validity was also observed, $F(1,21) = 23.05, p < .001$, with slower responding to targets of either type when presented in cued locations versus uncued locations, indicating IOR. Unlike Experiment 1, there was no interaction between target type and cue validity, $F < 1$. Mean IOR for spider targets was -19 ms and did not differ from the mean IOR for object targets (-25 ms), $t < 1$[6].

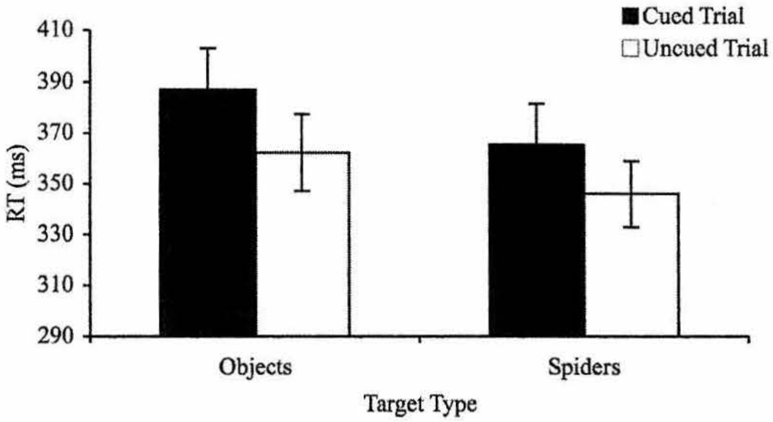

Figure 5. Group mean RT obtained in Experiment 2 (mixed blocks) for locating object or spider targets presented at just previously cued or uncued locations. Vertical bars indicate +/- 1 S.E.

This failure of emotional targets to modulate IOR is inconsistent with the hypothesis that rapid on-the-fly analysis of emotional content in targets can modulate IOR, eliminating this as a possible account for effects observed in Experiment 1. IOR modulation by context induced by repeated exposure to threatening stimuli thus remains a viable explanation along with the possibility that expectation of target content may play a role. Moreover, the data from the current experiment might provide some evidence to

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[6] This absence of an interaction between target type and cue validity was still absent when the trial numbers were equated to match those from Experiment 1 at the 1000 ms SOA, $F < 1$.

distinguish between these two potential accounts. Specifically, IOR effects were then examined on trials that had been preceded by three trials of the opposite type. IOR for spider-target trials that had been preceded by three object-target trials in succession was contrasted with IOR for object-target trials that had been preceded by three spider-target trials. If repeated exposure to threatening stimuli had induced a change in affective state, then IOR should be smaller for trials with object targets preceded by spider-targets than for spider-target trials preceded by a string of object-target trials. If on the other hand expectation accounts for the IOR modulation observed in Experiment 1, then the opposite effect should be seen because after three successive trials with the same target type, participants should be expecting the opposite target type to occur, owing to expectation of 'randomness'. Sensitivity to target expectations has been demonstrated behaviourally and at a neurophysiological level, with changes in activity in prefrontal cortex during changes in target presentation probabilities for instance (e.g., Casey et al., 2001). This expectancy account predicts smaller IOR for spider-targets preceded by object-target trials than for object-targets preceded by spider-target trials.

Only 12 % of trials (965 trials in total) overall fit the criteria for this post-hoc analysis, limiting statistical power. Nevertheless, there was a significant IOR effect, $F(1,21) = 10.77, p < .01$, although the interaction of IOR with target type was not significant, $F(1,21) = 2.20, p = .15$ (Mean RTs obtained from this analysis are reported in Table 1). However, consistent with the prediction that repeated exposure to threatening stimuli should induce a change in context that might reduce IOR, the IOR effect (-11 ms) was small and non-significant, $t(21) = 1.28, p = .21$, for objects following a run of spider-target trials but was more than twice as large (-26 ms) and highly significant, $t(21) =$

3.16, $p < .01$, for spider trials preceded by object trials. This analysis favours the account that repeated exposure to spiders induced a change in affective state that was capable of mitigating IOR and does not support the idea that expectation, *per se* (of spider targets), reduces IOR. It also provides further evidence against the possibility that on-the-fly target content analysis modulates IOR.

Table 1. Mean RTs for trial-by-trial analysis in Experiment 2.

	Cued Trial RT		Uncued Trial RT	
	M	*SE*	*M*	*SE*
Object Target (preceded by 3 spider trials)	385	18	374	18
Spider Target (preceded by 3 object trials)	372	18	346	12

Taken together, Experiments 1 and 2 show that IOR is not modulated by emotional codes derived from targets after their presentation, but, rather, is influenced by sustained exposure to emotionally valenced stimuli via an induced temporary change in affective state. Experiments 3 and 4 sought to explore whether this effect was specific to spider stimuli or reflected a more general response to threatening stimuli. Using a single category of stimuli (faces) further tested whether category predictability contributes to IOR modulation.

Experiment 3

In this and Experiment 4 targets to be detected were images of either emotional or neutral faces. The design and procedure for each experiment mirrored those of the previous two experiments. Using face images as targets had three important benefits. Firstly, investigating whether the effect of affective context on IOR induced by exposure to spiders (Experiments 1 and 2) would also be found with other emotionally-relevant stimuli could be established. Secondly, faces allowed much greater control over low-level stimulus features in the emotive versus neutral target conditions because the same face identities were used in all conditions. Thirdly, faces belong to a single object category and thus, unlike Experiments 1 and 2, these stimuli made category predictability identical in the neutral and emotional conditions. If category predictability accounts for the modulation of IOR seen in Experiment 1, then no differences in IOR magnitude should be found.

In Experiment 3, using the procedure and design of Experiment 1, angry face targets were presented to one group of participants and neutral face targets were presented to another group. Based on the results of Experiment 1, I predicted smaller IOR for the angry face group than for the neutral face group would be found.

Methods

Participants

Forty experimentally naïve participants (27 females; mean age 19 years) were recruited as before. Participants were randomly and equally assigned to each target type (neutral, angry) condition.

Apparatus and Stimuli

Apparatus was the same as before. Emotional face stimuli consisted of six individuals (3 males) posing either an angry or neutral expression (12 stimuli in total) and were selected from the Ekman and Friesen (1976) series. Face stimuli were presented upright, measuring 4.8° by 5.9°. These stimuli were selected based on pre-testing accuracy of emotional expression identity across all the expressions composing the Ekman and Friesen (1976) series by three independent participants, ensuring that the faces included in the experiment were sufficiently salient in the emotion they expressed. This was achieved by measuring performance accuracy on correctly identifying the emotional expression each actor posed in a paper-based questionnaire. Only actors employing expressions correctly identified across all participants were included in the stimulus set.

Design and Procedure

The procedure was the same as Experiment 1 except that only the 1000 ms SOA was used, and a green fixation cross was presented for 2000 ms to mark the beginning of each new trial. There were 72 trials for each of the combinations of variables: Cue location (left, right), target location (left, right), with target type (angry, neutral) as a between-group factor. This made a total of 288 experimental trials. Each experimental session began with 8 practice trials. Experimental trials were conducted in two separate blocks of 144 trials each, with a rest period between blocks. The experimental session lasted approximately 45 minutes.

Results and Discussion

Error rates. Accuracy was marginally modulated by target content, $F(1,38) = 3.25$, $p = .08$, with error rates being 3% for angry face detection and 2% for neutral face detection, indicating a potential speed accuracy trade-off because detection for angry faces was faster than that for neutral faces (described below). Moreover, there was a hint that accuracy was affected by cue validity, $F(1,38) = 3.13$, $p = .09$. Error rates in cued trials were at 3% and error rates in uncued trials were at 2%. Note the target type and cue validity interaction was non-significant, $F<1$.

RTs. RTs were entered into a mixed effects ANOVA specifying cue validity as the within-subject ANOVA and target type as the between-group factor. Target detection was significantly slower for targets presented at previously cued versus uncued locations, $F(1, 38) = 24.45$, $p < .001$, indicating the presence of IOR. As can be seen in Figure 6, participants were faster to detect angry faces than neutral faces in this task, $F(1, 38) = 5.79$, $p < .05$.

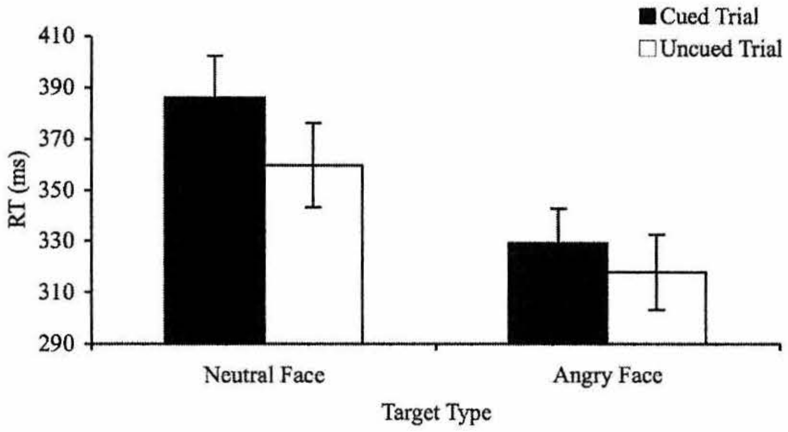

Figure 6. Group mean RT obtained in Experiment 3 (target type blocked) for locating angry or neutral face targets presented at just previously cued or uncued locations. Vertical bars indicate +/- 1 S.E.

Consistent with Experiment 1 where IOR was reduced for emotional versus neutral targets, IOR was significantly smaller when detecting angry faces than when detecting neutral faces, *F(*1, 38) = 3.66, *p* = .05. The IOR effect for angry faces was -11 ms, less than half the IOR effect for the neutral faces (-27 ms). This difference is similar to that found in Experiment 1 (-12 ms for spiders versus -20 ms for objects). Note that even in the presence of a potential speed-accuracy trade-off here, this pattern of results still converged with the results of Experiment 1 where no such speed-accuracy trade-off was present. Therefore, the marginally impaired performance in the angry versus neutral condition did not influence the modulation of IOR here.

Taken together, these findings indicate that IOR can be modulated by the content of target stimuli when target type is blocked. The possibility that predictability of target category played a role in Experiment 1 can be ruled out because in Experiment 3 the same effects of emotional content on IOR magnitude were observed, yet in the latter experiment, category predictability was identical in both conditions.

Experiment 4

Experiment 4 mirrored Experiment 2 in that it used a within-subject design and varied the emotional expression of the target face randomly from trial to trial. The question addressed here was whether the reduction in IOR found with angry target faces in Experiment 3 was dependent on an affective state induced by sustained exposure to these stimuli or whether it reflected on-the-fly processing of emotional content in the target. In addition to using angry and neutral expressions on face targets, happy and fearful expressions were also presented in this experiment. Using several examples of stimuli varying in emotionality enabled on-the-fly processing by emotional stimuli beyond threat-relevance to be identified. Images of the same individuals posing all four expressions (angry, fearful, happy, and neutral) were used.

Methods

Participants

Twenty-five experimentally naïve adults (17 females, mean age 27 years) participated.

Apparatus and Stimuli

The apparatus was the same as that used previously. As in Experiment 3, images of six adults (3 males) from the Ekman and Friesen (1976) set each expressing angry, happy, fearful, and neutral expressions were used as target stimuli (24 stimuli in total).

Design and Procedure

The procedure was the same as in Experiment 3. The expression and identity of the target was varied pseudorandomly from trial to trial so that 18 trials for each of the combination of emotional expression (happy, angry, fearful, neutral), cue location (left, right), and target location (left, right) were presented, making a total of 288 experimental trials.

Results and Discussion

Error rates. Error rates were less than 2% and were not modulated by target type, $F < 1$, cue validity, $F(1,24) = 1.62$, $p = .22$, or their interaction, $F(3,72) = 1.41$, $p = .25$.

RTs. Mean RTs for target detection for each target type (emotional expression) are presented in Figure 7.

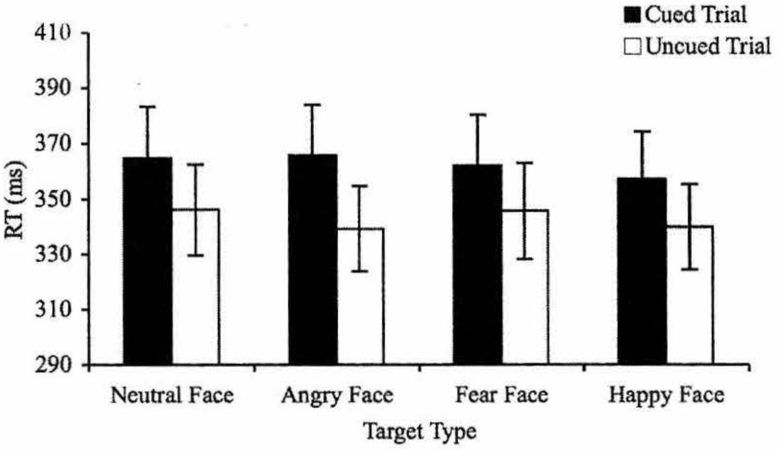

Figure 7. Group mean RT obtained in Experiment 4 (mixed blocks) for locating angry, happy, fearful, or neutral face targets presented at just previously cued or uncued locations. Vertical bars indicate +/- 1 S.E.

RTs were analysed in a repeated measures ANOVA specifying cue validity and target expression as within-subject factors. RTs were not significantly modulated by target expression, $F(3,72) = 1.95$, $p = .13$, although detection of happy faces was somewhat faster than for targets with the other expressions. Target detection was 20 ms slower for face targets presented in previously cued locations, $F(1,24) = 22.52$, $p < .001$, consistent with IOR. Target expression and cue validity did not interact, $F < 1$, indicating that IOR was unaffected by target expression[7]. As expected, these findings are highly consistent with those of Experiment 2. There were insufficient trials to investigate the modulation of IOR by prior exposure on three successive trials to angry faces (as was done for spiders in Experiment 2). The null result obtained here supports the contention that on-the-fly processing of emotional content in images cannot modulate IOR.

Experiment 5

Using blocked versus randomised target type presentations, findings from the series of experiments reported thus far suggest that sustained exposure to threatening stimuli induces a transient affective state that diminishes IOR, and that IOR mechanisms are otherwise "blind" to the emotional content in targets once visual orienting responses are initiated. Although supported by the post-hoc analysis of Experiment 2, I sought to test this more directly and systematically by devising an experiment comprised of a series of short same-target 'mini' blocks (4, 8, or 12 trial strings). The trials within each mini-block had face targets with the same expression (angry or neutral) and block type was alternated, creating a large number of switch trials (trials with a change in target type). I

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[7] Again trial numbers here were equated with those from Experiment 3. The target expression and cue validity interaction still remained non-significant, $F(1,38) = 2.52$, $p = .12$.

was specifically interested in comparing the RTs obtained on switch trials for different block types to determine whether the target type in the preceding block influenced IOR. If the mechanisms underlying spatial orienting are sensitive to affective context (Experiments 1 and 3), exposure to a series of angry face trials should lead to a reduction in the magnitude of IOR obtained in response to a neutral face target (neutral-switch trials), and exposure to a series of neutral face trials should lead to larger IOR effects obtained in response to angry face targets (angry-switch trials).

Methods

Participants

Twenty-eight experimentally naïve adults (20 females, mean age 21 years) participated.

Apparatus and Stimuli

The apparatus was the same as previously used. Consistent with Experiment 3, images of six adults (3 males) from the Ekman and Friesen (1976) set each expressing angry or neutral expressions were used as target stimuli (12 stimuli in total).

Design and Procedure

Experimental trials were divided equally into 48 mini-blocks, half containing angry face targets and half containing neutral face targets. Block expression type was systematically interleaved. Mini-blocks varied in length, comprising 4, 8, or 12 trials, so that a switch in target type could not be anticipated easily, and to minimise any effect of expectancy of an expression block switch. Each combination of mini-block length and expression was presented eight times, making a total of 384 trials. Within each block and specifically on the first trial of each block, each combination of cue location (left, right) and target location (left, right) was presented an equal number of times and in a pseudorandom order. Face stimuli were randomly selected for each expression block and appeared an equal number of times across the course of the experiment. The testing session always began with an angry block and the procedure was otherwise the same as for the previous experiments. The first trial of each testing session and the one immediately following a mid-session break were removed from analyses owing to the absence of any preceding trial events.

Results and Discussion

Error rates. Accuracy in this task was marginally greater following localisation of angry targets (97.2%) than neutral targets (96.7%), *F*(1,27) = 3.64, *p* = .07. Further, accuracy was improved in uncued trials (97.5%) versus cued trials (96.5%), *F*(1,27) = 5.20, *p* = .03, with the interaction between target expression and cue validity also reaching significance, *F*(1,27) = 5.65, *p* = .03. This interaction can be explained by poorest performance when localising neutral targets in cued trials (96%) compared to uncued trials (98%), with performance localising angry targets being equivalent in cued and uncued trials (97%). This difference in accuracy does not reflect a speed-accuracy trade-off, with faster and more accurate performance when localising angry targets (Table 2).

RTs. Using a repeated measures ANOVA specifying cue validity and target expression, mean RT averaged across switch and non-switch trials demonstrated localisation was marginally faster for angry versus neutral targets, $F(1,27) = 3.72, p = .06$, indicating somewhat better performance with angry face targets (see Table 2). Target detection was slower for targets presented at previously cued locations, indicating IOR, $F(1,27) = 32.03, p < .001$. Face target expression and cue validity did not interact, $F(1,27) = 2.39, p = .13$.

Table 2. Mean RTs for Experiment 5 (all correct trials).

	Cued Trial RT		Uncued Trial RT	
	M	*SE*	*M*	*SE*
Angry Face Target	382	18	359	17
Neutral Face Target	382	17	364	18

Analysis of these RTs as a function of effect of block length (4, 8, or 12 trials), target expression, and cue validity revealed no modulation of mean RT by mini-block, $F < 1$; moreover, block length did not interact with target expression, $F(1,40) = 1.48, p = .24$, and the three-way interaction between block length, target expression, and cue validity was also non-significant, $F < 1$. Consequently, data was collapsed across block length to compute the measure of primary interest here: The mean RT for switch trials (the first trial of each new block). The group mean switch RTs for cued and uncued trials for each target type are presented in Figure 8 and were analysed in a repeated measure

ANOVA specifying cue validity and target expression as the within-subjects factors. This analysis showed that although target expression did not modulate RTs, *F* < 1, response times were slower for targets presented at cued locations versus uncued locations, demonstrating IOR, *F*(1,27) = 41.10, *p* < .001. Importantly, cue validity significantly interacted with target expression, *F*(1,27) = 5.13, *p* < .05. Mean IOR magnitude was significantly larger for angry targets (-36 ms) than neutral targets (-16 ms), *t*(27) = -2.26, *p* < .05. Expressed differently, IOR was significantly smaller immediately after a mini-block of angry face targets than it was after a mini-block of neutral targets.

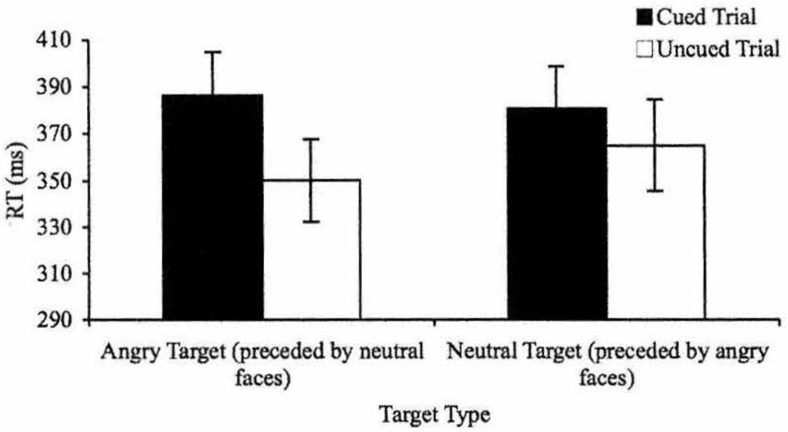

Figure 8. First trial analysis of group mean RT obtained in Experiment 5 for locating angry or neutral face targets presented at just previously cued or uncued locations. Note here that angry targets were preceded by a block of neutral target trials, and neutral targets were preceded by a block of angry target trials. Vertical bars indicate +/- 1 S.E.

Mean RT for all trials excluding switch trials were also analysed as a function of cue validity and target expression. RTs were faster to detect angry face targets, *F*(1,27) = 4.26, *p* = .05, and there was a significant IOR effect, *F*(1,27) = 26.45, *p* < .001. Cue validity did not interact with target expression, $F < 1$, indicating that face expression did not modulate IOR magnitude when RTs were averaged across serial position within each mini-block. For angry, non-switch trials, IOR was -21 ms and for neutral, non-switch trials it measured -18 ms.

The finding that IOR was smaller for neutral switch trials than angry switch trials at first glance appears opposite to the findings of Experiment 3, where IOR was smaller for angry targets than neutral targets. However, in the current experiment with short alternating blocks, target type was fully confounded with (and opposite to) the target type on the preceding block. In Experiment 3 preceding target type and current target were matched. By combining the results from these two experiments, it is obvious that target type on preceding trials (that set up affective context) determines IOR magnitude, not the emotional content of targets on current trials.

These results thus demonstrate two points. Firstly, sustained exposure to threatening stimuli attenuates IOR measured for non-threatening stimuli (Experiment 5) or for threatening stimuli (Experiment 1 and 3). Secondly, affective states induced by emotional stimuli appear to be transient in their effect on IOR because they can be nulled by exposure to even a short series of neutral stimuli. This latter point is supported by the absence of an effect of target expression on IOR in the non-switch trials. For these trials, as the mini-block continues, there is presumably a reduction in the impact of the preceding context that is concurrent with a build-up of the current context, one cancelling the other out and leading to a null effect.

Experiment 6 and Meta-Analysis

The results from Experiments 1 – 5 support the hypothesis that sustained exposure to threatening stimuli attenuates the magnitude of IOR compared to sustained exposure to non-threatening or neutral stimuli. In this final experiment, and accompanying meta-analysis, I wanted to determine if this effect was limited to negative stimuli, or if a positive affective context could also modulate IOR. Here the target stimuli were photographs of sweet foods that had to be localised, employing the same methodology as Experiment 1. Furthermore, to maximise the positive affective value of these stimuli, participants completed the experiment after not eating five hours prior to the testing session. The data collected from this positive condition is first described, and then combined with the data from Experiment 1 (blocked spiders and objects) to explore whether IOR generated in this positive affective condition is comparable to the negative or the neutral conditions from Experiment 1. If the magnitude of IOR is comparable to the negative condition, this would suggest that the neural mechanisms underlying visual orienting are sensitive to affective context, regardless of valence. However, if the observed attenuation of IOR is a threat-specific effect, IOR obtained with positive targets should be comparable to the IOR effect obtained with the neutral target stimuli.

Methods

Participants

Twenty experimentally naïve adults (17 females, mean age 22 years) were recruited. To encourage a positive affective response to these stimuli, participants were instructed to abstain from eating or drinking anything but water five hours before the experimental session.

Apparatus and Stimuli

The apparatus were the same as before. Food images (6.61° by 6.61°) were sweet finger foods including cup cakes, doughnuts, strawberries, and cookies.

Design and Procedure

The design and procedure were the same as Experiment 1.

Results and Discussion

Error rates. Consistent with the previous experiments, error rates were low (<1%), and were unaffected by cue validity, target type, or their interaction, *F*'s<1.

RTs. Analysis first focused on the results obtained when localising food targets, and this data is presented in Figure 9. At the short SOA (100 ms), responding was 25 ms faster to localise targets presented at the cued than the uncued location, $t(19) = -4.94$, $p < .001$. At the longer SOAs (500, 1000, 1500, 2200, 3200 ms), a repeated measures ANOVA specifying cue validity and SOA showed that this benefit of cuing was reversed, with responses slower to targets presented at the cued versus the uncued location, $F(1,19) = 6.32$, $p < .05$, consistent with IOR (note the relatively small -7 ms IOR magnitude collapsed across SOAs, described more below). Although RTs decreased with increasing SOA, $F(3,49) = 21.23$, $p < .001$, IOR did not change as a function of SOA, $F < 1$.

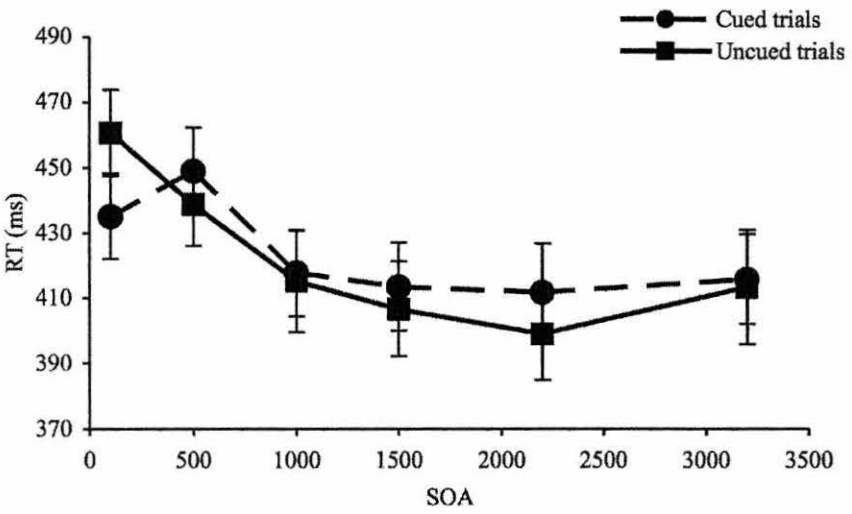

Figure 9. Group mean RT obtained in Experiment 6 (target type blocked) for locating sweet food targets presented at just previously cued or uncued locations. Vertical bars indicate +/- 1 S.E.

After confirming the successful generation of IOR when participants localised positive target stimuli, this data was then compared to the results obtained in Experiment 1.

A mixed effects ANOVA specifying target location and SOA as within-subjects factors, and target type as a between-group factor was then conducted on the combined RT data from Experiments 1 (spider, object) and 6 (sweet food) for this analysis. At the 100 ms SOA, localisation responses were 20 ms faster to targets presented at cued than uncued locations, $F(1,67) = 40.11$, $p < .001$, consistent with attentional facilitation by the cue. This facilitation effect was not influenced by target type, $F < 1$. Figure 10 displays the mean facilitation and IOR effects as a function of SOA and target type.

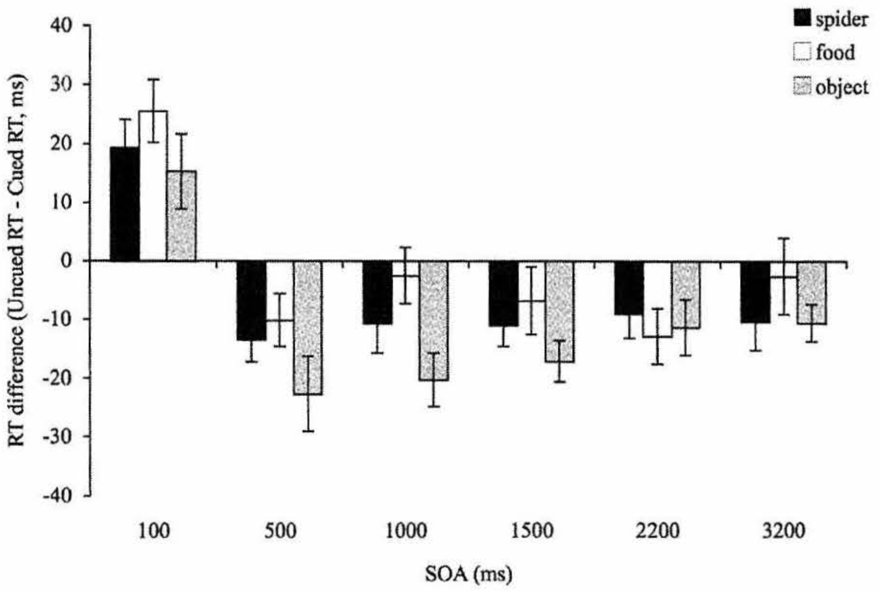

Figure 10. Facilitation and IOR effects as a function of SOA for each target type across the blocked conditions (spider, food, object). A positive value represents attention facilitation and a negative value represents IOR. Vertical bars indicate +/- 1 S.E.

IOR was again found in the RT data, evident by slower target localisation at cued than uncued locations, $F(1,67) = 69.58, p < .001$. Consistent with Experiment 1, the magnitude of IOR changed as a function of target type, $F(2,67) = 3.95, p < .05$, with the mean IOR effect for food (-7ms) and spider (-11ms) targets being smaller than the mean IOR effect for object targets (-16 ms). Although the three-way interaction between target location, SOA, and target type was non-significant, $F < 1$, visual examination of Figure 8 suggests the effect of target type disappears with increasing SOA as observed in Experiment 1. Therefore, analysis focused on the effect of target content on the midrange SOAs (500, 1000, 1500 ms) and the long SOAs (2200, 3200ms) separately. IOR was unaffected by target type in the long SOA conditions, $F < 1$. However, at the mid-range

SOAs, IOR was modulated by target type, *F*(2,67) = 5.59, $p < .01$, and this interaction did not change as a function of SOA, $F < 1$. Experiment 1 found that IOR was smaller for spider targets (-12 ms) versus neutral targets (-20 ms) at these midrange SOAs, *F*(1,48) = 4.47, $p < .05$. Furthermore, IOR was also reduced for food (-7 ms) versus neutral targets, *F*(1,43) = 8.83, $p < .01$. No difference in the magnitude of IOR obtained in the food and spider conditions, *F*(1,43) = 2.04, $p = .16$, was found. Taken together these results suggest that the reduced IOR effect in response to sustained exposure to emotional stimuli is not limited to threat-relevant stimuli as demonstrated by Experiments 1 - 5. Affective states induced by positive stimuli can also attenuate IOR.

Chapter 6: Section Discussion

In six experiments I explored whether IOR could be modulated by the emotional content of target stimuli. Emotional targets (Experiment 1, images of spiders; Experiment 3 and 5, angry faces; Experiment 6, images of sweet foods) significantly reduced the magnitude of IOR but only after sustained exposure to these stimuli when they were presented in blocks. When the emotional content of targets was randomised between trials within a block, IOR appeared insensitive to stimulus emotionality. A third experimental approach using alternating mini-blocks with neutral or emotional targets confirmed that the visual orienting mechanisms mediating IOR are sensitive to temporary affective contexts established by exposures to emotional stimuli, but are unable to respond on-the-fly to a target's emotional content. This general conclusion is consistent with previous suggestions that, once initiated, IOR is a largely ballistic mechanism (Rafal & Henik, 1994; Tipper & Kingstone, 2005) and suggests that the visual orienting mechanisms responsible for IOR are responsive to top-down but not bottom-up emotional codes.

Before exploring this conclusion in greater detail, it is useful to consider a possible account of these findings based on low-level stimulus features. Indeed, previous research has demonstrated that the measurement of object-based IOR is sensitive to target complexity; specifically, IOR is greater in cue-target displays consisting of more complex objects than visually simpler objects (e.g., Leek et al., 2003; Reppa & Leek, 2003). Although the emotional versus neutral stimuli used in Experiments 1, 2, and 6 differed in their low-level features (and their level of categorical diversity), Experiments 3, 4, and 5 were designed to overcome this potential confound of visual dissimilarity by employing face stimuli which varied only in terms of emotional expression. Nevertheless across all experiments a highly similar and consistent pattern of results was found. However, it is worth noting that emotionally expressive and neutral faces do still vary in respect of low-level image properties, and this is a challenge for all investigations using emotionally charged stimuli to address. Although employing ecologically valid stimuli is advantageous to represent real world viewing, these stimuli come at a cost in respect of their perceptual variance. In the Experiments reported here, it does seem unlikely that stimulus complexity explains the results obtained. For instance, in addition to changes in IOR magnitude, it could be hypothesised that reaction times would also be sensitive to the visual complexity of target stimuli. However, no consistent modulation of response times by target type was observed in Experiment 3 (responding was faster to angry versus neutral targets), Experiment 4 (no modulation of response time by target expression), and Experiment 5 (responding in switch trials was unaffected by target expression, with only a marginal modulation in performance observed across all trial types). Furthermore, considering the findings that more complex objects produced larger IOR effects in previous research (Leek et al., 2003; Reppa & Leek, 2003), the crucial finding reported here was instead a reduction in IOR in the more complex (angry) facial expression conditions (Experiment 3).

The conclusion that IOR is insensitive to bottom-up coding of stimulus emotionality computed on-the-fly does not imply that rapid, bottom-up (or 'preattentive') processing of threatening stimuli cannot modulate spatial attention, *per se*. Indeed, numerous previous studies have shown that spatial attention appears to be drawn more quickly to unique threat stimuli when presented in arrays of non-threatening stimuli (e.g., Fox et al. 2000). Specifically, Experiments 2 and 4 indicate that bottom-up codes for threat in stimuli cannot deter IOR once initiated by the activation of an irrelevant cue.

Finding that threatening targets only modulate IOR when presented in blocks of trials is best explained by postulating that repeated exposure to threatening stimuli sets up an affective context that induces a temporary brain state capable of influencing spatial orienting. This state is relatively short-lived and, in addition to being nulled by exposure to neutral targets (Experiment 5), may also decay with time after exposure to affective stimuli. This would explain the effect of emotionality on IOR being present in Experiments 1 and 6 for the mid-range SOAs, but being absent for the long-range SOAs.

Although such a contextual affective state might be akin to mood, these results suggest that it is more rapidly adapting than mood and is capable of altering visual orienting mechanisms in a flexible and transient manner, inconsistent with the concept of mood. For example, in Experiment 5 changes in IOR dependent on affective context after as few as four stimulus exposures were observed, i.e., contextual episodes lasting between about 8 and 30 seconds. Furthermore, previous studies linking mood and performance on spatial attention tasks (Compton, 2000; Compton et al., 2004) provide no support for the notion that mood might underlie the effects observed here. Specifically, these studies showed that low positive affect is associated with slowed shifting of spatial attention, a finding that at first glance seems especially at odds with the observation of reduced IOR (i.e., faster shifting) with negative stimuli. Compton (2000) asked participants to complete a mood questionnaire at both the beginning and end of the testing session. After completion of the first questionnaire, participants completed a traditional spatial cuing task and then watched a sad film clip. Negative affect scores (pre and post sad film) were then correlated with performance on the orienting task. The magnitude of attentional facilitation correlated with negative affect: Greater facilitation scores predicted greater changes in negative affect by the end of the testing session. However, IOR did not correlate with any changes in negative affect[8]. A second study by Compton et al. (2004) demonstrated that it was the absence of positive affect, rather than the presence of negative affect that modulated shifts of spatial attention. Here participants completed a single mood questionnaire prior to an equivalent visual orienting task, with positive and negative affect dissociated on the basis of a principal components analysis. Positive affect correlated with attentional facilitation, with less positive affect related to enhanced facilitation effects. Furthermore, no correlation between negative affect and facilitation was found as described previously. However, consistent with Compton (2000), neither positive nor negative affect scores correlated with the observed IOR effects. An extrapolation from this study, albeit speculative, suggests that temporary induction of negative mood is unlikely to account for the findings reported here.

Transient changes in arousal may be a more viable explanation. Arousal is a well-established dimension of emotional response (Lang, 1995) and interacts with attentional processes (see Coull, 1998, for a review). It is a well-recognised principal that arousal effects typically have an inverted u-shaped function, with modest increases in arousal improving performance but large increases lowering performance (Yerkes-Dodson law,

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[8] Compton (2000) did report that response times in uncued trials were faster for individuals higher in negative affect at the longer SOA; however, this did not affect IOR.

Yerkes & Dodson, 1908). Evidence supporting the notion that arousal may account for the modulation of IOR effects observed here is that in Experiment 1 and 5, RTs were, on average, faster to threatening target stimuli than they were to neutral targets. Speed of responding, *per se*, cannot however account for the reduced IOR effects observed here. Mean RT to neutral face expressions (with large IOR, Experiment 2A) were overall faster (by nearly 30 ms) than mean RT to spiders (with reduced IOR, Experiment 1A). Moreover in Experiment 2B, mean RTs were faster to neutral objects than spider targets, but the IOR effect remained the same. Furthermore, In Experiment 1A, mean RTs were equivalent in the neutral (large IOR) and spider (small IOR) condition. This absence of any clear dissociation in speed of responding and IOR magnitude suggest either that arousal cannot mediate both effects or that (assuming arousal mediates response speed) arousal is not the mechanism mediating affective contextual states that in turn determine IOR magnitude. The resolution of this issue remains for future research.

How could the brain develop affective contextual states driven by exposure to emotional stimuli? A study by Codispoti et al. (2003) showed that repeated exposure to unpleasant images, as opposed to neutral stimuli, can result in neuroendocrine changes, specifically increases in noradrenaline, cortisol, and ACTH levels, as well as decreases in prolactin levels. Other physiological changes (increased skin conductance, decreased heart rate, increased facial EMG activity, and enhanced startle reflex) have also been reportedly induced by exposure to emotional stimuli (e.g., Bradley et al., 1996; Smith et al., 2005). Although these changes are typically reported in responses to unpleasant stimuli, sustained exposure to pleasant stimuli also produce physiological changes including a reduction in the magnitude of the startle reflex, increased skin conductance (Bradley et al., 1996; Smith et al., 2005), and neuroendocrine changes including increases in prolactin levels (Codispoti et al., 2003). Moreover, attention to images of threatening faces (as well as animal images and fear-conditioned stimuli) have been shown to reliably activate the amygdala (see Phelps, 2006, for a review), a structure with projections to numerous other brains sites (e.g., hypothalamus, visual cortex) capable of producing changes in both neurophysiology (Davis, 2000) and visual processing (Amaral & Price, 1984). These reports suggest that exposure to the threatening images used in these experiments may have provoked sustained but easily modified neuroendocrine and other physiological responses that are able to activate neural mechanisms capable of modulating visual orienting mechanisms.

Experiment 6 revealed a smaller IOR magnitude in response to positive target stimuli (versus neutral stimuli). In this condition, to enhance the positive affective response to these stimuli I manipulated the satiety level of participants by instructing abstinence from eating prior to the testing session. It is possible that this hunger manipulation alone was sufficient to produce the top-down influence of IOR measured here. However, it is likely that this manipulation in conjunction with the compatible image type reduced IOR. This conclusion draws support from Experiment 9 presented in the next section of this thesis, and therefore the influence of hunger and positive stimuli on IOR will be considered in more detail there.

In interpreting the results of the experiments reported here, IOR can be conceptualised as an automatic attentional consequence of spatial cuing, initiated by first orienting to and then withdrawing away from a cued location (e.g., Posner & Cohen, 1984; Posner et al., 1985). However, IOR may also be expressed as an oculomotor bias, reflecting the inhibition of a response to a cued location (e.g., Hunt & Kingstone, 2003; Klein & Taylor, 1994; Taylor & Klein, 1998; 2000). Regardless of the mechanism underlying the *cause* of IOR, these data have implications for theories underlying the *consequences* for IOR in visual cognition in the presence of emotion. The data reported here suggest that changes in affective context reduce IOR, which may be mediated by a reduction in the criterion to respond to both emotional and non-emotional stimuli, facilitating target detection (Ivanoff & Taylor, 2006; Klein & Taylor, 1994; Reuter-Lorenz et al., 1996). Performance in the experiments reported here were at ceiling; however, a more difficult cuing task may yield a significant difference in performance accuracy between affective and non-affective contextual conditions, with more errors under the former affective condition owing to this reduced criterion to respond (see also, Ivanoff & Klein, 2001). The contribution of contextual information to visual orienting is also consistent with the hypothesised role of the superior colliculus in controlling the criterion to respond to visual stimuli (Dean et al., 1989), discussed in Chapter 3.

It is also noteworthy to comment on the cuing benefits measured in the experiments reported here. Analysis of cuing benefits at the short (100 ms) SOA revealed no effect of target content on the magnitude of the cuing effect in the positive, negative, and neutral conditions, $F < 1$. This is somewhat surprising considering the modulation of IOR by emotionality. One possible explanation is that the smaller number of observation in these conditions (one short SOA versus six long SOAs) together with the variance of a between-group design may mask any effects of target type. A second possibility is that the peripheral cuing at this short SOA in orienting attention prior to target onset is so reflexive that top-down affective context would not influence this effect. This seems unlikely considering the IOR data (i.e., affective state modulates IOR, which is also a reflexive effect), and the relationship between affect and attentional facilitation previously reported by Compton et al. (2004). However, IOR and attentional facilitation may reflect two different processes (see Danziger & Kingstone, 1999, for instance); therefore, maybe it is unreasonable to consider that affective states should exert similar effects on these two phenomena. Future research is required to fully understand whether these two mechanisms are indeed separate, but more importantly for the relevance of this thesis, whether under any circumstances sustained exposure to emotionality can influence attentional facilitation.

In the experiments reported here, a localisation response was used to measure responding to target stimuli; therefore, the emotional value of the stimulus was task-irrelevant. Previous research by Taylor and Therrien (2005) also found null effects of target content (social, non-social) on IOR in a spatial cuing task employing a localisation response. However, in a second series of experiments, Taylor and Therrien (2008) presented social and non-social stimuli as targets once more, but participants were instead required to make a discrimination response as to whether the target was an intact face or a scrambled face. The purpose of this manipulation was to make the target task-relevant, thereby increasing the possibility that as meaningful stimuli, faces may be able to break through the inhibition present at a cued location (resulting in a smaller IOR effect).

Surprisingly, the opposite result was found: IOR was larger when the target was a face compared to when it was a non-face (scrambled face and pixilated face). Moreover, the time course also differed for each target type: IOR developed later for face targets (1000 ms SOA) than non-face targets (500 ms SOA), an effect which was absent when making a localisation response to these same stimuli. This finding indicates that IOR is sensitive to stimulus content when it is relevant to the task. In localisation tasks where stimulus content is irrelevant, no modulation of IOR is observed.

Taylor and Therrien (2008) proposed that the larger IOR effect observed for face targets in this task reflected a shift in criterion at the cued location, enabling more time to process meaningful stimuli, enabling accrual of information and more efficient responding. The socio-biological relevance of faces seems particularly important here. Chasteen and Pratt (1999) asked participants to make discrimination responses to targets that were words or non-words. IOR was larger for low frequency words than high frequency words. Importantly, IOR was equivalent for non-words and high frequency words, indicating that the relative meaning of a stimulus alone is not sufficient to disrupt IOR in a discrimination task, where otherwise IOR would have been smallest for the non-words. Therefore, the exacerbated IOR effect observed by Taylor and Therrien (2008) seems primarily driven by the salience of face stimuli rather than the mere presence of a meaningful stimulus.

Current research has also suggested that IOR magnitude may be affected by target content dependent upon the task involved. Relevant to this thesis is a study where emotional stimuli (faces) were presented as targets, and participants responded with either a localisation or discrimination response. IOR was significantly smaller for emotional faces than for neutral faces when making a discrimination response; however, IOR magnitude was equivalent for these target types when making a localisation response (Geoff Cole, personal communication). Furthermore, in highly anxious participants, discrimination responses to negative words abolish IOR in contrast to discrimination responses to positive and non-emotional words (Carolina Pérez Dueñas, personal communication). Therefore, the sensitivity of IOR to emotionality can be demonstrated as occurring on-the-fly; however, focused attention to the emotional stimulus is required for the manifestation of this effect. Therefore, it is a logical hypothesis that tasks employing a detection response will also demonstrate the insensitivity of IOR to on-the-fly processing of target content, consistent with results reported here.

In summary, the present series of experiments provide two important additions to current understanding of the link between the perception of emotion and visual orienting. First, these experiments provide clear evidence that the mechanisms mediating IOR are 'blind' to the emotional content of target stimuli once spatial orienting is initiated. This insensitivity provides an important clue to how spatial attention may be controlled, indicating that rapidly processed emotional information from faces and other ecologically relevant stimuli is neither ubiquitously nor instantly available to visual orienting mechanisms. Second, these results show that coding affective context builds up as a result of repeated exposure to emotional stimuli, and that the neural mechanisms capable of coding affective context are able to attenuate IOR. Thus, these findings support the notion that the mechanisms mediating IOR are ballistic in their mode of response and that they can be modulated by top-down contextual information.

Section 3: IOR and emotional compatibility between stimulus and response

Abstract

In simple detection tasks, responding is faster to emotional stimuli if the response mode is compatible with the emotional nature of the stimulus. For instance, executing an avoidance response to an image of a spider is faster than executing an approach response to the same spider image. The experiments reported here investigated whether the mechanisms underlying IOR interacted with this apparent emotional stimulus-response compatibility effect. Participants made an avoidance localisation response to emotionally compatible (negative) and incompatible (positive) target stimuli. Response times were faster to localise targets in the emotionally compatible condition in contrast to the emotionally incompatible condition. This emotional compatibility benefit was equivalent between locations subject to inhibition and at novel, uninhibited locations, indicating that IOR and emotional stimulus-response compatibility did not interact to determine responding in this task. These results suggest that the mechanisms subserving IOR are independent of the mechanisms underlying emotional compatibility effects.

Chapter 7: Section Introduction

The experiments presented in the previous section suggest that IOR is unaffected by the stimulus-driven emotional content of a visually presented target. Instead, sustained exposure to emotional stimuli attenuated the magnitude of IOR obtained, indicating top-down modulation of the effect. I hypothesised that this reduction in IOR may reflect a change in the criterion to respond to the cued location, with affective context enhancing sensitivity to potential target onsets (emotional and non-emotional). This notion represents the broader theoretical issue that IOR is intrinsically linked to response-related processes (Ivanoff & Klein, 2001; 2006; Ivanoff & Taylor, 2006; Klein & Taylor, 1994; Taylor & Klein, 1998). Under certain conditions, it is possible to introduce a task wherein the response mode and target parameters can be manipulated to be compatible or incompatible with each other. Typically, responding is faster to targets in compatible conditions than in incompatible conditions. The purpose of this thesis section was to investigate whether compatibility between stimulus and response interact with IOR, specifically when this compatibility was emotional in nature.

Emotional, or motivationally relevant, stimuli elicit automatic behavioural responses that exist in two dimensions (e.g., Lang et al., 1990). The first, *appetitive*, promotes foraging and engagement in the surround, resulting in positive outcomes to the organism. The second, *aversive*, promotes withdrawal from potential sources of threat, and underlies an organism's defensive behaviours. These two response tendencies are commonly referred together as *approach-avoidance*. When the response is emotionally compatible with the valence of a stimulus (approach positive, avoid negative), task performance is significantly facilitated. Emotional incompatibility (approach negative, avoid positive) between stimulus and response impairs performance (Eder & Rothermund, 2008). In this next series of experiments, participants made an avoidance localisation response to emotionally compatible (negative), incompatible (positive), and neutral target stimuli, presented at previously cued and uncued locations. The principal interest here was whether this benefit of emotional compatibility between target and response would change as a function of cue validity. Specifically, would the emotional compatibility benefit (the difference in responding to compatible and incompatible targets) differ between locations subject to IOR, and locations unaffected by IOR?

Motivational pre-dispositions to approach or avoid

From an evolutionary perspective, the decision whether an organisms should approach or avoid a given stimulus or situation is believed to underlie all motivational tendencies to behave, and promotes adaptation of the species (Elliot & Covington, 2001). Indeed Konorski (1967) defined the basic unconditioned reflexes of an organism as being either *preservative* (i.e., approach) or *protective* (i.e., avoid). Preservative reflexes were considered appetitive, involving responses toward matter in the environment (including acquisition of resources and finding a mate). In contrast, protective reflexes were considered defensive, directing the body away from matter in the environment. This biological dichotomy was proposed to underlie all reflexive behaviour, as well as forming the basis of emotion (Konorski, 1967).

Consistent with this, Davidson, Ekman, Saron, Senulis, & Friesen (1990) described approach-avoidance as components of emotion, hard-wired behavioural tendencies to respond in a given situation[9]. For instance, seeing a snake in the grass would trigger avoid behaviours, whereas seeing a ripe strawberry would instead trigger approach behaviours. Research has demonstrated behaviour approximating approach-avoidance across multiple species ranging from single cell organisms (e.g., Schneirla, 1965) to non-human primates (e.g., Hopkins & Bennett, 1994). Moreover, it has been suggested that approach-avoidance behaviours may be represented by lateralised anterior cerebral asymmetry: The left frontal regions may be associated with processing approach emotions (positive stimuli) and the right frontal regions may be associated with avoid emotions (negative stimuli; Davidson et al., 1990). This asymmetry of approach-avoidance has also been addressed in the absence of emotional stimuli (Maxwell & Davidson, 2007). Lateralisation of approach-avoidance behaviours has also been observed in primates, with right-handed chimps demonstrating faster approach responses than left-handed chimps, for example (Hopkins & Bennett, 1994).

Lang et al. (1990; 1997) considered the organisation of emotion on a biphasic appetitive-aversive dimension, proposing that emotionality affords specific behavioural responses to approach or avoid, depending upon the contextual valence of the current situation. In their view, exposure to emotional stimuli (positive, negative) primes associated behaviours (approach, avoid), increasing their likelihood of occurrence. They proposed that basic reflexes (appetitive and aversive) are enhanced when congruent with current emotional states, but these same reflexes are attenuated during incongruent emotional states (Lang et al., 1990; 1997). Primary evidence for this proposal was drawn from a series of studies manipulating the emotional context in which the startle response

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[9] Note that although these responses are hard-wired, they can be enhanced, weakened, or replaced according to the individual and demands of the situation (Davidson et al., 1990; Lang et al., 1990).

was elicited. The startle response is a primitive defensive reflex, characterised by jerking of the head, a movement that may extend throughout the body, and rapid closure of the eye-lids. An unexpected acoustic tone is typically used to elicit startle responses in the lab. Lang et al. (1990) reported the startle reflex to be enhanced in response to viewing fear conditioned stimuli and during viewing of unpleasant images. However, the startle reflex was diminished during viewing of pleasant pictures, confirming this proposed association between behavioural reflexes and emotional state.

Emotional compatibility between stimulus and response

Compatibility between stimulus and response has been shown to facilitate reaction times and accuracy in numerous tasks, with stimulus-response (S-R) incompatibility having a more negative effect on these performance measures (e.g., Simon, 1969; Stroop, 1935; Eriksen & Eriksen, 1974). For example, when participants have to respond to a tone presented in either the left or right ear, response times are facilitated if the response is made toward the ear (spatially compatible) in which the tone was played, in contrast to when a response is made away (spatially incompatible) from the stimulated ear (Simon, 1969).

The notion that emotion affords approach-avoidance behaviours (Davidson et al., 1990; Lang et al., 1990; 1997) has elicited a substantive amount of research exploring performance in tasks that encompass emotional compatibility between stimulus and response. Perhaps the earliest demonstration of emotional S-R compatibility effects was by Solarz (1960), where participants were trained to respond to cards containing differently valenced words. Participants either pushed the card away (approximating avoidance) or pulled the card toward their body (approximating approach) using a lever to control this motion. Responding was faster in compatible S-R conditions (pull-positive and push-negative) than incompatible S-R conditions (pull-negative and push-positive), demonstrating for the first time the importance of stimulus emotional content in determining fluency in behavioural responding.

As described in the Solarz (1960) study, levers are typically used in the lab to approximate approach-avoidance behaviours. It is widely believed that pulling the lever towards the self (arm flexion) approximates approach, and pushing the lever away (arm extension) approximates avoidance. Arm extension to negative stimuli and arm flexion to positive stimuli are deemed compatible responses, in contrast with arm extension to positive stimuli and arm flexion to negative stimuli, which are deemed incompatible responses. In addition to facilitating behavioural responding, engaging in these movements is also believed to influence stimulus processing. For example, Cacioppo, Priester, and Berntson (1993) found participants evaluated neutral stimuli more positively when engaging in arm flexion, and more negatively when engaging in arm extension.

Another method used to approximate avoidance behaviour involves placing the palm of the hand and pushing down on a work surface (initiating arm extension). The comparative response is to place the palm of the hand under the work surface and push upwards, in order to approximate approach behaviour (initiating arm flexion). Neumann and Strack (2000) found participants were faster to categorise positive words than negative words when the non-dominant response hand induced arm flexion (palm pushing up). When the non-dominant hand induced arm extension (palm pushing down), negative words were categorised faster than positive words. Other methods of engaging the approach-avoidance systems have included nodding and shaking of the head (Förster & Strack, 1996), engaging in upright or kneeling positions (Förster & Stepper, 2000), and initiating or preventing smiling (Strack, Martin, & Stepper, 1988). Exteroceptive cues have also been used to activate approach-avoidance systems to observe emotional compatibility effects. Neumann and Strack (2000) asked participants to categorise adjectives that were surrounded by an array of concentric circles. The circles created the illusion of either movement toward or away from the screen. Consistent with the proprioceptive studies, categorisation was faster for positive words when the illusion implied movement toward the screen, and faster for negative words when the illusion implied movement away from the screen.

In Experiments 7 - 10 of this thesis, to approximate an avoidance response, participants pressed and held down the response keys at the beginning of each trial. On target onset, the localisation response was made by the release of one of the response keys. Previous research by Wentura, Rothermund, and Bak (2000) has successfully demonstrated emotional compatibility effects using a key release response. Participants were faster to release the response key in the presence of negative words than positive words. In the experiments reported here, faster response times should be observed in compatible (negative target localisation) than incompatible (positive target localisation) conditions for targets presented at uncued locations, where any inhibitory effects of prior cue location are absent. The question posed here was whether this emotional compatibility effect would also be present at the cued location, the location that is subject to inhibition.

IOR and response-related properties

The literature described above supports the notion that emotional stimuli afford behavioural response tendencies that can be manipulated to be compatible or incompatible to the valence of the particular stimulus. The purpose of the experiments reported here was to investigate whether these emotional compatibility effects interact with IOR. A recent advancement of the IOR hypothesis postulates that an inhibitory tagging mechanism acts in IOR, which affects processing of target stimuli presented at cued (inhibited) locations (Fuentes, Vivas, & Humphreys, 1999). This inhibitory tagging mechanism appears to prevent stimuli from activating response-related properties, and has been demonstrated in tasks where response interference is typically observed owing to stimulus-driven conflict, as in the case of flanker interference tasks. Flanker interference is created when a target stimulus is flanked by a distractor stimulus that shares or is associated with properties of the target. Distractors can be compatible with the target (share the same property, for instance two letters) or incompatible (share different properties, for instance a letter target and a number distractor). Compatibility between target and distractor speeds discrimination performance in these tasks, in contrast with incompatibility, that instead creates response competition and slows discrimination performance (Eriksen & Eriksen, 1974).

Fuentes et al. (1999, Experiments 3 and 4) used a modified cuing paradigm, where participants responded to a target flanked by distractors (compatible and incompatible) at either the cued or uncued location. At the uncued locations, discrimination responses were slower with incompatible stimuli than compatible stimuli, demonstrating the normal flanker interference effect. In contrast to this, at cued locations discrimination responses were faster with incompatible stimuli than compatible stimuli: IOR reversed the flanker effect. Fuentes et al. (1999) interpreted these findings as evidence that when a stimulus is presented at a location that is subject to inhibition, this inhibition prevents the activation of response-related properties. Therefore, when distractor-target identities are related, inhibition at the location where the distractor is presented reduces its interference in responding to the target. Similarly, Vivas and Fuentes (2001) demonstrated that Stroop interference was reduced when making colour discriminations between targets (red, blue, and green words or patches) presented at previously cued locations, in contrast to targets presented at uncued locations. This provides further support to the proposal that the inhibitory mechanisms underlying IOR interfere with response-related properties (Fuentes et al., 1999; Vivas & Fuentes, 2001). This interference of inhibition on response properties suggests that inhibition may also act on S-R compatibility effects. The presence of inhibition at a cued location may prevent the activation of associated responses to target stimuli presented there; therefore, in the experiments reported here, any advantage of emotional S-R compatibility at the uncued (uninhibited) location may be abolished at the cued (inhibited) location.

IOR and S-R compatibility

Evidence that IOR may interact with S-R compatibility can be drawn from studies manipulating cue validity in tasks that generate Simon effects in response time data. As described previously, the Simon effect refers to the facilitated responding in a task where there is spatial compatibility between the location of a stimulus and the location of a response (Simon, 1969). For instance, responding with the left-hand to a target presented in the left visual field will be significantly faster than responding with the left-hand to a target presented in the right visual field. Spatial cuing tasks employing discrimination responses provide a unique opportunity to measure the interactions between Simon effect and the IOR effect within the same paradigm. Responses and targets can be both spatially compatible and incompatible at both cued and uncued locations. This is unlike detection or localisation tasks, where only a single response, or responses that are always compatible with the target location, respectively, are required.

Whether IOR interacts with the Simon effect is important in understanding whether response processes contribute to IOR. Converging empirical research suggests that IOR effects do not interact with Simon effects. For example, both Pratt et al. (1997) and Lupiáñez et al. (1997) successfully generated IOR in a discrimination task, and speeded responding was seen in S-R compatible conditions. However, there was no reliable interaction of IOR and this apparent S-R benefit in responding in either study. Similarly, Ivanoff and Klein (2001) used additive factors logic to present the argument that if IOR reflects response-related processes, then it should interfere with the Simon effect (also a response-related process); however, if IOR does not interact with response processes, no interaction between the two variables of interest should occur, with their effects instead being additive. In their experiment, S-R compatibility was created by the presence of a non-responding effector (the index finger) positioned on a response key. This key was present on the keyboard in a position spatially compatible to a potential target location in the periphery, although responding was only ever made with the responding effector of the other hand. Target detection was slower to targets presented in a spatial location compatible to the non-corresponding effector than when the targets were presented in a spatial location compatible with the responding effector; however, this RT effect did not interact with IOR (Ivanoff & Klein, 2001). Thus, this study also failed to demonstrate any interaction between the Simon effect and IOR. These studies suggest that IOR may not affect S-R compatibility, at least in terms of spatial compatibility. Extrapolating the findings from these studies in terms of a functional account of IOR suggests that if the mechanisms underlying the effect are blind to stimulus content, once the onset of a target meets the threshold to respond, response compatibility effects may emerge consistent with responding at uncued locations, where there is no criterion to respond.

Here I have discussed two hypotheses related to the IOR effect and S-R compatibility. The first suggests that inhibition to a cued location may interfere with response-related processes to stimuli subsequently presented there (Fuentes et al, 1999; Vivas & Fuentes, 2001). This would predict that emotional compatibility effects will be absent for targets presented at cued locations, but present for targets presented at uncued locations (Figure 11A). However, a second (null) hypothesis predicts that the compatibility of the avoidance response to negative stimuli will occur regardless of IOR effects (Figure 11B; Ivanoff & Klein, 2001; Lupiáñez et al., 1997; Pratt et al., 1997).

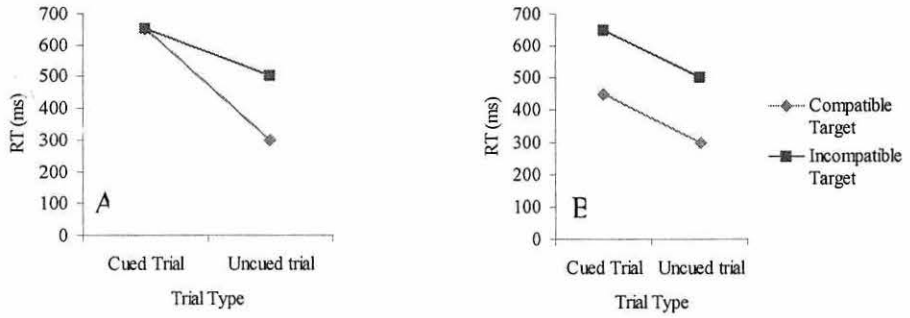

Figure 11. The predicted effects of IOR on emotional S-R compatibility. *A*. Inhibition at a cued location may prevent the activation of response-related processes, abolishing the S-R compatibility effect clearly present at the uncued location. *B*. No difference in emotional S-R compatibility effects as a function of prior cue location.

Whatever the nature of S-R emotional compatibility and IOR interactions, the findings may be complicated by the proposed lateral asymmetry of approach-avoidance previously described in the literature (Davidson et al., 1980). Therefore, an additional factor included in the experiments reported here was the visual field of target presentation. Furthermore, any emotional S-R compatibility differences may also be modulated by the continuity of contextual affective state, with emotional S-R compatibility effects limited to conditions where affective state is held constant, in contrast to conditions where affective state is variable (Lang et al., 1990; 1997).

To address these issues, Experiments 7 – 10 presented emotional (negative, positive) and non-emotional (i.e., neutral) stimuli as targets to be localised in a spatial cuing task. Target localisation was achieved by an avoidance response. In Experiment 7 and 8, participants localised simple (an asterisk) and complex (an object) target stimuli using an avoidance response, comparing the data obtained to data collected when executing a conventional key press response. The purpose of this manipulation was to ensure that any differences in RTs and IOR magnitude observed in the subsequent emotional target conditions were owing to the nature of the target stimuli (compatible or incompatible with response), rather than owing to any underlying differences from changing the response mode. Experiment 9 presented emotionally compatible (spiders) and incompatible (sweet foods) stimuli as targets to be localised. RTs at cued and uncued locations in the emotionally compatible condition were compared to the RTs at cued and uncued locations in the emotionally incompatible condition. These stimuli were presented in valenced blocks to maintain affective context consistent with Lang et al. (1990; 1997). This affective context was disrupted in Experiment 10 by varying the emotionality of the target (spiders, objects) on a trial by trial basis, and measuring the resultant effects on RTs. In all cases, cues were simple open circles.

Experiment 7

The purpose of Experiment 7 was to explore whether there were any underlying differences in RTs and IOR when making an avoidance response compared to a conventional key press response to localise target stimuli. If slowed responding to cued locations reflects a shift in criteria to respond to targets subsequently presented at these locations (e.g., Ivanoff & Taylor, 2006; Klein & Taylor, 1994; Reuter-Lorenz et al., 1996), it is plausible that the mode of response (key press, avoidance response) may contribute to defining this criteria. Therefore it is necessary to establish this effect, if present, on responding prior to the introduction of emotional stimuli. Consequently, participants in this experiment were randomly and equally assigned to a response mode condition that required either a conventional key press response or an avoidance response to localise the target stimulus.

The target presented here was always an asterisk, a visually simple and affectively neutral stimulus. Furthermore, a range of SOAs were employed in the experimental design to probe whether responding changed as a function of cue-target interval. In these control experiments (Experiments 7 and 8), visual field was also included in the analysis as a variable of interest, the reason being that the avoidance response used here may be inherently affective, even prior to the introduction of emotional stimuli. Therefore, RTs (and IOR) could change as a function of the visual field where the target was presented.

Methods

Participants

Twenty experimentally naïve adults (13 females; mean age 21 years) were divided equally into two groups, with ten participants in each response mode condition (avoidance, conventional).

Apparatus and Stimuli

The apparatus and stimuli are reported in Chapter 4. Note the only difference here was the use of an asterisk (1.9° by 1.9°), which served as a target in both response mode conditions.

Design and Procedure

The procedure was the same as previously described in Chapter 4 for the conventional key press condition. However, in the avoid condition there were two changes to the trial sequence, as illustrated in Figure 12. First, an initial prompt was presented for 4000 ms to remind the participant to hold down both response keys at the beginning of each trial and to continue depressing them throughout the trial until response. Second, offset of this prompt was proceeded by a green fixation cross presented for 2000 ms to signal the beginning of the trial.

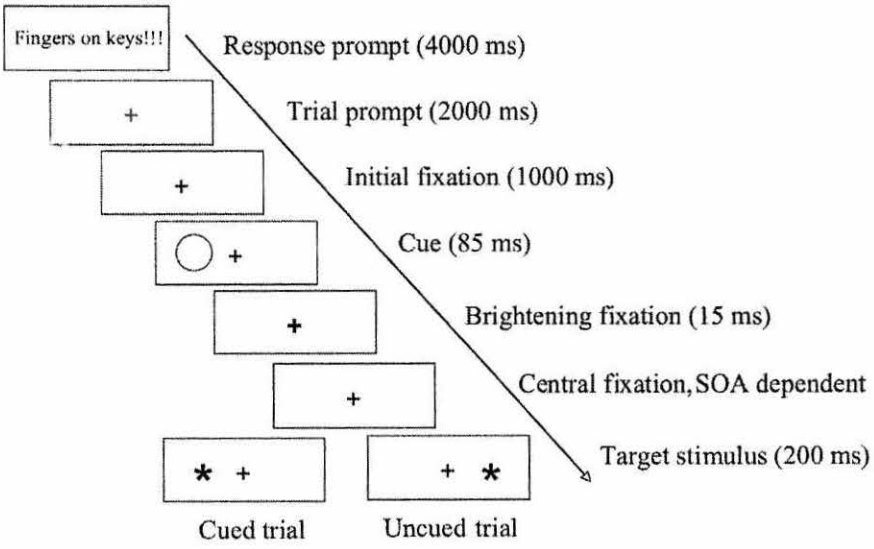

Figure 12. Trial sequence for Experiment 7. Here the task was to localise an asterisk target that was presented at either a cued or uncued location using an avoidance response.

Data Analysis

RTs were defined as the speed of releasing a response key following target onset. Note that in the present and subsequent experiments, responding was recorded from cue initiation. This was to ensure that any trials where participants may have released a response key prior to target onset were excluded from analysis. Furthermore, owing to potential laterality effects of emotional compatibility and incompatibility in responding, the visual field where the target was presented was also included as an additional factor in all the analyses reported here. Therefore the variable *visual field* always refers to the visual field where the target was presented. A repeated measures ANOVA specifying response mode as a between-group factor and cue validity, SOA, and visual field as within-subjects factors was performed on the RT data reported below. All data analysis procedures were the same otherwise as reported in Chapter 4.

Results and Discussion

Error rates. Accuracy (greater than 99% for both groups) was not modulated by response mode, $t(18) = 1.51, p = .15$, visual field, $F(1,18) = 3.58, p = .08$ (note that accuracy was 98.6% in the left visual field and 99.3% in the right visual field, hence this trend toward significance), and the interaction between visual field and response mode was also non-significant, $F < 1$.

Short SOA RTs. Table 3 presents the RT data from both the short (100 ms) and long (500, 1000, 1500, 2200, 3200 ms) SOAs. Note that in Supplementary Figure 1 of the Appendix that this data is plotted graphically, collapsing the data across visual fields. The mixed effects ANOVA conducted on the RT data at the 100 ms SOA revealed RTs were unaffected by response mode, $F < 1$, and visual field of target presentation, $F < 1$. Responding to targets presented at cued locations was no different than responding to targets presented at uncued locations, $F(1,18) = 1.17, p = .29$, indicating no benefit of spatial cuing on target detection. Note that this absence of a cuing benefit does not negate any measures of IOR: The two effects of exogenous orienting are likely to be independent of each other (e.g., Danziger & Kingstone, 1999). No other effects were significant, qualified by the non-significant visual field, cue validity, and response mode interaction, $F < 1$.

Long SOA RTs. RTs did not change as a function of visual field, $F < 1$, or the response mode employed, $F < 1$; however, RTs marginally decreased with increasing SOA, $F(3,45) = 2.80$, $p = .06$. Responding to targets presented in cued locations was 23 ms slower than responding to targets presented in uncued locations, $F(1,18) = 54.03$, $p < .001$, indicating IOR. Importantly, IOR did not interact with response mode, $F < 1$, SOA, $F < 1$, or visual field, $F(1,18) = 1.18$, $p = .29$. There were no further significant interactions, qualified by the non-significant four-way interaction between visual field, cue validity, SOA, and response mode, $F < 1$.

Table 3. Mean RTs for simple target localisation using either a conventional response or an avoidance response in Experiment 7. Note SE is presented in parentheses.

		Conventional response						Avoid response					
		SOA						SOA					
Visual Field	Trial Type	100	500	1000	1500	2200	3200	100	500	1000	1500	2200	3200
Left	Cued trial	428 (23)	408 (16)	414 (17)	397 (12)	399 (16)	402 (16)	442 (17)	436 (15)	435 (17)	427 (14)	432 (17)	423 (18)
	Uncued trial	435 (20)	403 (17)	395 (23)	386 (14)	369 (16)	382 (24)	461 (21)	415 (15)	409 (15)	403 (16)	400 (17)	405 (16)
	Validity effect	7	-6	-19	-11	-31	-20	20	-21	-27	-24	-32	-18
Right	Cued trial	436 (17)	417 (18)	418 (15)	407 (13)	409 (18)	418 (19)	444 (14)	430 (15)	417 (14)	419 (11)	421 (16)	407 (12)
	Uncued trial	425 (17)	391 (19)	385 (17)	385 (18)	389 (18)	375 (14)	451 (16)	404 (14)	394 (15)	394 (12)	390 (11)	403 (13)
	Validity effect	-10	-26	-33	-22	-20	-42	7	-26	-23	-25	-31	-5

Table 4. Mean RTs for complex target localisation using an avoidance response in Experiment 8. Note SE is presented in parentheses.

		SOA					
Visual Field	Trial Type	100	500	1000	1500	2200	3200
Left	Cued trial	477 (17)	445 (16)	451 (20)	456 (22)	452 (18)	441 (16)
	Uncued trial	479 (21)	438 (23)	429 (14)	421 (22)	432 (22)	431 (21)
	Validity effect	2	-7	-22	-35	-20	-11
Right	Cued trial	478 (17)	460 (19)	464 (23)	455 (18)	465 (19)	460 (21)
	Uncued trial	473 (21)	433 (18)	425 (19)	423 (21)	418 (19)	446 (22)
	Validity effect	-4	-27	-38	-32	-46	-14

These data provide convincing evidence that the magnitude and time course of RTs and IOR in this paradigm were unaffected by response mode. This null effect of response mode (avoid, conventional) has not previously been reported in IOR tasks, and in the next Experiment, I further probed whether stimulus complexity would produce differential effects on RTs and IOR when using an avoidance response.

Experiment 8

In Experiment 8, participants made avoid responses to targets that were more visually complex (everyday objects) than the asterisks previously used. This data was then compared with the data collected from the avoidance response condition in Experiment 7, to determine whether stimulus complexity differentially affected RTs at cued and uncued locations when making avoid responses. Based on previous reports of the blind nature of IOR to target content here (Section 2), and in Taylor and Therrien (2005; 2008, Experiment 4), it seemed unlikely that stimulus complexity would create a disturbance to IOR when making an avoidance localisation response. However, to establish the baseline effects of avoid responding, prior to the use of emotional stimuli, this experiment was necessary.

Method

Participants

Ten naïve adults (8 females; mean age 24 years) were recruited as before.

Apparatus and Stimuli

The apparatus were the same as before. Here targets to be detected were images of computer-generated objects, previously described in Experiment 1.

Design and Procedure

The design and procedure were the same as before.

Data Analysis

Note here that the mixed effects ANOVA specifying the within-subjects factors of SOA, cue validity, and visual field was conducted as before on this complex object data.

Results and Discussion

Error rates. Accuracy did not differ between detection of simple and complex objects, $F < 1$. Accuracy was not modulated by visual field, $F(1,18) = 1.29, p = .27$, or the interaction between visual field and target complexity, $F(1,18) = 1.29, p = .27$.

Short SOA RTs. RT data (all SOAs) for this experiment is presented in Table 4. As previously observed in Experiment 7, no difference in RTs to targets presented at cued and uncued locations were observed, $F < 1$. The effect of visual field, $F < 1$, and the cue validity and visual field interaction, $F < 1$, did not contribute to the pattern of data presented here.

Long SOA RTs. Complex target localisation RTs were slower in cued trials versus uncued trials, $F(1,9) = 55.46$, $p < .001$, indicating IOR. Although IOR did not change as a function of visual field, $F(1,9) = 2.41$, $p = .16$, there was a hint in the data that magnitude of IOR was modulated by SOA, $F(4,36) = 2.42$, $p = .07$, with a smaller IOR effect at the 3200 ms SOA, -14 ms, in contrast to the mean IOR magnitude generated across the remaining SOAs, which was -36 ms. No other main effects or interactions were significant, F's < 1.06, p's $> .39$.

The long SOA ANOVA was then repeated, including data from the avoid condition in Experiment 7 where a visually simple target stimulus was employed. Thus, target type (asterisk, object) was specified as a between-group factor in this new analysis, to explore target complexity effects on RTs and IOR when making an avoidance response. Note that cue validity, SOA, and visual field remained as the within-subjects factors in this analysis. RTs were unaffected by target complexity, $F(1,18) = 1.98$, $p = .18$, and visual field, $F < 1$. Responding was slower to targets presented at cued versus uncued locations, $F(1,18) = 107.64$, $p < .001$, confirming IOR, which was unaffected by target type, $F < 1$, and visual field, $F(1,18) = 1.07$, $p = .32$, with the three-way interaction between visual field, cue validity, and target type also being non-significant, $F(1,18) = 2.12$, $p = .15$. SOA also did not interact with these variables, $F < 1$. These results demonstrate that RTs and IOR measured by avoid localisation responses remain unaffected by stimulus complexity, and further support the notion of the unseeing nature of the mechanisms underlying IOR. Furthermore, the absence of any modulation of RTs and IOR by visual field suggest that the avoidance response here does not change as a function of the assumed asymmetry of avoid responding (right hemisphere, Davidson et al., 1990; Maxwell & Davidson, 2007) in the absence of emotional stimuli. Therefore in these control experiments, the avoidance response is probably more accurately defined as a key release response, which does not affect RTs or IOR any differently than a conventional key press response.

Experiment 9

Experiments 7 and 8 demonstrated that there was no relationship between RTs and IOR using a key release response to localise neutral (simple and complex) target stimuli in contrast to a key press response. In Experiment 9, participants responded to either a negative or a positive target stimulus using the avoidance response. Localising negative stimuli using an avoidance response is emotionally compatible, in contrast to localising positive stimuli with an avoidance response, which is emotionally incompatible. Therefore, at uncued locations, response times should be facilitated to localise target stimuli in the compatible condition. The point of interest here was what would happen to this emotional compatibility effect at the cued locations that are subject to inhibition. Figure 11 presented the hypotheses for Experiment 9: IOR may reduce the compatibility benefit (Fuentes et al., 1999; Vivas & Fuentes, 2001) or have no effect at all on responding (Ivanoff & Klein, 2001; Lupiáñez et al., 1997; Pratt et al., 1997). Furthermore, differential effects of emotional compatibility may be modulated by visual field presentation of the target (in both cued and uncued locations), based on the cerebral asymmetry of the approach-avoidance dichotomy (Davidson et al., 1990). To maintain a consistent affective state to maximise aversive and appetitive conditions (Lang et al., 1990), target valence was blocked between subjects in this experiment.

Method

Participants

Forty naïve adults (30 females; mean age 20 years) were recruited, and were randomly and equally assigned to the negative target (a spider) or the positive target (sweet food) condition. In the negative condition, participants were low fearful of spiders. In the positive condition, to enhance a positive affective response to the stimuli, participants were asked to not eat or drink anything but water 5 hours before the testing session.

Apparatus and Stimuli

The apparatus were the same as before. Negative target stimuli were spiders, and the positive target stimuli were sweet food targets, previously described in the stimulus section of Experiments 1 and 6.

Design and Procedure

The design and procedure were the same as before.

Data Analysis

Data analysis was the same as before. Note that the variable *stimulus compatibility* refers to the emotional valence of the target as being either compatible (negative) or incompatible (positive) with the response mode (avoidance). This stimulus compatibility variable was therefore specified as a between-group factor in the analysis reported below, with SOA and cue validity specified as within-subjects factors.

Results and Discussion

Error rates. Error rates were less than 2%, and were not modulated by stimulus compatibility, $F < 1$, the visual field of target presentation, $F < 1$, or their interaction, $F < 1$.

Short SOA RTs. RTs as a function of cue validity, SOA, and stimulus compatibility are presented in Figure 13A for targets presented in the left visual field, and Figure 13B for targets presented in the right visual field. Analysis of RTs at the 100 ms SOA revealed faster responding to localise targets presented at cued versus uncued locations, $F(1,38) = 4.56$, $p < .05$, indicative of an attentional benefit of spatial cuing on target performance. The cuing benefit was 7 ms in magnitude in the negative target condition, and 8 ms in the positive target condition. This facilitation effect did not interact with stimulus compatibility, $F < 1$, or visual field, $F < 1$. However, as can be seen in Figure 13, RTs were faster when making an avoidance response to negative targets than positive targets, $F(1,38) = 7.96$, $p < .01$, suggesting emotional compatibility here facilitated response times. No other main effect or interaction was significant, F's < 1.55, p's > .22.

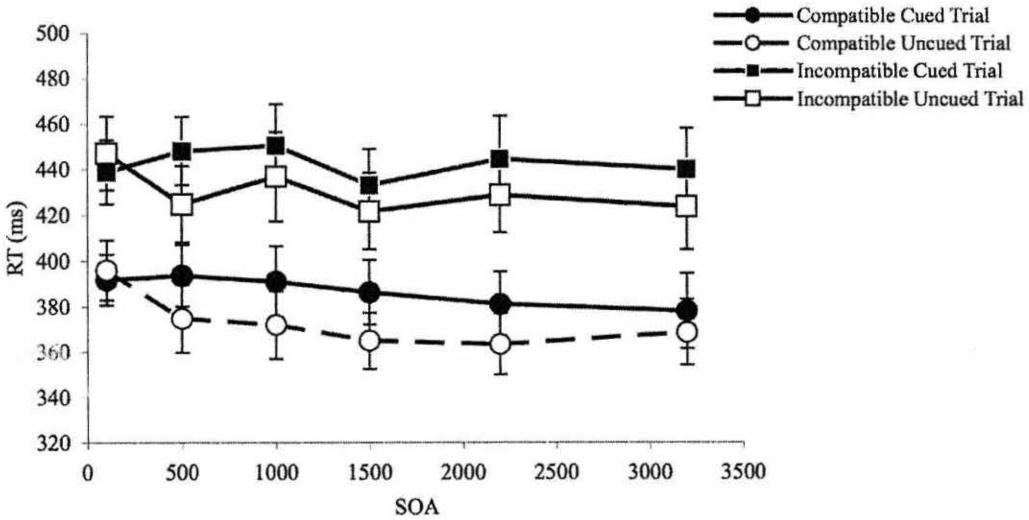

Figure 13A. Group mean RT obtained in Experiment 9 (target type blocked) for locating an emotionally compatible (spider) and incompatible (sweet food) target plotted as a function of SOA. Data is shown for targets presented in the left visual field. Vertical bars indicate +/- 1 S.E.

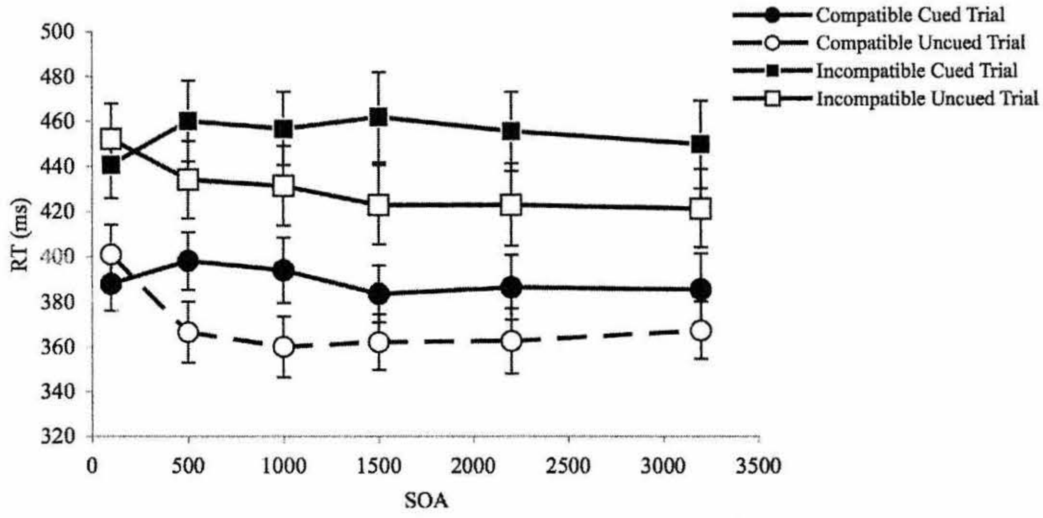

Figure 13B. Group mean RT obtained in Experiment 9 (target type blocked) for locating an emotionally compatible (spider) and incompatible (sweet food) target plotted as a function of SOA. Data is shown for targets presented in the right visual field. Vertical bars indicate +/- 1 S.E.

Long SOA RTs. The first noteworthy finding was the overall main effect of stimulus compatibility, $F(1,38) = 9.06, p <. 01$. RTs were significantly faster to localise negative targets than positive targets when executing an avoidance response, demonstrating the benefit of emotional S-R compatibility in facilitating responding. Furthermore, visual field presentation did not interact with stimulus compatibility, $F < 1$, or modulate localisation RTs in general, $F < 1$. The absence of any modulation of RTs by visual field indicates that emotional compatibility effects were not dependent upon the lateralised presentation of target stimuli, adhering to cerebral asymmetries of approach-avoidance (Davidson et al., 1990). Analysis of only uncued trials (no inhibition, and removing the within-subject factor of cue validity from the ANOVA) revealed that localisation responses were 61 ms faster in the stimulus compatible condition, $F(1,38) = 8.90, p < .01$, than in the stimulus incompatible condition. This emotional compatibility effect did not interact with visual field, $F < 1$, or SOA, $F < 1$, with the three-way interaction between these variables also being non-significant, $F < 1$.

The second point to note here is that IOR was present in this task, evident by slower RTs to localise targets presented in cued versus uncued locations, $F(1,38) = 87.47$, $p < .001$. If IOR interacted with emotional S-R compatibility, this would be present in a significant cue validity and stimulus compatibility interaction. However, this interaction, $F < 1$, as well as the three-way interaction between cue validity, visual field, and stimulus compatibility, was non-significant, $F < 1$. The mean IOR effect in the emotionally compatible condition was -22 ms, and in the emotionally incompatible condition, the mean IOR magnitude was -23 ms. Nevertheless, I also analysed cued trial RTs in a separate ANOVA, which revealed localisation responses were 62 ms faster in the stimulus compatible condition, *F*(1,38) = 8.98, $p < .01$, than in the stimulus incompatible condition. Although cued RTs in general were marginally modulated by visual field (evident by faster responding to the left visual field target presentations), *F*(1,38) = 3.21, $p = .08$, this did not interact with stimulus compatibility, *F*(1,38) = 1.12, $p = .3$. However, the visual field, SOA, and stimulus compatibility effect interaction was also trended toward significance, *F*(4,152) = 2.09, $p = .08$. This interaction can be explained by cued RTs being slower in the right visual field (462 ms) than the left visual field (433 ms) in the incompatible stimulus (positive) condition at the 1500 ms SOA.

I then collapsed together RTs from each long SOA and visual field to illustrate the absence of IOR modulation on emotional compatibility in this task. Mean RTs for target localisation in cued and uncued trials in the emotionally compatible and incompatible conditions are presented in Figure 14. This figure clearly shows that IOR (indicated by slower responding to targets presented at cued locations) is not affected by emotional compatibility between stimulus and response measured in this experiment (see also Figure 11b).

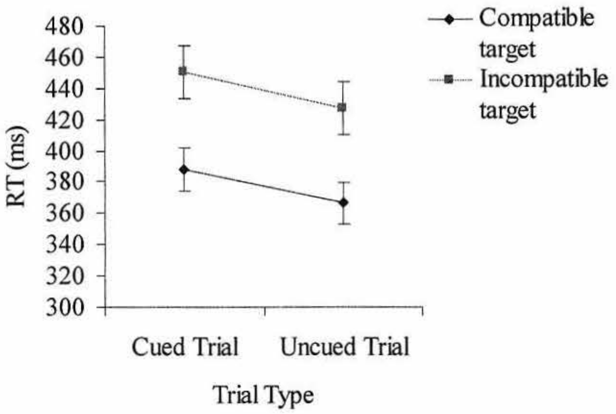

Figure 14. Mean RTs collapsed across visual field and SOA to localise target stimuli in the emotionally compatible and emotionally incompatible S-R conditions. Vertical bars indicate +/- 1 S.E.

An additional point of interest here was the observation that IOR tended to be larger in the right visual field than the left visual field, $F(1,38) = 9.56, p < .01$, although this effect did not differ as a function of stimulus compatibility, $F < 1$. Note that this effect also was present descriptively in Experiments 7 and 8. To further explore this, the data from the compatible and incompatible condition were re-analysed with data from a neutral target condition for the long SOA conditions only, in a cross-experimental analysis. The neutral target condition consisted of the data collapsed together from the key release localisation of visually simple (Experiment 7) and visually complex (Experiment 8) targets. (Note there were no differences between RTs or IOR in these conditions.) This analysis demonstrated two important points.

First, IOR was larger when measured in response to target presentation in the right visual field versus the left visual field, $F(1,57) = 9.57, p < .01$. However, this interaction of cue validity and visual field was unaffected by target type (compatible, incompatible, neutral), $F < 1$. To ascertain whether this was driven by the emotional target conditions, the analysis was repeated to compare compatible (negative) to neutral target conditions, and incompatible (positive) to neutral target conditions. In both positive versus neutral, $F(1,38) = 4.35, p < .05$, and negative versus neutral, $F(1,38) = 5.75, p < .05$, target conditions, IOR was larger in the right visual field than the left visual field. However, in neither condition was the three-way interaction between cue validity, visual field, and target type significant, F's < 1.19, p's $> .28$. Therefore, there seems to be a general tendency for IOR to be greater when measured in response to targets presented in the right visual field than when the same targets are presented in the left visual field (regardless of emotionality) in this task.

Second, the presence of IOR evident in the RT data, $F(1,57) = 169.23, p < .001$, was not affected by the content of the target (compatible, incompatible, or neutral), $F < 1$, with the interaction between visual field, cue validity, and target content also being non-significant, $F < 1$. These results indicate that the magnitude of IOR was unaffected by target content (emotional, non-emotional), consistent with the findings of Section 2 (Experiments 2 and 4). However, this pattern of results was also unexpected considering the equivalent experiments presented in Section 2 (Experiments 1 and 6), where sustained exposure to emotional stimuli attenuated IOR in contrast to the neutral target condition. This was not seen in the current experiment, despite the sustained affective context. Furthermore, re-analysis of the mid-range SOAs (500, 1000, and 1500 ms) as conducted previously in Experiment 1, also failed to reveal any significant modulation of IOR by target content, $F < 1$.

At first glance, this absence of an affective context modulation of IOR suggests that perhaps the execution of an avoidance response (irrespective of whether the target is compatible or incompatible) negates the previously observed effects of emotionality on IOR. However, a more parsimonious explanation may be sought by comparing the experimental designs between the conventional and avoid conditions. Specifically, there was a key methodological difference in the experimental design that may explain the absence of emotion-IOR effects. I included additional preparation time in the avoidance condition (4000 ms preparation delay and 2000 ms warning fixation at the beginning of each trial), which may have dampened the effects of prior to exposure to emotional stimuli. From the data presented in Experiments 1 - 6, emotion-IOR effects appear to be highly transient and easily reversed. Therefore, it is plausible that repeated exposure to emotional stimuli has to occur in repeated succession in a small temporal window in order to influence visual orienting mechanisms. To test this hypothesis, Experiment 10 presented both objects and spiders as targets in a single cuing task using only the 1000 ms SOA. The experiment parallels Experiment 2 precisely in timing, and although in that previous experiment, no overall differences between target type and IOR magnitude were found, post-hoc trial by trial analyses revealed smaller IOR to neutral stimuli following sustained exposure to negative stimuli. If IOR measured by avoid responses is unaffected by target emotional content, then this same post-hoc analysis should reveal no difference of prior exposure to emotion on IOR. However, if the null effect of target type here results from insufficient exposure to emotional stimuli then this should be overcome in Experiment 10, replicating the post-hoc analysis of Experiment 2.

Experiment 10

Experiment 9 demonstrated that IOR did not interact with the emotional compatibility between a stimulus and its response. Benefits of emotional compatibility in speeding RTs were seen at both cued and uncued locations. However, differences in IOR magnitude were not seen between the emotional (compatible, incompatible) and neutral target conditions. This is in direct contrast with the Experiments reported in Section 2, which showed an attenuation of IOR when emotional valence was also blocked. One possible explanation was owing to the difference in the timing of trial events, with a temporal delay at the beginning of each trial in Experiment 9, a delay absent in its blocked counterparts in Experiments 1 and 6 of Section 2. Therefore, Experiment 10 was designed to replicate Experiment 5, where target type (emotional and non-emotional) was mixed within-subjects, using the same temporal parameters with the response mode being the only methodological difference. This would ascertain post-hoc whether changes in affective state induced by several target exposures would attenuate IOR as shown previously, or alternatively whether successive avoid responding to localise target stimuli negates affective modulation of IOR. Experiment 10 also enabled a further opportunity to explore whether IOR would influence S-R emotional compatibility in a different experimental design (where affective contextual state was no longer held constant). However, here the incompatible condition was not included; therefore, RTs in the neutral target condition were used as a baseline to calculate any emotional compatibility benefits.

Method

Participants

Fifteen naïve adults (12 females; mean age 21 years) were recruited as before.

Apparatus and Stimuli

The apparatus were the same as before. Stimuli were either spiders or objects previously used in these experiments.

Design and Procedure

The design and procedure were the same as Experiment 2 with the important exception that participants were now making an avoidance response to localise targets.

Results and Discussion

Error rates. Error rates were low (less than 2%), and did not differ as a function of target type, $F<1$, visual field, $F(1,14) = 2.63$, $p = .17$, or their interaction, $F(1,14) = 1.07$, $p = .32$.

RTs. A repeated measures ANOVA specifying cue validity, stimulus compatibility, and visual field as within-subjects factors was conducted on the RT data. Target localisation RTs were significantly affected by visual field presentation. RTs were 21 ms faster in the right visual field than the left visual field, $F(1,14) = 30.23$, $p < .001$. Therefore, RTs as a function of visual field, cue validity, and stimulus compatibility (compatible, neutral) are presented in Figure 15. Consistent with Experiment 9, localisation responses were faster in the emotionally compatible condition than the neutral condition, $F(1,14) = 15.58$, $p < .01$. Furthermore, this stimulus compatibility effect did not change as a function of visual field, $F(1,14) = 1.41$, $p = .26$, again demonstrating that laterality plays no role in emotional compatibility effects here.

RTs were slower for locating targets at the cued relative to the uncued locations, $F(1,14) = 10.02$, $p < .01$, indicating IOR. IOR did not significantly interact with stimulus compatibility, $F(1,14) = 1.41$, $p = .26$. The mean IOR effect was -16 ms in the neutral condition, and -21 ms in the compatible condition. At the cued location, the emotional compatibility benefit (neutral RT – compatible RT) was 14 ms, and at the uncued location, this benefit was 9 ms. The absence of an interaction between IOR and emotional S-R compatibility is consistent with the null effect reported in Experiment 9. Note also that visual field presentation did not modulate IOR, $F < 1$, and the interaction between visual field, IOR, and stimulus compatibility was also non-significant, $F < 1$.

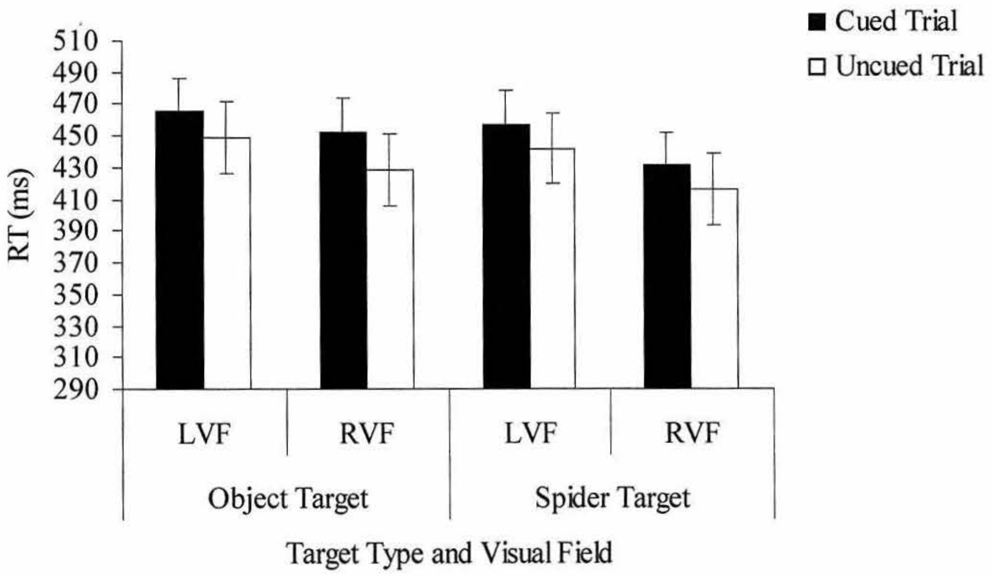

Figure 15. Group mean RT obtained in Experiment 10 (target type mixed) for locating spider or object targets presented at just previously cued or uncued locations using an avoidance response. Vertical bars indicate +/- 1 S.E.

These findings are important for two reasons. First, consistent with the measures obtained in Experiment 9, IOR did not interact with the emotional compatibility between target and response. Emotional compatibility benefits were statistically equivalent at both the cued and uncued location. Second, these findings replicate the critical finding of Experiments 1 – 6 that IOR is not sensitive to the emotional content of a target stimulus when processed on-the-fly.

RT and IOR effects were then examined for trials that had been preceded by three trials of the opposite type (collapsing together data from both visual fields, see Table 4). This was to establish whether the difference in temporal events between Section 2 and Experiment 9 explained the absence of affective modulation of IOR in the latter experiment. Therefore, IOR for spider-target trials that had been preceded by three object-target trials in succession were contrasted with IOR for object-target trials that had been preceded by three spider-target trials. Only 12 % of trials were included in this post-hoc ANOVA analysis (618 trials overall) of cue validity and stimulus compatibility. Although there was no difference in speeded responding to spider targets making an avoidance localisation response, $F(1,14) = 2.81$, $p = .12$, localisation RTs at cued locations were significantly slower than localisation RTs at uncued locations, $F(1,14) = 7.63$, $p < .05$, confirming the presence of IOR. The modulation of IOR by stimulus compatibility did not reach significance, $F(1,14) = 2.09$, $p = .17$; however, comparing RTs between cued and uncued object target trials, which were preceded by three spider target trials, failed to reveal a significant IOR effect, $t < 1$. In contrast to this, comparison of RTs from cued and uncued spider target trials, which were preceded by three object target trials, did yield a significant IOR effect, $t(14) = 3.7$, $p < .01$.

Table 4. Mean RTs for trial by trial analysis in Experiment 10.

	Cued Trial RT		Uncued Trial RT	
	M	*SE*	*M*	*SE*
Object Target (preceded by 3 spider trials)	451	21	439	21
Spider Target (preceded by 3 object trials)	450	22	419	19

These data support the importance of sustained exposure to emotion in determining the magnitude of IOR. Further, they provide a useful clue to the transient nature of emotion effects on IOR. In Experiment 9, when a 6000 ms delay was added to each trial, IOR was not attenuated by sustained exposure to emotion. However, when no such delay was imposed in the same spatial cuing procedure, IOR was attenuated in the emotional versus neutral target conditions. This suggests that repetitive exposure to emotional stimuli alone is not sufficient to attenuate IOR, but there is a temporal component to IOR-emotion interactions. This point will be further considered in the Section Discussion.

Chapter 8: Section Discussion

In the four experiments reported here, I explored whether IOR would interact with the emotional compatibility between stimulus and response. Emotionally compatible targets (spiders) were localised significantly faster then emotionally incompatible (sweet foods) and neutral (complex objects) targets. This emotional compatibility benefit was present, and equivalent in magnitude, at both cued and uncued locations. Indeed there was no evidence that IOR interacted with emotional compatibility, even when affective context was held constant (Experiment 9), as well as when affective context was variable (Experiment 10). These results are consistent with the notion that once the onset of a target stimulus reaches the criterion required to execute a response to a cued location, subsequent stimulus-response processes are comparable to target locations where no such criteria threshold is present.

Previous research has suggested that emotional stimuli elicit response tendencies to approach or avoid (Davidson et al., 1990; Lang et al., 1990; 1997), with evidence that this responding may be lateralised (see Maxwell & Davidson, 2007, for a recent review). Developing this principal further has been a series of studies that demonstrate the benefits of compatibility between emotional stimuli and response behaviours in facilitating performance in a range of tasks (e.g., Förster & Stepper, 2000; Förster & Strack, 1996; Neumann & Strack, 2000; Solarz, 1960; Strack, et al., 1988). Lang et al. (1990; 1997) proposed emotional responding would be enhanced when the affective context of a situation is kept constant. However, in the experiments reported here, emotional compatibility effects were observed both when the affective state was stable (achieved by presenting blocks of same valence trials, Experiment 9), and when the affective state was unstable (by presenting valenced targets intermixed with neutral targets, Experiment 10). Moreover, emotional compatibility effects were not modulated by visual field presentation, suggesting that any potential laterality effects of avoidance responding in this experiment were absent and did not influence performance.

This latter point of a null laterality finding was somewhat surprising, considering the proposed asymmetry of emotion in the brain (Davidson et al., 1990; Maxwell & Davidson, 2007). This presents a wider theoretical issue of the reliability of this laterality notion. Indeed a recent review of neuroimaging studies of emotion addressed this issue. Wager and colleagues (2003) conducted a meta-analysis across 65 PET and fMRI studies to explore whether a consistent pattern of results were obtained from neurophysiological data measuring emotion processing. Recall that Davidson et al. (1990) proposed a frontal asymmetry of emotion processing, with the left hemisphere coding positive / approach related emotions, and the right hemisphere coding negative / avoidance related emotions. However, in this meta-analysis (Wager et al., 2003), no valence (positive, negative) lateralisation effects were found in the lateral frontal cortex, and approach-withdrawal lateralisation only trended towards significance, $p = .08$. Interestingly, the anterior medial prefrontal cortex showed increased activity for approach related emotion; with the rostral anterior cingulate showing increased activity for avoidance related emotions. Perhaps the search for left and right hemisphere lateralisation effects (behaviourally and neurophysiologically) mask more regional specific encoding of emotion, which may or may not then show any subsequent lateralisation of function. Moreover, purely behavioural measures may be insensitive to such regional specific effects, explaining the absence of any laterality effects reported here.

Speeded responding to emotional stimuli is typically observed in response time tasks (e.g., Brosch & Sharma, 2005; Eastwood et al., 2001; Flykt, 2005; Fox et al., 2000; Öhman et al., 2001), even in the absence of emotional compatibility between stimulus and response. In this thesis for instance, RTs in Experiment 2 were faster to localise spider stimuli than object stimuli. Therefore, to verify the emotional compatibility effects reported here, I conducted an additional analysis to compare response times between the equivalent experimental conditions of Sections 1 and 2 that used negative stimuli (spider) as targets. Figure 16A presents the RT data obtained from uncued trials for Experiments 1 and 9 (blocked spider targets). Note uncued trials were included in this Figure and subsequent analyses principally because target localisation is unaffected by any inhibitory processes.

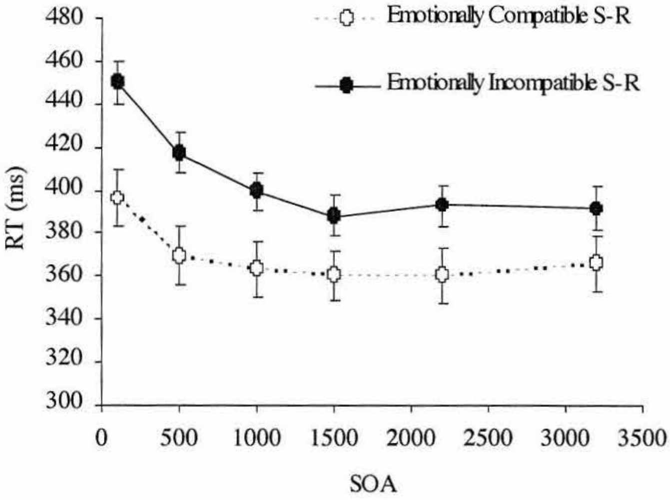

Figure 16A. Group mean uncued RTs to localise negative target stimuli for the emotionally compatible response condition (Experiment 9, blocked target design) and the emotionally incompatible response condition (Experiment 1, blocked target design). Vertical error bars indicate +/- 1 S.E.

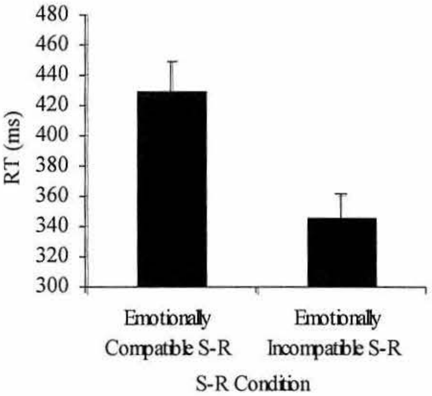

Figure 16B. Group mean uncued RTs to localise negative target stimuli for the emotionally compatible response condition (Experiment 10, mixed target design) and the emotionally incompatible response condition (Experiment 2, mixed target design). Vertical error bars indicate +/- 1 S.E.

Analysis of uncued RTs in the blocked spiders condition of Experiment 1 (using a conventional key press response) and the uncued RTs in the blocked spiders condition of Experiment 9 (using an avoidance response), revealed localisation performance was still significantly faster in the emotionally compatible S-R condition, $F(1,43) = 6.75$, $p = .013$, validating the emotional S-R compatibility effect observed here. However, this benefit of emotional S-R compatibility was not observed when conducting the same analysis of uncued RTs to localise target stimuli in Experiments 2 and 10, where target content was not held constant. Instead, faster responding in the conventional key press response condition was found, $F(1,35) = 12.59$, $p = .001$ (Figure 16B). Perhaps the manifestation of speeded responding when stimulus and response are compatible is especially sensitive to affective context in this experiment. Maintenance of affective context through blocking target emotional content yields emotional S-R compatibility effects; however, disruption to this context by varying the emotional content of targets nulls this response benefit in this task (see also Lang et al., 1990).

Nevertheless, in both the blocked target condition and the mixed target condition reported here, there was no evidence that IOR interacted with responding beyond the slowed response times traditionally observed to targets presented at cued versus uncued locations (Posner & Cohen, 1984; Posner et al., 1985).

Fuentes et al. (1999) proposed an inhibitory tagging hypothesis of IOR, where the inhibition present at a cued location interferes with response-relevant properties of target stimuli subsequently presented there. Indeed, flanker interference effects were reversed when the target-distractor array were presented at cued locations, subject to IOR. The reduction in Stroop interference reported by Vivas and Fuentes (2001; see also Fuentes, Boucart, Vivas, Alvarez, & Zimmerman, 2000) also provided converging evidence that inhibition may prevent the activation of response-related processes following target onset. These findings provided a strong initial hypothesis that emotional compatibility effects measured at previously cued locations would be abolished, owing to the inhibition at these locations preventing the automatic activation of the avoidance response (Figure 11A). However, the data reported in Experiment 9 are inconsistent with this hypothesis: Emotional compatibility effects were equivalent at both the cued and uncued target locations.

Instead the data reported here converge with the previous null findings of IOR and S-R compatibility interactions (Ivanoff & Klein, 2001; Lupiáñez et al., 1997; Pratt et al., 1997). However, a subsequent omnibus analysis of these and additional experiments by Ivanoff et al. (2002) suggested IOR does interact with the Simon effect, and the failure of previous studies to find an IOR and S-R compatibility interaction was owing to insufficient statistical power. Combining the data across IOR-Simon task experiments did reveal a significant IOR and S-R compatibility interaction, with the Simon effect being enhanced by IOR (Ivanoff et al., 2002). Therefore, I conducted a post-hoc power analysis using the mean response times collapsed together for each SOA in the compatible and incompatible condition, and for responding to targets presented at the cued and uncued location. Although the emotional compatibility main effect was sufficiently powerful (.84), the interaction between compatibility and IOR had very weak power (.04), suggesting that the non-significant interaction reported here could be explained by insufficient statistical power. Indeed, based on the parameters of the current design, I would need to run upwards of 500 participants to increase the power of this interaction to only .2.

Nevertheless, perhaps the Simon effect and emotional S-R compatibility effects reflect different underlying neural processes, and it is unfair to make such strong comparisons between them. Emotional compatibility may reflect a more symbolic convergence of stimulus and response representations (see also, Eder & Klauer, 2007; Eder & Rothermund, 2008), with the Simon effect instead being more reflexively driven by spatial S-R correspondence. Thus, I will also consider other factors that may have contributed to this non-significant IOR and emotional S-R compatibility interaction, aside from a statistical factor.

The non-significant interaction between IOR and emotional S-R compatibility was somewhat surprising considering the believed automaticity of emotional stimuli in eliciting approach-avoidance response tendencies (Lang et al., 1990; 1997). For instance, Chen and Bargh (1999) instructed participants to push or pull a lever to categorise visually presented valenced words as "good" or "bad". In the compatible condition, participants pulled the lever to positive words and pushed the lever to negative words. In the incompatible condition, participants pushed the lever to positive words and pulled the lever to negative words. As shown previously by Solarz (1960), categorisation responses were faster in the compatible than in the incompatible condition. A second experiment removed the conscious categorisation element of the task instead instructing participants to either push or pull the lever at the beginning of each block in response to the stimulus. Again, participants were faster to respond in the emotionally compatible condition, and

Chen and Bargh (1999) used this replication as evidence of an automatic link between stimulus evaluation and response mode: Even in the absence of conscious categorisation of emotion, emotional compatibility effects were still observed.

However, whether emotional stimuli truly elicit automatic tendencies to approach or avoid has recently come into question. Rotteveel and Phaf (2004) claim that arm extension and flexion are not automatically elicited in response to emotional stimuli, and failed to replicate any emotional compatibility effects in an affective priming task (where the occurrence of conscious evaluation is minimal). Furthermore, Markman and Brendl (2005) and Bamford and Ward (2008) also argue against motoric pre-dispositions to approach or avoid, instead citing situational and contextual factors in determining the occurrence of emotional compatibility effects. This research (Bamford & Ward, 2008; Markman & Brendl, 2005; Rotteveel & Phaf, 2004) raises an interesting issue of whether the previously measured emotional compatibility effects (e.g., Chen & Bargh, 1999; Förster & Stepper, 2000; Förster & Strack, 1996; Neumann & Strack, 2000; Solarz, 1960; Strack, et al., 1988) are reliant on purely automatic processes, or are mediated by contextual or situational factors. Potential evidence to support this contextual hypothesis of emotional S-R compatibility effects may come from the data presented in Figure 16. Facilitation of avoid responding to negative targets was only present when these targets appeared in blocks where valence was kept constant. When the affective context was unstable, this compatibility effect was absent (in fact it was reversed with faster responding to negative stimuli using a conventional key press response). Therefore, pre-dispositions to avoid negatively valenced stimuli may be mediated by the current affective context of a given situation, rather than reflecting an automatic response bias to this stimulus category.

The notion that emotional stimuli may not automatically elicit behavioural response tendencies, as previously hypothesised (Lang et al., 1990; 1997), may be crucial for understanding the absence of any interaction between emotional compatibility and IOR in the experiments reported here. Inhibitory tagging (Fuentes et al., 1999) may only operate on more explicit response-related properties of target stimuli, which are not dependent upon affective context to be expressed. The relationship between a negative stimulus and an avoidance response may not be sufficiently intrinsic to measure any interaction with IOR.

Although more research is required to determine whether emotional stimuli automatically elicit emotional responding, the null effect reported here is consistent with a previous study that explored whether IOR interacted with action affordances. In real-world situations, perception of stimuli can activate action-representations of responses they afford (Tucker & Ellis, 1998). For instance, seeing a football activates action-representations related to kicking. Morgan and Tipper (2005) presented an image of a door handle, which was either oriented to the left or oriented to the right. Note that right-oriented handles were compatible with a right hand response, and left-oriented handles were compatible with a left hand response. The cue and target stimuli were presented on either the affording (where the hand grips) or the non-affording (where the hand does not grip) part of the door handle, with the target stimuli requiring a localisation response (left or right key press). Therefore, target stimuli could be presented in action compatible and action incompatible locations, which may or may not have been previously cued. Furthermore, the door handles were presented centrally across the midline (passive condition), as well as tilted to imply action (active condition; see Figure 17).

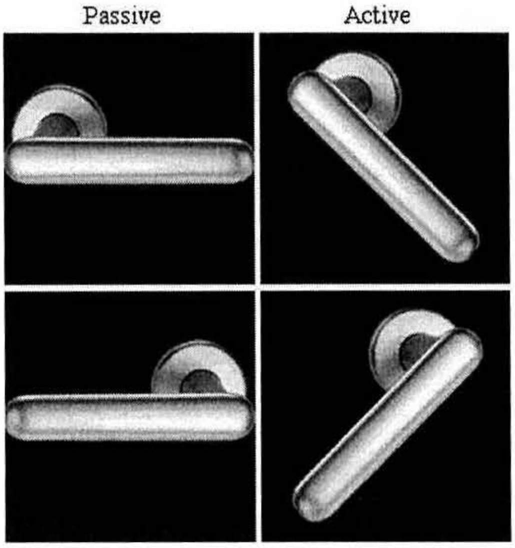

Figure 17. Examples of the stimuli used in Morgan and Tipper (2006). In the passive condition, door handles were angled along the horizontal midline, and in the active condition, the door handles were tilted to imply action. Door handles in the upper panels are compatible with a right-hand response, and door handles in the lower panels are compatible with a left-hand response.

Although Morgan and Tipper (2006) demonstrated both consistent action-compatibility effects (faster response times in compatible versus incompatible conditions) and significant IOR effects, no interaction between these two variables were found. This was true even when door handles were titled to imply action, as well as in further experimental trials where motion was implied by increasing the tilt of the handle throughout a trial sequence. A final experiment incorporating reaching movements also did not reveal the IOR and action-compatibility interaction. The absence of this interaction was not owing to limited statistical power: Collapsing data across the different handle manipulations also supported the absence of any interaction between IOR and action compatibility (see Ivanoff et al., 2002). Assuming emotional stimuli do elicit approach-avoidance tendencies, Morgan and Tipper's (2006) data converges with the failure to find any interaction in Experiments 9 and 10 reported here between IOR and response compatibility, when emotional in nature.

The absence of IOR sensitivity to target content in Experiment 9 furthers our understanding of the emotion-IOR effects present in Experiment 1 - 6. Specifically, Experiment 9 demonstrates that repeated exposure to emotional stimuli is not sufficient to modulate the visual orienting mechanisms underlying IOR. Although previous research (e.g., Bradley et al., 1996; Smith et al., 2003) has suggested that sustained exposure to emotional images may induce changes in mood state, the repeated exposure to emotional stimuli here was not sufficient to change affective state to attenuate IOR as previously observed in Experiments 1 – 6. This suggests that the top-down modulation of IOR by emotion is extremely sensitive to the temporal proximity between successive target exposures. Onset of an emotional stimulus may initiate an affective response, and if the next trial sequence occurs during the course of this response, then IOR is attenuated. However, if the next trial is presented once this affective response has begun to decline to baseline, then IOR is unaffected. Support for such a proposal comes from ERP recordings during long exposure (6 seconds) to pleasant, unpleasant, and neutral pictures. Codispoti et al. (2006) found the affective content of these pictures modulated the LPP component, with affective modulations of the ERP trace by these pictures up to 3000 ms post-picture onset. However, no modulation of ERPs (slow waves) by picture content was observed past this time. This absence of late slow wave modulation by affect is surprising, given the stimuli were displayed throughout the later stages of the ERP recording. However, this finding does suggest that affective responses to emotional images are relatively short-lived, even when the emotional content of the stimulus remains visible.

Short successive exposures to emotional stimuli in Experiments 1 and 3 may maintain an emotional response throughout the experimental session, effectively keeping the affective system 'topped-up'. This would explain why the introduction of a temporal delay in each trial resulted in no modulation of IOR in Experiment 9. Any explanation involving the response mode is ruled out with Experiment 10, where no temporal delay is present, and successive exposures to emotional stimuli abolished IOR. This affective transiency interpretation would also explain the absence of emotion-IOR effects in the longer SOA conditions of Experiment 1. Furthermore, designing the experiments to be self-paced here (and in Section 2), probably unnecessarily increased the variance of emotion-IOR interactions, with participants taking rest breaks when required, interfering with continuity of the induced affective state. Future research in this area would benefit from precise neurophysiological recordings during the experimental procedure, in an attempt to provide an objective indicator of this affective transiency in contributing to the manifestation of IOR. Recording ERPs during the experimental session would be one approach to measure affective responses during spatial cuing tasks. Codispoti et al. (2006) found habituation in recording affective reactions to emotional pictures using other physiological indexes (heart rate, skin conductance), suggesting these may not be appropriate measures to use when studying emotion-IOR effects.

The results here also provide a better understanding of the modulation of IOR observed previously in Experiment 6 by positively valenced stimuli. There it was unclear whether the modulation of IOR was owing to the hunger manipulation, the positive target stimuli, or a combination of the two factors. In Experiment 9, finding that IOR was not reduced in the incompatible target condition using a hunger manipulation suggests that both a combination of stimulus-driven emotionality and food abstinence produced the observed attenuation of IOR in Experiment 6. If IOR had been smaller in magnitude for only the incompatible S-R condition reported here, this would have suggested that a continuous state of hunger could produce top-down modulation of IOR, regardless of the nature of the target stimuli employed. Whether the sweet food targets used here are sufficient to modulate visual orienting in the absence of a hunger manipulation, and whether they are a reliable source of positively valenced information in other paradigms, is an issue remaining for future research.

Finally, I want to draw attention to Experiments 7 and 8, which failed to reveal any attentional benefits of prior cuing on target localisation. This absence of a cuing effect is puzzling. Combing the data sets together (N = 20), responding at cued locations was 460 ms, and at uncued locations responding was 457 ms, and still failed to reveal a significant cuing benefit, $F(1,18) = 1.25$, $p = .28$. Nevertheless, a significant cuing benefit was seen in Experiment 9 (N = 40), suggesting that attentional facilitation can be generated and measured in this paradigm. Perhaps the absence of attentional facilitation in the earlier experiments was simply owing to a smaller group of participants with highly variable responding. It is unlikely that the neutral value of target stimuli determined the magnitude of the cuing benefit here, with significant cuing benefits, unaffected by target type, reported in Experiment 1. Nevertheless, the interaction between emotion and the effects of spatial cuing on both facilitation and inhibition will be considered further in the next section of this thesis.

In summary, these results indicate that IOR does not interact with the emotional compatibility between stimulus and response in the experiments employed here. Conceptualising IOR as reflecting a shift in the criterion to respond to a cued location, the present data suggests that once the onset of a target meets this criteria, response compatibility effects emerge consistent with responding at uncued locations. Furthermore, these data provide additional support and understanding to the top-down, rather than stimulus-driven, modulation of IOR by emotionality. Taken together, the results from Experiments 1 - 10 indicate IOR is truly a reflexive phenomenon, with the mechanisms subserving the effect being blind to the emotional content of the visual scene. Emotional stimuli seem unable to break through the inhibition present at a spatial location to exert control over responding. However, once detected, response-related emotional processes present in conditions unaffected by inhibition become apparent, and facilitate responding.

Section 4: Visual orienting and value learning

Abstract

The majority of research investigating whether the mechanisms underlying IOR are sensitive to emotion has manipulated the emotional content of the spatial cue employed. This research has generally found mixed results of IOR sensitivity to emotion, and this may be attributed to the variation in emotional saliency these stimuli afford. To rectify this issue, Experiment 11 introduces a novel value learning procedure, in which stimulus value (rewarding, punishing, versus neutral) is acquired in an instrumental learning task. These stimuli are then presented as peripheral cues in a spatial cuing task designed to generate both IOR effects and cuing benefits. A general slowing in response time was observed in the value cue conditions (rewarding, punishing) compared to the neutral cue condition, although this slowing in performance did not influence the magnitude of the IOR effect. However, this slowed responding prevented any benefit of spatial cuing from being observed. Interestingly, this increase in response times when the cue had value was limited to performance in cued trials, with responding in uncued trials remaining unchanged. These results were interpreted within a framework of spatial interference, created by converging and overlapping neural representations of cue value and target location evident in cued trials but not uncued trials.

Chapter 9: Section Introduction

The previous experimental sections of this thesis have examined whether the mechanisms subserving IOR were sensitive to the emotional content of target stimuli. The primary focus of this section is to investigate whether the emotional content of peripherally presented spatial cues influence the generation and measurement of IOR. A secondary interest here was whether emotional cues could also modulate attentional facilitation. The latter topic has previously been discussed in Chapter 2, but recall that emotional (versus neutral) cues produce performance impairments in spatial cuing tasks consistent with difficulties in disengaging attention from their location (Fox et al., 2002; Yiend & Mathews, 2001, see also Koster et al., 2004; 2005).

This introductory section will be organised into three domains. First, I will review the existing studies that have employed emotional cues in tasks designed to generate and measure IOR, and I will demonstrate the inconsistency in the results that have been obtained. Second, I will highlight the importance of controlling the emotional salience of stimuli used in these tasks, a factor that may explain the conflicting reports of IOR sensitivity to emotional cues. Third, I will describe how I will employ a new approach to control stimulus salience, value learning, and examine the literature related to this.

Existing studies employing emotional cues

The typical rationale for employing emotional cues in spatial cuing paradigms has been to explore whether the emotional value of those cues influence engagement and disengagement processes of visual orienting. Recall that if emotional cues influence target responding on cued trials, this reflects the effect of emotion on engagement (i.e., attracting visual attention). Conversely, if emotional cues influence responding in uncued trials, this reflects the effect of emotion on disengagement (i.e., holding visual attention). In tasks designed to generate IOR, the logic is slightly different (although cued and uncued RTs are still analysed as a function of cue valence). Emotional cues may hold attention to their location, preventing disengagement, and no accumulation of inhibition (assuming IOR is generated by the withdrawal of attention from cued locations). Therefore, the traditional slowed responding to targets at cued locations would not be observed, with cuing a location potentially benefiting target detection as a consequence. In the case of non-emotional cues that do not hold attention, the disengagement of attention will occur normally, enabling the accrual of inhibition and slower responding to targets presented at cued than uncued locations.

Here I will discuss the five key studies that have employed emotional cues in a spatial cuing paradigm to observe their effects of emotion on the generation and measurement of IOR. A summary of all the methodological differences between the experiments described here is presented in Appendix B to elucidate the diversity in the approaches to studying this topic. Note that the initial studies exploring the sensitivity of IOR to emotional cues were driven by anxiety researchers, employing the spatial cuing paradigm to probe whether attentional biases to threat-relevant information in anxiety reflect an attentional engagement or disengagement deficit.

IOR is sensitive to emotional cues

Yiend and Mathews (2001) explored whether spatial cues varying in threat value would modulate indexes of visual orienting between anxious and non-anxious participants. Here, IAPS (Lang et al., 1995; 2005) images were employed as spatial cues, independently pre-tested to determine their threat value (high, mild, not threatening; 60 of each type). After onset, cue stimuli remained on the screen throughout the trial sequence (2000 ms), and a target that required a discrimination response was then presented at the cued location. The target was always an arrowhead pointing up or down, and this discrimination response was based on the direction of the arrow target. A significant interaction between cue valence and cue validity was found. Both high and low anxious participants showed an equivalent IOR effect in conditions employing non-threatening spatial cues. However, no IOR effect was found in conditions employing threatening cues. Moreover, this absence of IOR was not affected by anxiety or the strength of threat value (high, mild) of the cue image. Analysis of response times revealed that target discrimination responses were unaffected by cue content in cued trials. However, responding was slower in uncued trials containing threatening cues than non-threatening cues. These results were used as evidence to support the notion that threatening cues result in a delay in the disengagement of attention from their location.

Converging evidence to support a disengagement deficit hypothesis in response to emotional cues diminishing IOR was provided by Fox et al. (2002). Here the cues were schematic faces varying in emotion (angry, happy, neutral; a single exemplar of each emotion) and were presented for 300 ms. Target stimuli required a localisation (left, right) response upon onset (here the SOA was 960 ms), and participants were categorised as being high or low anxious. Again, a significant cue valence and cue validity interaction was found, which importantly did not interact with anxiety level. IOR magnitude was smaller (-2 ms) and non-significant in trials containing angry face cues, in contrast to trials containing happy (-19 ms) and neutral (-14 ms) face cues. No separate analysis of cued and uncued trials was reported, making it difficult to determine the underlying source of this IOR abolition. However, visual examination of this data (Figure 18) suggests the effect may have been mediated by faster responding in valid locations (i.e., cued trials), particularly in the high anxious participants. The authors concluded that the disruption to IOR increased attentional dwell to the angry faces.

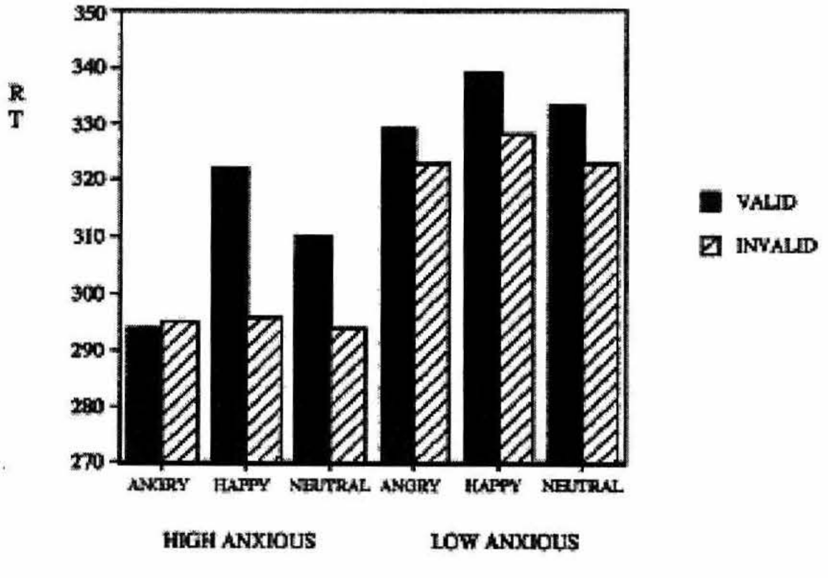

Figure 18. Mean response times as a function of trial type, emotional cue content, and anxiety level reported in Fox et al. (2002; Experiment 2). Note the variability in performance in valid (cued) trials in contrast to invalid (uncued) trials.

An additional experiment reported by Fox et al. (2002) substituted the happy face cue with a jumbled face cue, which was composed of the features of the angry face. Further, participants were also subjected to a mood induction procedure to increase state anxiety. However, this mood manipulation was only successful in the high anxious group. Consistent with their previous experiment, IOR was influenced by the emotional content of the cue, although this interaction was limited to high anxious participants. In this high anxious group, IOR was only significant following a neutral face cue (-19 ms), but was abolished in conditions containing angry (+3 ms) and jumbled (-1 ms) face cues. Finding that jumbled face cues eliminated IOR was somewhat surprising, and the authors propose that low-level features of the angry face present in the jumbled face (specifically the eyebrows) and the ambiguity in expression may be responsible for this result. Participants low in anxiety showed an equivalent IOR effect across the three cue types. Again no analysis of cued and uncued response times was reported, but visual examination of the data (Figure 19) may provide some clues to the source of this IOR effect deterioration.

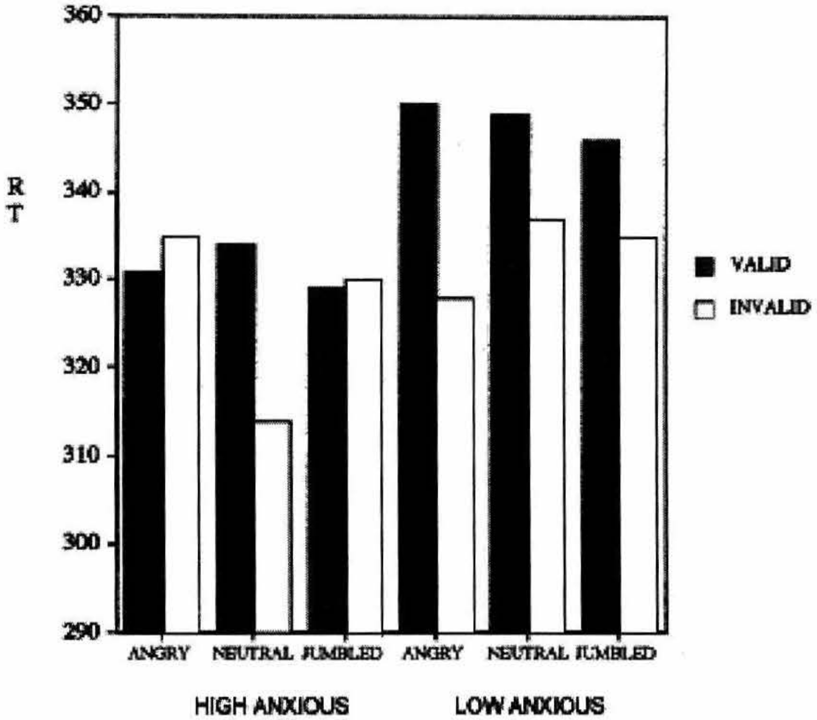

Figure 19. Mean response times as a function of trial type, emotional cue content, and anxiety level reported in Fox et al. (2002; Experiment 3). Note the variability in performance now in invalid (uncued) trials in contrast to valid (cued) trials, particularly in the high anxious group.

In high anxious participants, threat-relevant (angry and jumbled faces) cue content appears to slow responding in uncued (invalid) trials. Note that this potential modulation of uncued trials by threatening cues is consistent with Yiend and Mathews (2001), but is in the opposite direction to the apparent modulation of performance in cued (valid) trials by these cues in their preceding experiment. Nevertheless, this interpretation of the data from Fox et al. (2002) is primarily speculative, and would require statistical verification.

In both these studies (Fox et al., 2001; Yiend & Mathews, 2002), IOR was abolished in response to emotional cues, and (with the exception of the second IOR experiment of Fox et al., 2002) was an effect present in both high and low anxious participants. This is an important point because subsequent research has typically interpreted these findings as evidence that only anxious participants show IOR sensitivity to emotional cues in these tasks, when instead the effect was manifested in participants regardless of anxiety level.

IOR is insensitive to emotional cues

More recent research has demonstrated that the IOR effect does not change between conditions employing emotional and non-emotional cue stimuli. Stoyanova et al. (2007) presented fearful and neutral faces (sourced from Ekman & Friesen, 1976, and Matsumoto & Ekman, 1988; 36 exemplars of each), as well as scrambled luminance patches, as peripheral spatial cues (300 ms presentation). After a 900 ms SOA, a target localisation response was required. The magnitude of IOR was unaffected by cue content, and even when multiple SOAs (500, 1000, 1500 ms) were included to examine any potential time course contribution, IOR was still unaffected by emotion. These null effects were also found if a central re-fixation cue was presented after cue onset, as well as when no re-fixation cue was present and an endogenous shift to central fixation from peripheral cue location was required. These findings were used to support the hypothesis that the mechanisms underlying IOR are blind to the emotional content of visually presented stimuli.

Further support to the notion that the IOR effect is indifferent to emotional cues was provided by Lange and colleagues (2008). Here, spatial cues were either social (angry face, happy face, neutral face; one male and one female exemplar) or non-social (spider, butterfly, cross; one exemplar of each), presented prior to a target which required a detection response. Short (150, 250 ms) and long (550 ms) SOAs were used, with only data from the latter SOA fully reported (note that IOR effects were also found at the shorter SOAs). Participant selection was also manipulated, measuring IOR effects generated in response to these cues with randomly selected samples, as well as samples pre-determined to be especially sensitive to cue content (spider fearful and socially anxious participants). There were two important findings. First, in randomly recruited participants, IOR was unaffected by the emotional content of the cue (social and non-social). Measures of spider fear did not correlate with IOR effects obtained in the non-social cue condition, and measures of social anxiety also did not correlate with IOR magnitude obtained in the social cue condition. Second, when participants were pre-selected as spider fearful or socially anxious, IOR effects were equivalent between participants pre-selected as non-fearful and non-anxious in respect of the non-social and social stimuli sets employed.

Examination of these studies (Lange et al., 2008; Stoyanova et al., 2007) presents a conflicting account of the measurement of IOR to emotional cues. IOR was unaffected by cue content when levels of fear and anxiety were manipulated as participation criterion, and when these levels were naturally fluctuating in the samples tested. These null findings of cue content on IOR also converge with a previous report by Avila and Parcet (2002). In this study, threatening and non-threatening words (eight of each) were presented as spatial cues, remaining on screen throughout the trial. Participants were again divided into anxious and non-anxious groups. Although SOA (short, long) and tasks instructions (informed of cue location, not informed) were manipulated here, the condition of interest was when the cue was uninformative at the longer (500 ms) SOA: The IOR effect was equivalent following both threatening and neutral cues, and anxiety did not contribute to the magnitude of IOR measured.

Here I have described five independent studies, investigating whether the mechanisms subserving IOR are sensitive to the emotional content of peripherally presented spatial cues. On the one hand, there was evidence to suggest that emotional cues diminish the IOR effect (Fox et al., 2002; Yiend & Mathews, 2001). On the other hand, IOR was also demonstrated as a stable phenomenon, unaffected by cue content and any measurable individual differences (Avila & Parcet, 2002; Lange et al., 2008; Stoyanova et al., 2007). However, there were clear methodological differences across the five studies described above, which may explain the mixture of results reported here. The main differences between each of the studies are presented in Appendix B. I have chosen to focus on four of these methodological differences, and I will discuss each in turn as potential sources of variance in the findings reported here.

SOA. It is unlikely that the variability in SOAs reported across the five studies described above were responsible for the different reports of IOR modulation by emotion. Indeed, IOR was diminished both when a mid-range (960 ms; Fox et al., 2002) and a long-range (2000 ms; Yiend & Mathews, 2001) SOA was employed. In contrast to this, Stoyanova et al. (2007) systematically varied the SOA in their investigations, finding that the time course and magnitude of IOR were unaffected by the emotional nature of the cue. This would suggest that although the SOAs employed were variable, this variability was consistent across the studies described here.

Task. When employing emotional targets, the nature of the task may be important in determining IOR magnitude (Cole, personal communication). The nature of the task also varied between the experiments described above (localisation, detection, and discrimination). However, IOR was abolished in a localisation task (Fox et al., 2002), a task which was also employed by Stoyanova et al. (2007) who found no modulation of IOR by emotional and non-emotional cues. Therefore, it is unlikely that the type of task employed in these studies influences the magnitude of IOR obtained in response to emotional cues.

Cue duration. It was particularly interesting to note the variability in cue duration employed in these tasks, which varied from 100 ms (Lange et al., 2008) to 2000 ms (Yiend & Mathews, 2001). Mogg and Bradley (2006) recently investigated the contribution of exposure duration to attentional biases towards images of spiders in a dot-probe task in high and low spider fearful participants. Spider images were paired with images of cats, and were presented for 200, 500, or 2000 ms prior to probe onset. Attentional biases toward spiders were only seen in the high fearful spider participants when the image exposure duration was short (200 ms). In contrast, there was no evidence of attentional biases between high and low fearful spider participants with longer image exposure durations (500 ms, 2000 ms). These findings suggest that attentional biases toward threat-relevant stimuli are not sustained during longer exposure durations to these stimuli. Perhaps cue exposure duration could explain the differential IOR and emotional cue findings. However, conflicting results were found when both short (100 ms, Lange et al., 2008; 300 ms, Fox et al., 2002) and long (1000 ms, Avila & Parcet, 2002; 2000 ms, Yiend & Mathews, 2001) cue exposure durations were employed. Furthermore, the same cue exposure duration (300 ms) was employed by both Fox et al. (2002) and Stoyanova et al. (2007), again with conflicting results of IOR modulation by emotional cues.

Stimulus salience

The methodological differences described above do not present conclusive evidence that SOA, task employed, or cue duration differentially contribute to the emotional cue content modulations on IOR being present or absent. However, a crucial defining factor in these experiments is the stimuli sets that they employ. Interestingly, only the two studies that show an IOR reduction to emotional cues (Fox et al., 2002; Yiend & Mathews, 2001) report any independent testing of their stimuli to verify their emotionality. Therefore, it is unclear whether the stimuli presented in the studies presenting null effects of emotion on IOR are sufficiently emotional, and this may explain the observed insensitivity of IOR to cue content. Alternatively, the stimuli used across the studies vary in their emotional salience both between experiments (threatening scenes versus an iconic spider drawing) and within experiments, in respect to individual differences in their meaning.

In the experiment reported here, I aimed to control the emotional quality of the stimuli presented as spatial cues in order to investigate whether this content can influence the IOR effect. As described in the introduction to this thesis, one reliable approach previously used to control the emotional salience of stimuli was to employ a classical conditioning procedure. Recall that an otherwise neutral stimulus can be repeatedly paired with an aversive stimulus. Repeated pairings of the two stimuli with time will lead to the neutral stimulus, when presented alone, generating an emotional response typically associated with the aversive stimulus. Stimulus conditioning is advantageous, ensuring stimuli acquire emotional salience prior to the experimental task (Armony & Dolan, 2002). Moreover, conditioning procedures can be individualised, and do not rely on *a priori* assumptions that certain visual images (including photographs of snakes and angry or fearful faces) are inherently threatening.

In this next experiment, an instrumental (or operant) conditioning procedure was instead used, termed *value learning*, where participants learn to associate the selection of a stimulus with a specific response outcome (e.g., Pessiglione, Seymour, Flandin, Dolan, & Frith, 2006). This response outcome can be defined in terms of valence (rewarding, punishing, no outcome) as well as probability (high, low) of occurrence. Therefore, the stimulus has an *expected value*, defined by the learned (past) associations of selection and outcome. Thus, when that stimulus is re-encountered after the value learning procedure, this prior learning experience determines its saliency. The critical advantage here being that objective measures of experience have been obtained during the learning procedure, and stimulus saliency is precisely controlled. This same objective measure and control cannot be obtained for emotional images or even classically conditioned stimuli.

Value Learning

Learning the expected value (EV) of a stimulus is not only a potential tool to control stimulus saliency in the lab, but may also reflect existing neural mechanisms that enable prediction of outcomes prior to stimulus selection. Neural codes of EV provide a common unit of currency (Montague & Berns, 2002) for the representation of multiple stimulus selections and their outcomes, enabling efficient comparisons to be made between stimulus selection options. This may be an important principal in decision-making behaviours in determining the optimal choice of action in a given situation (Montague & Berns, 2002; Pessiglione et al., 2006). Reward prediction in particular seems to drive behaviour in animals, and the neurotransmitter dopamine has been repeatedly associated with rewarding stimuli (Schultz, Dayan, & Montague, 1997). Indeed, anticipation of reward and not punishment is associated with increasing activity in the nucleus accumbens (NAcc) of the ventral striatum, a structure intrinsically linked with dopamine (Knutson, Adams, Fong, & Hommer, 2001; see also Knutson, Taylor, Kaufman, Peterson, & Glover, 2005, for NAcc and an additional role of the medial prefrontal cortex).

Previous studies employing value learning paradigms have been primarily interested in the neural circuitry underlying the acquisition of stimulus value. The orbitofrontal cortex (OFC) in particular has been identified as important in representing learned value (O'Doherty, 2004). In one study (Gallagher, McMahan, & Schoenbaum, 1999), the ability to maintain and update stimulus value was investigated in rats with and without OFC lesions. A classical conditioning procedure was employed where first rats learned to associate the onset of a light stimulus with the provision of food. A second stage involved devaluing the food by pairing it with a noxious injection. A final testing phase measured appetitive behaviours during the onset of the original light stimulus, in the absence of any food. A reduction in appetitive behaviours was observed in rats with intact OFC. However, no such reduction was observed in rats with OFC lesions, suggesting that the value of the light stimulus was not updated from the initial conditioning procedures, and was still responded to as favourable. Therefore, the integrity of OFC seems crucial to updating and maintaining the representation of stimulus value.

Furthermore, activity in the OFC also mirrors activity in the basolateral nucleus of the amygdala during anticipation of reinforcement (rewarding and aversive), suggesting the two structures may be intrinsically linked in determining stimulus value (Schoenbaum, Chiba, & Gallagher, 1998). Indeed the role of the amygdala in processing emotional valence in general (e.g., LeDoux, 1998) would indicate that it is a likely component of the neural circuitry underlying the processing and representation of stimulus value.

These findings together suggest that the neural representations of stimulus value occur at both a subcortical and cortical level, and provide an interesting neural circuitry underlying any potential value modulations of the IOR effect.

The current experiment

In the experiment reported here, I employed value learning as a tool to control and define the EV of visual stimuli, prior to their presentation as cues in a spatial cuing task.

Participants learnt the expected values of a set of otherwise neutral and novel stimuli presented in an instrumental learning task. These values were monetary in nature, specifically, financial gain and loss, which varied in probability of occurrence[10]. The stimuli were always presented in pairs, and participants selected one of the stimuli, receiving feedback on their selection. Valence was kept constant within the stimulus pair, but one of the stimuli was associated with a high probability of outcome, and the other stimulus was associated with a low probability of outcome. Participants were instructed to maximise their earnings, with the incentive that any money made would be given to them at the end of the experiment. Therefore, to maximise earnings in this task, participants needed to learn which stimuli were associated with reward and loss, and learn the probability of selection outcome. To maximise financial gain, selection of high probable gain and low probable loss stimuli would be necessary. After completion of this task, these value stimuli were then presented as spatial cues in a cuing task and their effects on both IOR and attentional facilitation were measured.

One previous study from our lab has employed value learning as a tool to explore whether learned stimulus value influences visual cognition (Raymond & O'Brien, under review). Participants first learned the EV of a set of face stimuli. These faces were then presented with other novel faces as T2 targets in the attentional blink paradigm (Raymond et al., 1992). T1 targets were abstract visual stimuli requiring a perceptual response (constructed of circles or squares), and T2 stimuli were faces requiring a recognition response (old or new face). When there were sufficient resources to process T1 and T2 (employing a long SOA between the two target stimuli), face recognition

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[10] Note that EV can also be defined in terms of magnitude of reward and the delay between selection and reward (or punishment; e.g., Montague & Berns, 2002), but these variables were kept constant in the experiment reported here.

performance was better for faces associated with high probability of outcome than faces associated with a low probability of outcome or faces associated with no outcome at all (neutral). However, when T1 and T2 were presented in close temporal proximity (employing a short SOA between their presentations), faces associated with reward (high and low probable) escaped the AB. In contrast to this, performance accuracy was significantly impaired for faces associated with loss and no value. In this study, reward-related stimuli were prioritised for processing, facilitating their detection under limited capacity conditions where attentional resources were engaged in the T1 task.

Employing this value learning approach enables the adaptive versus reflexive hypotheses of IOR to be contrasted once more. If IOR is truly a reflexive effect, no difference in the magnitude of IOR should be observed when cue stimuli differ in expected value. In contrast, support for IOR as an adaptive effect would be drawn from modulation of the effect by the expected value of the cue stimulus. This adaptive modulation of IOR could be expressed in three ways. First, the mechanisms underlying IOR may be sensitive to the presence of valued stimuli, and the size of the IOR effect could vary in the presence of valued versus non-valued (neutral) cues. Second, modulations of IOR magnitude might be limited to cue valence, consistent with the negativity bias previously reported (Fox et al., 2002; Yiend & Mathews, 2001). Third, changes to the IOR effect may be influenced by valence and probability manipulations, such that only stimuli highly predictive of reward and punishment might influence the magnitude of IOR, being the most salient of the value stimuli. A fourth hypothesis is that IOR itself will be unaffected by cue value, but response time modulations by these value stimuli may be observed. Thus the effect of value on responding will be orthogonal to the manifestation of IOR.

Experiment 11

Experiment 11 was designed to explore whether the learned value of a cue stimulus would modulate the mechanisms subserving IOR and attentional facilitation. If IOR is truly insensitive to the content of the visual scene, then equivalent IOR effects should be observed irrespective of the value of the peripheral cue (Avila & Parcet, 2002; Stoyanova et al., 2007; Lange et al., 2008). However, if the mechanisms underlying IOR are sensitive to cue content, differential modulation of the IOR effect may be observed (Fox et al., 2002; Yiend & Mathews, 2001).

Previous research predicts that the magnitude of attentional facilitation may change as a function of cue value, representative of a disengagement deficit of visual attention (Fox et al., 2002; Yiend & Mathews, 2001). However, this research used emotional stimuli (scenes and schematic faces); cue EV *per se* has not previously been manipulated.

Three experimental phases are reported in Experiment 11, and participants completed all three phases during the experimental session. The first phase consisted of the value learning task, where participants learned to associate face stimuli with predefined monetary values of gain, loss, and neutral (no outcome), which varied in probability of outcome in the former two cases (high, low). In the second phase, these learned faces were presented as peripheral cues in a spatial cuing task, where participants localised a neutral target stimulus. The third phase employed a face localisation task where a learned face stimulus was simultaneously presented with a scrambled face stimulus, and participants responded to the location of the learned face. Effects of value were expected to facilitate speed of responding, consistent with emotional modulations of RTs observed in other tasks (e.g., Brosch & Sharma, 2005; Eastwood et al., 2001; Flykt, 2005; Fox et al., 2000; Öhman et al., 2001). This phase was always presented at the end of the experiment to verify the stability of stimulus value at the end of experimental session. The absence of value effects on performance would suggest that these stimuli lose their acquired saliency (in respect of valence and predictability) over time, and could explain the presence of any null effects of value on performance in the spatial cuing task.

Method

Participants

Thirty-eight experimentally naïve adults (21 females; mean age = 21 years) were recruited as before.

Apparatus and Stimuli

Apparatus and stimuli were the same as before, with the following exceptions. An open circle served as a target (2.58° by 2.58°) in all conditions. Face stimuli presented in the learning task and later as cue stimuli were twelve grey-scale computer-generated male faces (6 male, 3.43° by 3.24°) created using GenHead 1.2 (Genemation Limited, 2002-2004) software. The faces were all equiluminant, and the hair, neck, and teeth were not visible. There were two face exemplars for each value (high gain, low gain, high loss, low loss) and four exemplars for the neutral condition (no value assigned). In the face localisation task, 12 scrambled faces were used. These faces were scrambled from 12 different computer generated faces.

Design and Procedure

Value Learning Task. Participants first engaged in an instrumental learning task with the face stimuli to learn their value prior to the cuing task (see Figure 20). On each trial a pair of faces was presented 2.20° to the left and right of fixation, and remained on the screen until response. Participants were instructed to choose a face on each trial (spatially corresponding to the 'z' and 'm' key), with the aim of trying to make as much money as possible during the experimental session. As an incentive to perform, participants were told that any money they did make would be given to them at the end of the experiment (in fact all participants received £5 at the end of the testing session). Once the chosen face was selected, visual and auditory feedback was provided to indicate the outcome of response (gain, loss, no change). A running total of earnings were also provided in this display. A space bar response was required to initiate each new trial.

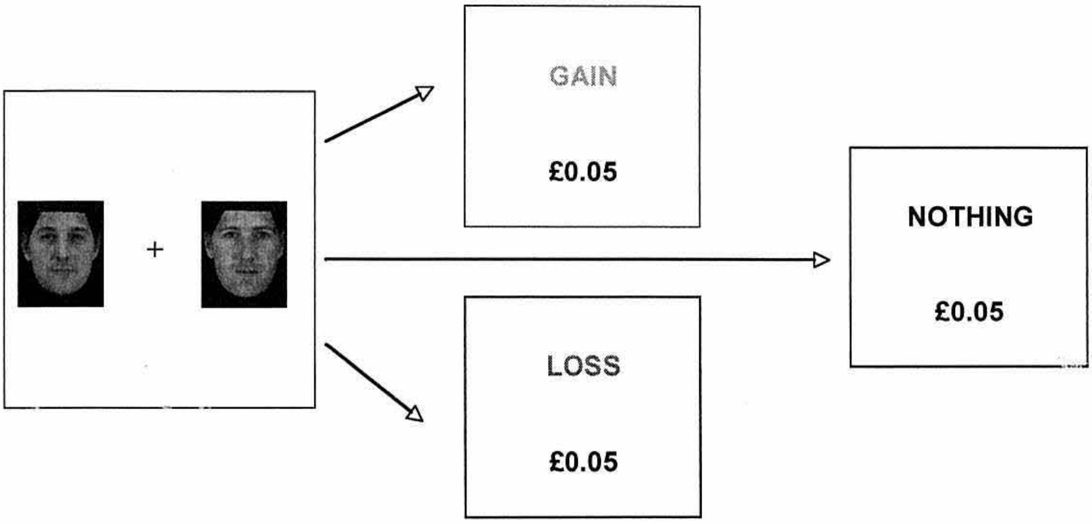

Figure 20. Example trial from the value learning task in Experiment 11. Faces were presented in pairs, and selection of one of these faces resulted in one of three possible outcomes, illustrated above.

There were six face pairs in total, two monetary gain pairs, two monetary loss pairs, and two pairs with no monetary consequences (neutral). Within the gain and loss pairs, one face when chosen had a high probability (80%) of outcome (high gain, high loss), and the other face had a low probability (20%) of outcome (low gain, low loss). Monetary gains and losses were always in the order of 5p. The value assigned to each face pair was counterbalanced across participants, and although the face pairs remained unchanged in the experimental session, their location (left or right of fixation) was randomised from trial to trial. Correct responding was measured as the selection of high gain and low loss faces in their respective pairs, with participant inclusion criterion for learning gain and loss being 65% accuracy or above (described more below). There were 100 trials for each face pair (600 trials total), and learning was measured as a function of performance on face selection in the last 30 trials of each face pair.

Spatial Cuing Task. On completion of the learning task, participants engaged in the spatial cuing task. A typical trial sequence is illustrated in Figure 21.

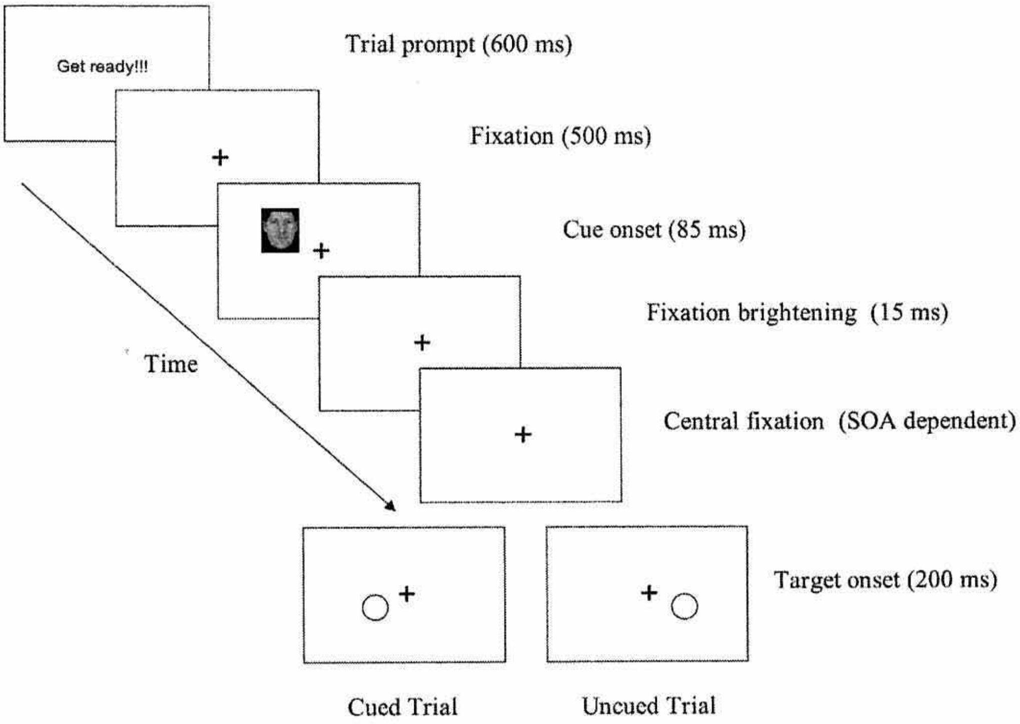

Figure 21. An example of the sequence of trial events in the spatial cuing task employed in Experiment 11. The target to be localised was a circle, presented either at the cued or uncued location below the location occupied by the cue.

Each trial began with an initial 600 ms 'get ready' prompt, followed by a central fixation cross, presented on a blank screen, which remained on throughout the trial. After 500 ms, a cue appeared for 85 ms, either 4.29° degrees left or right of fixation. After cue offset, the central fixation cross brightened for 15 ms. The target was then presented for 200 ms either to the left or right (5.14°) of fixation in either the previously cued or uncued location. The SOA was either brief (100 ms) or long (1500 ms). Cue and target stimuli were spatially separated above and below an invisible horizontal midline through the central fixation cross. When piloting this study, I was unable to generate any benefit of spatial cuing on RT performance at the shorter SOA, unless the cue and target were spatially separate. Presumably the spatial cue masked the subsequent target, impairing its detection (see also Fox et al., 2002), and this may explain the absence of cuing benefits in Lange et al. (2008). The procedure was otherwise the same as described in Chapter 4.

There were 480 trials in total representing each of combination of SOA (100 ms, 1500 ms), cue location (left, right), target location (left, right), and cue content (high gain, low gain, high loss, low loss, neutral). Each experimental session began with eight practice trials where an asterisk was used as a cue to avoid unequal exposures to the value stimuli.

Face Localisation Task. The final component of the testing session consisted of a localisation task (see Figure 22). At the beginning of each trial, a 'get ready' prompt was presented for 1500 ms. This was followed by the simultaneous presentation of two stimuli positioned to the left and right of central fixation for 200 ms. One of the stimuli was a previously seen face from the learning and cuing task, the other was a non-face stimulus (a scrambled face). Participants were instructed to respond as quickly and as accurately as possible to the location of the face using the 'z' and 'm' keys as before. A fixation screen then followed (2000 ms), and an end of trial prompt consisting of a red fixation cross, requiring a space bar response to initiate the next trial, finished the trial sequence.

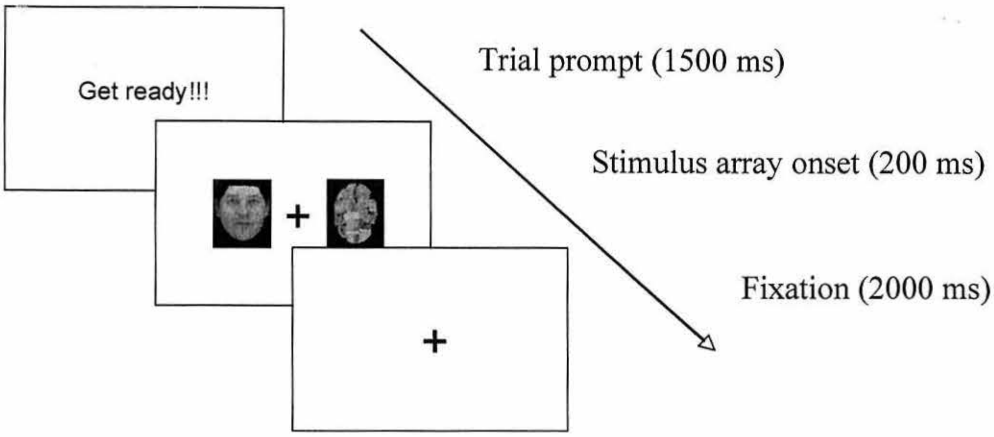

Figure 22. A typical trial from the face localisation task, completed at the end of Experiment 11. The task here was to localise the face target (left, right) as quickly and as accurately as possible.

Each of the 12 value faces were presented six times: Three presentations in the left visual field and three presentations in the right visual field. This led to a total of 72 trials. The experimental session (learning, spatial cuing, and face localisation tasks) lasted no longer than 90 minutes.

Data Analysis

Data from 28 participants were included in the analysis reported below. To be included in this analysis, participants had to meet the learning criteria of 65% for gain and loss face pairs in the analysis of the last 30 trials for each face pair (that is, selection of high gain and low loss faces being at or above 65%). Recall that there were two exemplars of each face valence pair, and learning had to be present for at least one of the face pairs. RTs were therefore only included if they corresponded to the learned face identity.

RT outlier analysis in the spatial cuing task differed from the previous experiments reported in this thesis. A recursive outlier analysis procedure was instead employed, where the mean and standard deviation were calculated for each condition and participant as described before. Upper and lower cut-off boundaries were determined by + / - two standard deviations from the mean, removing RTs falling outside these boundaries. Mean and standard deviations were then calculated on this initially cleaned data, and upper and lower boundaries were computed once more, and outlier RTs removed as a result. This process was repeated five times in total. This procedure along with the removal of incorrect responses (1 %; not affected by cue value, *F*<1) and pre-target release (1 %) responses, led to 10% of trials in total being removed.

Results and Discussion

Spatial cuing task

A global analysis of RTs including the within-subject factors of cue validity, cue value, and SOA, revealed a significant interaction between SOA and cue validity, *F*(1,27) = 16.82, *p* <.001. Therefore, the data reported below is presented for each SOA separately, with cue value and cue validity as the within-subjects factors of the ANOVA analysis.

Short SOA. Target localisation RTs for the short SOA as a function of trial type and cue value are presented in Figure 23. Surprisingly, there was no overall evidence that cue validity, *F*<1, modulated responding in this task. A facilitatory effect of spatial cuing was only observed in the neutral cue condition, *t*(27) = -2.36, *p* = .03, indicating that this paradigm was capable of generating a cuing benefit in the absence of learned cue value.

Interestingly, there was a main effect of cue value modulating RTs in this task, *F*(4,105) = 4.93, *p* <.01, although this did not interact with cue validity, *F*<1.

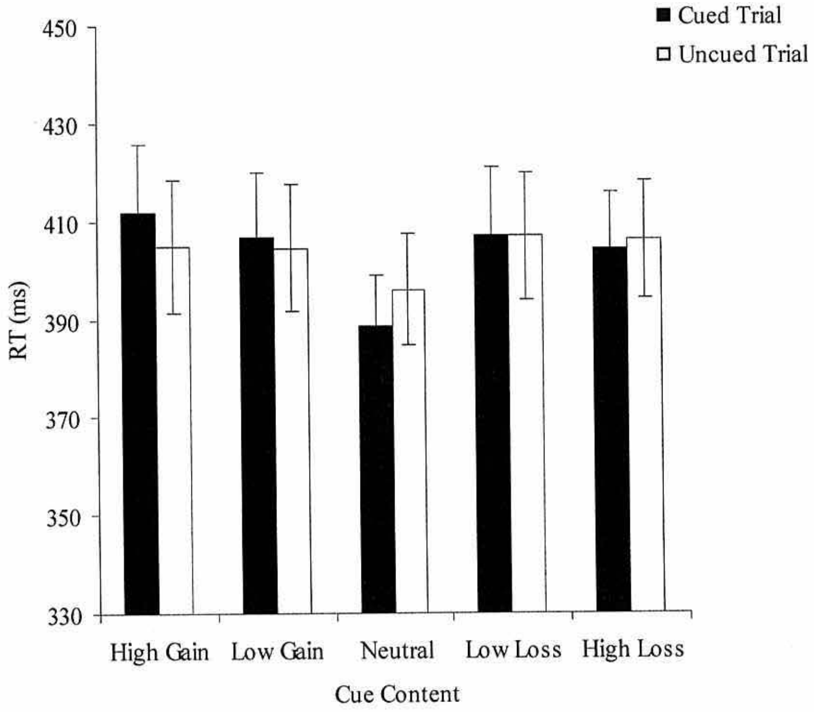

Figure 23. Mean RTs to localise neutral targets presented in cued and uncued locations as a function of the cue value in the short SOA condition of Experiment 11. Vertical error bars are +/- 1 S.E.

To further understand this main effect of cue value and the absence of a cuing benefit, I analysed RTs from cued and uncued trials separately as a function of cue value. Cue value did not modulate responding in uncued trials, *F*(4,108) = 1.20, *p* =.32, suggesting that cue value did not influence disengagement processes from the cued to the uncued location.

In direct contrast to this, RTs in cued trials were significantly affected by cue value, *F*(3,85) = 3.63, *p* <.05. The neutral cue condition was the baseline measure in this task, the cue being familiar but not associated with any value outcome. Therefore, I compared RTs in cued trials preceded by value cues to this neutral cue condition (cued RTs only). Mean cued RTs in trials containing these value cues (high gain, low gain, high loss, low loss) were all statistically slower than the mean cued RT measured in the neutral cue condition (Table 4). These results suggest that the learned value of a cue, irrespective of its valence and probability, significantly slowed responding in cued trials relative to performance in a neutral (no value) condition. This slowing in responding prevented any facilitation effect of spatial pre-cuing on target localisation from being observed.

Table 4. Results from the analysis of cued RTs for each cue value condition compared to neutral in the short SOA condition. Note the corrected p value for this analysis is .0125.

	df	*t*	*P*
High gain cue	27	3.24	.003
Low gain cue	27	2.90	.007
High loss cue	27	-4.03	.0004
Low loss cue	27	-2.74	.011

Long SOA. Figure 24 presents target localisation for cued and uncued trials as a function of cue content at the long SOA in this task. Target localisation RTs were slower at cued than uncued locations, indicating IOR, $F(1,27) = 46.56, p < .001$. There was also a main effect of cue value, $F(4,108) = 3.86, p < .01$, which did not interact with the IOR effect, $F < 1$.

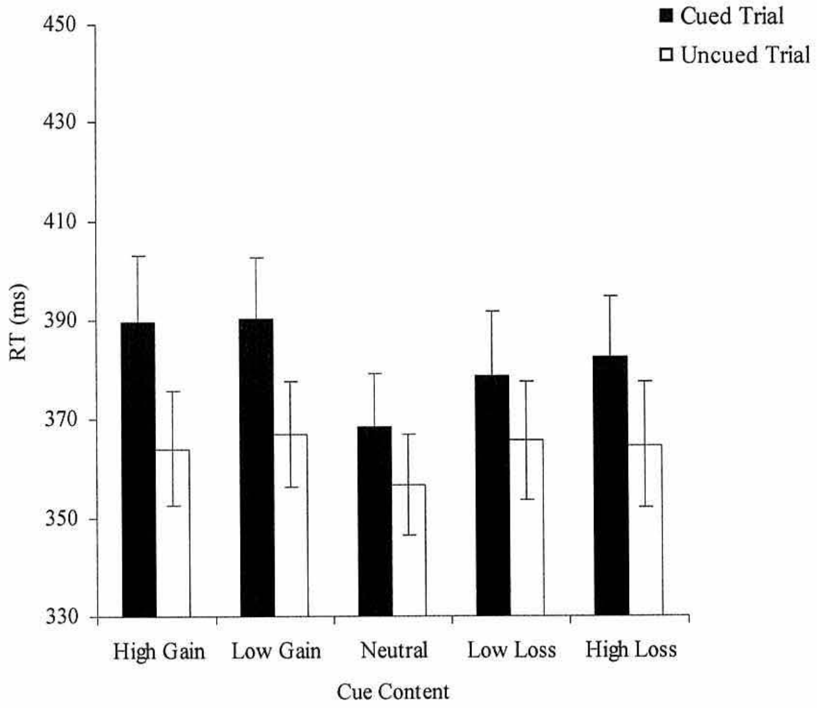

Figure 24. Mean RTs to localise neutral targets presented in cued and uncued locations presented as a function of the cue value in the long SOA condition of Experiment 11. Vertical error bars are +/- 1 S.E.

Consistent with the short SOA data, separate analysis of cued and uncued trials revealed no modulation by value in the latter (uncued) condition, *F*<1. However, responding in cued trials was significantly affected by the learned value of the cue, *F*(4,108) = 5.17, *p* <.01. Again comparison across the mean cued RTs for each cue condition relative to neutral revealed that responding in conditions across all values, with the exception of low loss (which was marginal), were significantly slower than responding in the neutral cue condition (Table 5). Consistent with the short SOA results, this finding suggests that cue value slows target localisation RTs when the target is presented in close spatial proximity to the cue.

Table 5. Results from the analysis of cued RTs for each cue value condition compared to neutral in the long SOA condition. Note the corrected p value for this analysis is .0125.

	df	*t*	*p*
High gain cue	27	3.77	.001
Low gain cue	27	3.97	.0005
High loss cue	27	-3.13	.004
Low loss cue	27	-2.48	.020

Although cue value apparently slows performance on cued trials, interestingly this effect does not appear to interact with the IOR effect. Cues associated with high gain and high loss were the most comparable conditions to previous investigations of IOR and emotional cue interactions, and I entered these values with the neutral cue condition in an additional analysis. IOR was of course present, indicated by slower responding in cued than uncued trials, *F*(1,27) = 28.57, *p* <.001. The main effect of cue value was also still present, *F*(2,54) = 5.53, *p* <.01, modulating responding in this task. However, the interaction between these variables did not reach statistical significance, *F*(2,54) = 2.47, *p* =.09. Nevertheless, I compared the mean IOR effect between the high gain, high loss, and neutral conditions. The mean IOR effect for the high loss condition was -18 ms, which did not differ from mean -12 ms IOR effect in the neutral, *t*<1, or gain, *t*(27)= -1.30, *p*=.21, conditions. The mean IOR in the gain condition was -26 ms, and appeared larger than the neutral condition, *t*(27)= -2.08, *p*=.05 (although corrected, this difference is non-significant, *p*<.017). However, to ascertain whether this was a genuine effect, which required more data points to reach statistical significance, I included data from an additional 9 participants in the gain and neutral conditions; these participants had not shown sufficient learning for loss faces, hence their exclusion in the global analyses. This additional analysis (n=37) failed to reveal a significant difference in the mean IOR effect for gain (-20 ms) and neutral (-12 ms) cue conditions, *t*(27)= -1.43, *p*=.16, and supports the notion that the IOR effect did not change as a function of cue content.

Face localisation task

The purpose of this final task was to ascertain whether value stimuli modulated performance in a simple localisation task at the end of the testing session (that is confirming no depreciation of stimulus value). This experiment appeared crucial during the experimental design procedure in case null effects of value had been observed in the spatial cuing task, and it was necessary to determine whether stimulus value actually exerted no effect on visual orienting and RTs, or whether this was symptomatic of the stimuli losing their value over the course of the experiment. Mean RTs as a function of target value for this task are presented in Figure 25.

A repeated measures ANOVA specifying stimulus value as the within-subject factor was conducted on the data here, revealing a marginal modulation of RTs in this task by stimulus value, *F*(3,85) = 2.58, *p* =.06. To understand this main effect further, I then repeated this analysis comparing valence (gain, loss) to predictability (high, low) as within subject factors, and thus excluding the neutral condition. Visual examination of Figure 25 suggests that RTs in the high gain and high loss conditions may be differentially influencing this performance effect here (high gain slowing, high loss speeding). Indeed there was a main effect of valence, *F*(1,27) = 5.89, *p* <.05, although predictability did not modulate responding, *F*<1. The interaction between these variables also did not reach significance, *F*(1,27) = 3.30, *p*= .08. Performance in the gain condition was significantly slower than in the loss condition, *t*(27)= 3.15, *p* <.017. However, loss performance did not differ from the neutral condition, *t*<1. In contrast, gain performance was significantly slower than performance in the neutral condition, *t*(27)= 2.58, *p* <.017. These data suggest that learned stimulus value was present and able to modulate performance at the end of the experiment.

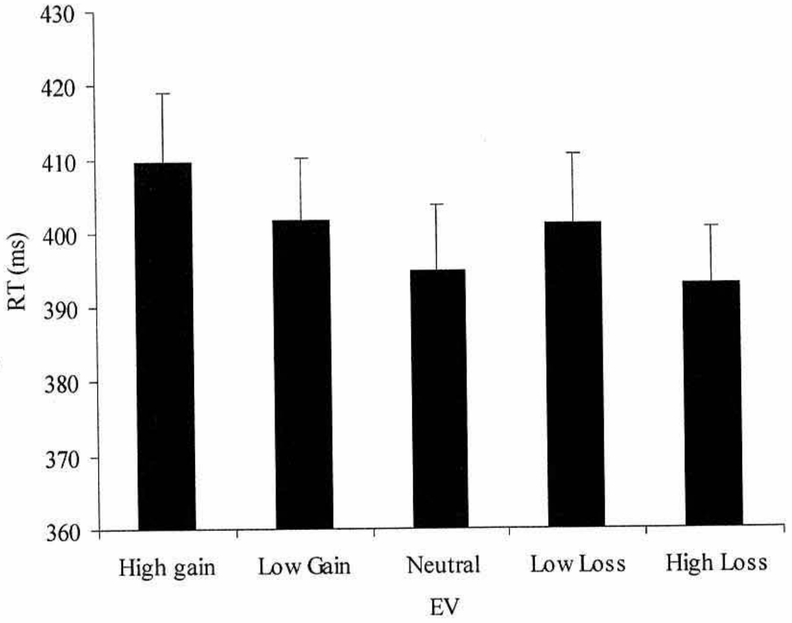

Figure 25. Mean RTs in Experiment 11 for localising face stimuli associated with value. Note the face target was always accompanied by a non-face (scrambled) distractor item. Vertical error bars indicate +/- 1 S.E.

Chapter 10: Section Discussion

Previous research has yielded mixed findings regarding the sensitivity of the mechanisms underlying IOR to the emotional content of peripherally presented spatial cues. However, these studies have employed a variety of emotional stimuli, which may vary in their emotional salience. To resolve this potential confounding variable, a new value learning procedure was employed in Experiment 11 to investigate whether stimuli controlled in respect of their valence and predictability would disrupt the IOR effect. These cues were also used in a shorter SOA condition to explore the effect of cue value on attentional facilitation. Although a general slowing in response times were observed in the value cue conditions compared to the neutral cue conditions, the IOR effect did not change as a function of cue content. Slower responding in the short SOA value cue conditions was also observed, and prevented any benefit of spatial cuing on target localisation performance. Interestingly, at both the short and long SOA, the effect of value was observed as exerting an influence on responding in cued trials, with performance in uncued trials remaining unchanged. In this discussion I will first review the present results and relate them to the current IOR and emotional cue literature. I will then examine neurophysiological evidence that supports a cortical interference interpretation of the results obtained from both the short and long SOA conditions. Finally, I will review two studies that have also claimed to investigate the modulation of spatial attention by monetary reward and punishment, and compare their findings to the results reported here.

IOR to emotional cues

The principal aim of this section was to bring together the contrasting findings of the existing literature exploring IOR sensitivity to emotional cues, precisely controlling the contribution of the expected value of the cue stimuli employed. Recall that both Fox et al. (2002) and Yiend and Mathews (2001) found that the IOR effect was diminished following exposure to threat-relevant spatial cues, in contrast to the IOR effect obtained in response to neutral and positive cues. In the latter study, this effect was mediated by emotional cue effects modulating RTs in uncued trials. No RT analysis as a function of trial type was reported in the Fox et al. (2002) study, and although it is possible to infer the potential locus of their effects from visual examination of the data (Figures 18 and 19), this approach lacks statistical precision. Nevertheless, the results presented here indicated that the magnitude of IOR was not influenced by the emotional value of the cue when it was controlled in respect of its salience (valence and predictability). This finding is consistent with the notion that the IOR effect is insensitive to cue content (Avila & Parcet, 2002; Lange et al., 2008; Stoyanova et al., 2007), and this interpretation is consistent with defining IOR as an RT difference effect: IOR itself is not a mechanism, but reflects the difference in responding to targets presented at previously cued and uncued locations. Further, the absence of any modulation of cue content on the IOR effect provides further support to the reflexivity hypothesis of IOR presented in this thesis.

An alternative interpretation of the data would suggest IOR modulation by cue content, assuming that cued trials are the principal behavioural manifestation of the effect (in respect of slowing), and it is cued trials that are principally affected by cue value.

However, this hypothesis is weakened by the same modulation of cued trials by cue value in the short SOA data. Therefore, it is arguably not IOR-specific cued trials that are affected by cue value, but performance in cued trials in general. To the extent that IOR is an effect and not a mechanism, the data presented here support the notion that IOR is insensitive to the value of peripherally presented spatial cues.

The purpose of employing the value learning condition was to ensure precise control over stimulus value (valence and predictability) to provide some resolution to the mixed findings of IOR sensitivity to emotional cues present in the literature. In the two experiments demonstrating smaller IOR effects in conditions containing threat-relevant cues (Fox et al., 2002; Yiend & Mathews, 2001), ratings data was provided to verify the emotionality of these stimuli, a measure not reported in the studies finding null effects of cue content on IOR. However, even when controlling stimulus value in Experiment 11, the IOR effect remained unchanged.

Although emotional stimuli are typically considered to be motivationally relevant (e.g., Englemann & Pessoa, 2007; Lang et al., 1990; 1997), perhaps value cues are more motivationally relevant than traditional examples of emotional stimuli, and exert a different effect on visual orienting. A recent study by Moritz and Laudan (2007) employed motivational, emotional, and neutral cues in a spatial cuing task to investigate attentional biases in schizophrenic patients and controls. Of the schizophrenic participants, half were displaying symptoms of paranoid delusions. After a short (450 ms) or long (1100 ms) SOA, participants localised a target stimulus following a peripheral spatial cue. Cue content consisted of neutral, anxiety-relevant, or paranoia-relevant images (10 of each category), presented for 400 ms. Therefore, the cue content was motivationally relevant when the cues presented images related to paranoia (e.g., fight scene, hostility in a face), and cue content was emotionally relevant when anxiety inducing images (e.g., snake, spider) were presented. Objects were used as images in the neutral condition (e.g., clock, chair).

The speed of target localisation was the primary interest in this study, rather than any differences in IOR as a function of cue content. Although schizophrenic patients were slower than controls overall, their responding differed as a function of cue type, with faster responding following paranoia-relevant cues (this was true for patients presenting and not presenting delusions symptomatology). This finding was interpreted as evidence that the paranoia-relevant cue had an alerting effect, facilitating target localisation. Moritz and Laudan (2007) report IOR was present in both SOA conditions, but did not analyse IOR as a function of cue content. Therefore, I wrote to the authors, and Stefan Moritz provided the statistical output for this experiment to explore this issue. Although there was a cue content and cue validity interaction, $F(2,112) = 5.58, p < .01$, the three-way interaction between cue content, cue validity, and group (schizophrenic, healthy control) was not significant, $F < 1$. Although response times were significantly influenced by the motivational relevance of the cue facilitating performance in the schizophrenic group, the IOR effect remained unchanged by this cue relevance across the patient and control group. Instead, examination of the descriptive statistics revealed that in general IOR was smaller in trials presenting neutral cues (-5 ms) than when paranoia-relevant (-21 ms) and anxiety-relevant (-30 ms) cues were presented, explaining the significant cue content and cue validity interaction. This greater IOR effect for motivational and emotional cues is surprising because it is in the opposite direction to previous reports of IOR sensitivity to emotional cues (Fox et al., 2002; Yiend & Mathews, 2001). However, it is questionable whether the IOR effect for neutral stimuli (-5 ms) reflects a significant difference between cued and uncued trial responding (and cannot be determined from this output). The potential absence of a significant IOR effect in a baseline condition therefore suggests caution in making any claims about the influence of cue content on IOR in this task. Unfortunately, I was also unable to ascertain from this output whether separate analysis of cued and uncued trials revealed modulation of responding as a function of the motivational content of cues as reported in Experiment 11.

Therefore, it would seem that to fully understand why emotional stimuli in some studies (Fox et al., 2002; Yiend & Mathews, 2001) and not other studies (Avila & Parcet, 2002; Lange et al., 2008; Stoyanova et al., 2007) modulate the IOR effect, a more systematic manipulation of all the experimental factors involved (including stimulus category, SOA, task type, individual differences, and procedural instructions) is required. Indeed a recent study by Waters et al. (2007) generated IOR effects in a procedure where cuing benefits were instead expected. Here, cue valence (negative, neutral, positive) was also manipulated. In high anxious females, the IOR effect was smaller in the negative cue condition than the pleasant and neutral cue conditions. In contrast with this, the magnitude of IOR in low anxious females was larger in the negative cue condition than the positive and neutral cue conditions. No modulation of IOR by cue content was observed in male participants, regardless of their anxiety level. This additional potential factor of gender and anxiety level influencing IOR sensitivity to emotion further serves to demonstrate the multifaceted nature of variables that may contribute to the generation and measurement of IOR.

Value learning effects on attention?

The interesting and noteworthy finding of Experiment 11 was that cue content influenced performance in cued trials, but no modulation of cue content on responding was observed in uncued trials. It is important to note that this finding cannot be explained in terms of forward masking, as the cue and target were spatially separate, and masking effects would also dissipate with the longer SOA condition (Posner & Cohen, 1984).

Nevertheless, this effect of value on responding was particularly surprising because the cost of value on slowing performance on cued trials did not reveal any additional cost or benefit on responding to targets presented in uncued trials. This raises three important points. First, the effect of value cues on performance appears inherently linked to the spatial location in which they were presented, interfering with subsequent processing of target stimuli presented near to that location, but not in an equivalent location in the opposite visual field of space. Second, measuring differential consequences of cue content on cued trial performance is typically associated with the cue exerting its influence on the engagement of visual attention (Fox et al., 2002). However, faster engagement to the cue location would predict faster target localisation responses, in contrast to the slower responding reported here at both short and long SOA conditions. Therefore, these value cues do not seem to differentially attract attention to their location to facilitate responding. Third, the consequences of processing cue value did not affect disengagement processes of visual orienting, evident by a null effect of cue value on performance in uncued trials. This is important because it suggests that the value cues were not encouraging dwell to their location and slowing the disengagement of attention as a consequence.

Taken together, these points suggest that the learned value of a cue stimulus slows target localisation performance, and this would seem an almost independent consequence of visual orienting of attention, restricted to instances when the cue and target are presented in close spatial proximity.

An OFC interpretation

Prior knowledge of the EV of a stimulus is likely to facilitate decision-making (Montague & Berns, 2002; Pessiglione et al., 2006), and may be more informative than emotionally relevant stimuli in guiding behaviour. As described in Chapter 9, value learning is intrinsically linked to (dopaminergic) interactions of specific cortical and subcortical regions (e.g., Knutson et al., 2001; 2005; Pessiglione et al., 2006; Schultz et al., 1997). Therefore, I turned to this neuroanatomical level to understand the results of the present experiment.

Finding that learned value cues slow responding to targets presented in cued trials may be evidence of an interference effect, where processing of value information impedes target processing when both processes occur in a spatially overlapping region. Stimulus value is likely to be represented in the OFC (O'Doherty, 2004), and lesions to the OFC prevent updating of value information (Gallagher et al., 1999). Recent research has also identified OFC involvement in spatial-oriented goal behaviours (Feierstein, Quirk, Uchida, Sosulski, & Mainen, 2006; Roesch, Taylor, & Schoenbaum, 2006). The representation of spatial information and reward value in the OFC may suggest a possible neural substrate of the interference effects observed here by cue value on cued trial performance, and I will discuss two empirical studies which support such a hypothesis.

Roesch et al. (2006) trained rats to select a left fluid well, a right fluid well, or free selection of either well, to receive a reward. Correct fluid well selection was determined by the prior presentation of one of three olfactory cues that indicated which fluid well should be selected for reward. This procedure associated reward with responding to a specific spatial location (left, right). Single-cell recording of neurons in the orbital regions of the OFC accompanied this behavioural task. The noteworthy finding relevant to this thesis was the selective activation of these OFC neurons to the spatial sources (left, right) of reward. Specifically, some OFC neurons only fired for rewards to be delivered in the left food well, with other OFC neurons firing only when rewards were to be delivered in the right food well.

Similarly, Feierstein et al. (2006) trained rats to associate olfactory cues with left or right reward locations as described above, again intrinsically linking space and reward in the behavioural task. Single-cell recordings were obtained from ventrolateral and lateral regions of the OFC in this task. Interestingly, and converging with Roesch et al. (2006), over half of these OFC neurons fired in response to the direction or location (left, right) of the source of reward. Moreover, there was also evidence that some OFC neurons fired in response to both spatial selectivity and reward outcome (the latter determined by recording during error trials). The authors interpreted this finding as evidence that rodent OFC encodes both stimulus value as well as spatial information required to achieve behavioural selection goals.

The findings of these two studies demonstrate that neurons in the OFC code spatial locations relevant to achieving behavioural goals, indicating that neurons in the OFC represent more than just the presence of stimulus value (O'Doherty, 2004). Assuming that rodent OFC neural activity can be analogised to human OFC neural activity, it is possible to speculate as to the nature of the cue value effects observed in the experiment reported here. Recall the effect of cue value was specific to cued trials (irrespective of SOA), slowing response times in contrast to the neutral cue condition. This suggests that the close spatial proximity of cue and target here is important. Perhaps response slowing in cued trials is symptomatic of converging activity in spatially selective neurons of the OFC that process both the location of value information and the location of target information. That is, if value information is spatially represented in the OFC (left, right)[11] and the goal of the task is to respond to the target location (left, right), both processes may be coded by overlapping regions of neurons in the OFC. This may create a conflict between the goal of processing value (or even trying not to process value as a task irrelevant cue) at a spatial location, and the goal of localising the target when it presented at the same spatial location.

If converging goal-related spatial activity in the OFC is responsible for the modulation of responding by cue value, this opens up an exciting new series of studies. For example, to demonstrate the location-based importance of this effect, a task probing object-based effects would be necessary. It would be predicted that if spatial

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[11] Note also that the spatial representation of value is further emphasised in the prior value learning task, which randomly presented stimuli to the left or right of fixation throughout.

representation of goals is important here, the removal of any spatial component of a task should prevent interference by value stimuli. Moreover, employing neuroimaging methods to support an OFC interpretation of this data would also be necessary (and additionally suggests that other cortical regions may be involved in conflict monitoring other than the anterior cingulate that is typically reported; Bush et al., 2000; Yamasaki et al., 2002).

The parietal cortex may also be hypothesised as a potential region important in value and target spatial conflict. The OFC has reciprocal connections to the posterior parietal cortex (Reep, Corwin, & King, 1996), and the parietal cortex has previously been conceptualised as containing a saliency map through which IOR in particular may operate (Vivas et al., 2003; 2006). However, I think this is a less likely candidate as the source of any spatial conflict between value and target locations. Value information is highly salient, and if visual processes are guided by saliency within this map (Itti & Koch, 2000; Itti et al., 1998), target responding would instead be facilitated to the location occupied by the value cue.

Motivation and attention

Employing a value learning paradigm to establish stimulus value *a priori* is advantageous, ensuring precise control over the motivational relevance of these stimuli to perceivers. Moreover, the elegance in the design presented here enabled the EV of visually presented stimuli to be varied on a trial by trial basis, and did not rely on the induction of a psychological motivational state to investigate the consequences of monetary gains and losses on spatial attention. The induction of such a psychological state could result in changes in mood or arousal, which may not be dissociable from motivation. Indeed the principal finding in Experiment 11 that value cues slow responding in cued trials is even more intriguing because this effect is in the opposite direction to what would be predicted by an arousal hypothesis. Typically, if the cues were alerting or arousing, then faster responding in cued trials (as well as uncued trials) would be expected. Therefore, arousal is an unlikely candidate to explain the results of Experiment 11. Of course, arousal is associated with a u-shaped function (Yerkes & Dodson, 1908); therefore, it is possible, although unlikely, that the value cue stimuli employed in Experiment 11 were sufficiently arousing to impair performance. However, the location specificity of the value effects reported here (occurring on cued trials only) also renders arousal an unlikely candidate underlying the effects of learned value reported here. Nevertheless, current research exploring attention and motivation relies heavily on motivational states rather than learned stimulus value, and I will describe two studies relevant to this thesis that demonstrate this point.

A recent report by Engelmann and Pessoa (2007) probed the interaction between motivation and spatial attention. Spatial attention was manipulated in a cuing task, where participants localised a target stimulus following a 70% predictive spatial cue. Motivation was manipulated by informing participants at the beginning of a block that improvements in accuracy and response times would be rewarded with a financial gain in some blocks, and failure to improve would result in financial loss in other blocks. Gain and loss were always paired with a neutral (no) outcome, with there being a 50% probability of reward /punishment, and 50% probability of there being no outcome within each block. Therefore, motivation was manipulated on a block by block basis, with attention manipulated on a trial by trial basis. A semi-transparent target was presented on one of two task irrelevant stimuli (a house or face) to increase the perceptual difficulty of the task. Perceptual sensitivity (d') to locate the target was the dependent measure used here, even though the visual integrity of the target was maintained throughout. Moreover, only perceptual sensitivity to targets presented in the left visual field were analysed and reported. Nevertheless, the principal finding here was that the magnitude of incentive (gain and loss) modulated task performance, with increasing magnitude linearly increasing with perceptual sensitivity.

This modulation of perceptual sensitivity by incentive seemed driven generally by performance in uncued trials rather than cued trials, although increasing task difficulty in a second experiment resulted in motivational effects on cued and uncued trial performance. Therefore, perceptual sensitivity in general was also enhanced in the cued (versus uncued) conditions, although trial type and incentive magnitude did not significantly interact. The authors present these findings as evidence that increasing motivation enhances the mechanisms subserving exogenous visual orienting of attention. However, note that the cue used here was 70% predictive and likely reflects endogenous visual orienting. Interestingly, in the response time data provided in the supplementary materials, only a cuing effect was reported, with no modulation of responding by incentive, and no interaction between cuing and magnitude of incentive. If motivation had genuinely influenced visual orienting of attention, arguably this should have been manifested in both response time and perceptual accuracy data.

A related imaging study by Small and colleagues (2005) also measured performance in an endogenous orienting task, where motivation was manipulated across three separate blocks. In the first (neutral) block, participants completed the cuing task, and their mean response time in non-cued trials (trials where no location was cued by a predictive arrow head) was used to determine a baseline measure of their performance in this task. In a 'win' block, participants were instructed they would earn money for every response faster than this baseline response time. In a 'lose' block, participants were instead instructed that they would lose money for every response slower than this mean baseline response time. In addition to this behavioural measure, fMRI was also employed as a tool to probe the potential neurophysiology underlying any attention and motivation interactions. The behavioural data was limited in finding a significant cuing benefit, and a general speeding in responding in the lose block (specifically uncued trials) versus the win and neutral blocks. Performance in the win block only trended toward being faster than the neutral condition (specifically in cued trials).

The posterior cingulate cortex (PCC) and medial prefrontal cortex (MPFC) showed positively correlated activity with the cuing benefit. This increased activity in the PCC was stronger in win and loss blocks, than the neutral block. Also of interest here was the positive correlation between activity in the right inferior parietal lobule (IPL) and cuing costs. Again, this increased activity of the IPL was greater in win and loss blocks, versus the neutral block. These results suggest that motivational incentives influenced the activity of the regions associated with cuing benefits and costs[12]. Interestingly, visual cortex activity was enhanced in the win and lose blocks in contrast to the neutral block.

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[12] Note also that OFC activation was associated with win blocks, and dorsal ACC activity was associated with loss blocks.

This finding converges with research described in the Introduction to this thesis showing similar increases in visual cortex activity in response to emotional stimuli (Lang et al., 1998; Morris et al., 1998; Vuilleumier et al., 2004). However, in the Small et al. (2005) study, this visual cortex activity was in the absence of emotional stimulus-driven input, suggesting that a common mechanism may be acting in both studies. One potential underlying mechanism here may be arousal, and would explain both the heightened perceptual sensitivity reported by Englemann and Pessoa (2007) and the speeded responding in the behavioural data reported by Small et al. (2005). Moreover, arousal may also be responsible for the enhanced PPC, MPFC and IPL activity during the motivational blocks in the latter study. Therefore, future research is this area needs to clearly dissociate arousal from motivation, and the development of value learning procedures may be one approach to achieve this.

In summary, Experiment 11 was designed to control the emotional value of stimuli presented as non-predictive spatial cues to measure their consequences on IOR and attentional facilitation. Although the IOR effect was not modulated by cue content, responding in cued trials was significantly impaired by value cues in contrast to the neutral cue condition. Similar slowing in performance was also observed in cued trials of the short SOA condition, preventing any cuing benefit. These findings suggest a unique interaction between spatial representations of stimulus value and response, providing an exciting new avenue for future research.

Section 5: Do the mechanisms underlying IOR modulate the emotional evaluation of visual stimuli?

Abstract

In this final empirical section, five experiments were conducted to explore whether the emotional quality of a stimulus is influenced by the object-based and location-based mechanisms subserving IOR. Visual images (emotional and non-emotional) were presented as spatial cues and were later presented for evaluation at locations either associated with inhibition, or at novel locations not associated with inhibition. Novel images were also presented for evaluation to contrast with ratings of previously seen spatial cues. The results provided evidence to support the notion that IOR mechanisms can modulate the emotional evaluation of visually presented stimuli, confirming the important role of IOR in determining stimulus salience.

Chapter 11: Section Introduction

The experiments of this thesis reported so far have explored whether the emotional content of a stimulus in the visual world influences the mechanisms subserving IOR. The rationale for these experiments evolved from the literature showing control over selective attention by emotionally-laden stimuli. Yet I have found no evidence that stimulus-driven emotionality affects IOR, confirming its ballistic nature. Although the absence of emotional guidance suggests IOR acts alone, independently of the emotion system, it seemed fruitful to consider whether the emotion system itself is vulnerable to the effects of IOR. The reasons for this are two-fold. Firstly, emerging research suggests that attentional inhibition may suppress the emotional evaluations of task-irrelevant stimuli, whilst at the same time facilitating the selection of task-relevant information (Fenske & Raymond, 2006). Secondly, IOR may function to reduce the salience of previously attended stimuli and locations (Itti & Koch, 2000; 2001; Itti et al., 1998), and decreased saliency may be manifested in the emotional response system, as well as in the behavioural response system that is classically measured.

Attention and emotion systems both work to prioritise processing of visual information and it would seem maladaptive if these two systems did not co-operate in the guidance and control over behavioural responding. Although there are a vast number of studies exploring the effects of emotion on attention, little research has investigated whether this is a purely uni-directional relationship. Can selective attention instead modulate affective responding? In addressing this question, Raymond et al. (2003)

explored whether the manipulation of prior attentional state could influence the emotional evaluations of otherwise neutral abstract visual stimuli. These stimuli are termed *Mondrians*, and are complex patterns of coloured circles or squares. Participants were presented with a two-item search array, and after target localisation, they were asked to evaluate the previously seen target, the previously seen distractor, or a novel item. This evaluation was made in terms of "cheeriness" or "dreariness", and required participants to select an appropriate rating of each item to be evaluated using a 3-point likert scale. The noteworthy result here was that participants consistently rated previously seen distractors as more negative than previously seen targets or novel items (see Figure 26). This apparent *devaluation* of distractors suggests that the mechanism underlying the attentional suppression of distracting or task-irrelevant stimuli, also suppresses the emotional value of these images. Raymond et al. (2003) replicated their findings in a second experiment, also demonstrating that devaluation effects generalised to different stimuli belonging to the same category as the previously seen distractors in the search task.

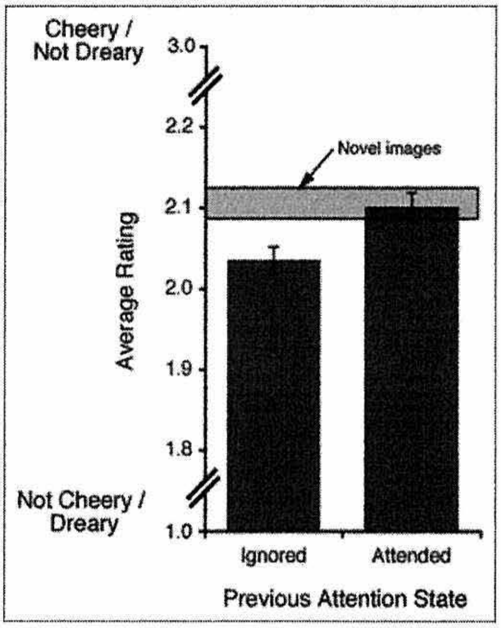

Figure 26. Mean ratings of distractors (Ignored), targets (Attended), and novel images. Note the reduced rating of distractor stimuli. Reprinted from Raymond et al. (2003).

This novel and exciting consequence of manipulating selective attention contradicts the vastly cited findings of mere exposure studies, wherein a more positive emotional evaluation is measured in response to repeated exposure to a stimulus (Zajonc, 1968; 2001). Mere exposure effects are widely considered to be the product of perceptual fluency produced by stimulus repetition. This fluency is thought to create feelings of familiarity. Misattribution of familiarity is then manifested as preference or liking (e.g. Reber, Winkielman, & Schwarz, 1998, although see Zajonc, 2001, for an alternative view). Clearly, the finding by Raymond et al. (2003) that repeated exposure results in more negative evaluations of otherwise neutral stimuli is in opposition to the fluency notion. However, studies of mere exposure have never considered the role of selective attention in stimulus evaluations.

To account for this apparent distractor devaluation effect, Raymond and colleagues (2003) posited a devaluation-by-inhibition account, where the role of selective attention is crucial to determining the fate of subsequently viewed stimuli: Top-down inhibition is applied to task-irrelevant stimuli during the localisation task, and this inhibition is encoded with the identity of the stimulus. Consequently, when that stimulus is re-presented for evaluation, the inhibition is reinstated. This reinstatement of inhibition results in the devaluation of the emotional quality of the stimulus.

Affective devaluation of task-irrelevant stimuli may be beneficial to attentional selection. Top-down inhibition applied to distracting items may serve to reduce their saliency, preventing their future selection (Raymond et al., 2003). Previous examinations of this notion have generally focused on response times and accuracy measures (for example, in negative priming or spatial cuing tasks); however, Raymond et al. (2003) provide the first example of an emotional consequence of inhibition, suggesting reciprocity between the attention and emotion systems.

The hypothesis that devaluation-by-inhibition reduces the salience of task-irrelevant items is of particular interest to this thesis. The visual world can be considered as existing in terms of a saliency map, i.e., a two-dimensional representation of salient objects and locations that make up the current visual scene. The most salient location is determined by maximal neuronal activation in contrast to other sources of competing neuronal activity underlying other less salient locations (Koch & Ullman, 1985). The focus of attention therefore moves from location to location driven by decreasing salience. In recent computational models of visual attention, IOR has been proposed as the mechanism that inhibits the current location of attention, thereby reducing the saliency of that location, and enabling the focus of attention to move onto the next most salient location in the visual scene (Itti & Koch, 2000; 2001; Itti et al., 1998). This converges with the adaptive accounts of IOR, functioning to bias attentional processes to novel locations and objects (e.g., Klein, 1988; Klein & MacInnes, 1999), facilitating stimulus selection (Ivanoff & Taylor, 2006).

If the inhibitory mechanisms underlying IOR function to reduce the saliency of previously attended locations (and objects), and devaluation is a measure of decreased saliency as a consequence of inhibition, it is plausible to hypothesise that stimuli presented at previously attended locations might be devalued compared to stimuli presented at novel locations. This hypothesis was tested in this final series of experiments.

A review of devaluation-by-inhibition

Converging evidence for Raymond et al.'s (2003) devaluation-by-inhibition hypothesis has come from a number of studies that use tasks designed to generate top-down inhibitory effects on stimulus selection processes, and then measuring the subsequent evaluative consequences of this inhibition. Devaluation-by-inhibition has been replicated a number of times now (e.g., Fenske, Raymond, & Kunar, 2004; Fenske, Raymond, Kessler, Westoby, & Tipper, 2005; Goolsby et al., 2008; Raymond, Fenske, & Westoby, 2005), and devaluation effects are measured even when participants are unaware they will complete a subsequent evaluation task (Veling, Holland, & van

Knippenberg, 2007). Neurophysiological correlates of devaluation have also been found (Kiss et al., 2007). Here I will review several studies conducted by Raymond and colleagues, critical to developing our understanding of this phenomenon, and where appropriate, how findings from the IOR literature contribute to the interpretation of the data.

The first replication of the devaluation effect came from Fenske et al. (2004) who were interested in whether prior exposure to distractor stimuli before the onset of a visual search array would result in their devaluation. Watson and Humphreys (1997; 2000) have previously found that visual search was more efficient when a sub-set of distractors were presented prior to the onset of a search display compared to when this 'preview condition' was absent and all distractor items were presented simultaneously with the target. An inhibitory account was provided to explain this preview benefit: Top-down inhibition applied to the distractors in the preview condition marks their position as non-target locations, facilitating performance in the subsequent search task (Watson & Humphreys, 1997; 2000). Fenske et al. (2004) reasoned that this top-down inhibition posited to mediate the preview benefit might also result in the devaluation of previewed distractors. To test this hypothesis, participants completed a visual search task where half the search arrays were preceded by a preview condition, and half the search arrays were not. After each search, a single stimulus was presented for evaluation and this stimulus was either a preview or a non-preview distractor. Consistent with Watson and Humphreys (1997; 2000), search was facilitated when the array was preceded by the preview condition. Moreover, previewed distractors were rated more negatively than non-previewed distractors, replicating the devaluation-by-inhibition effects observed by Raymond et al. (2003)[12]. Unlike the seminal paper though, targets in the search task were never presented for evaluation. Although not crucial to the interpretation of the preview-effect's modulation of search and evaluation, it would have been interesting to compare these data. In addition to the observed devaluation of preview distractors, non-preview distractors may have also been devalued relative to target stimuli. However, this was the first replication of the devaluation effect, illustrating the importance of inhibition to emotional evaluations.

Very recently, Griffiths and Mitchell (2008) explored whether the mechanisms underlying negative priming would also modulate emotional evaluations of visual stimuli. Negative priming refers to the poorer performance (speed and accuracy) in reporting a previously ignored stimulus when it becomes the focus of attention (Tipper, 1985). Griffiths and Mitchell (2008) presented pairs of line drawings, and participants were instructed to report one of the drawings based on a preceding instructional cue (a prime trial). A second pair of drawings was then presented, and again participants were cued to report one of the drawings (a probe trial). The probes to be reported were either the previously reported item, the ignored item in the prime trial, or a control item not present in either trial type. In addition to the negative priming effects measured for response time and accuracy, Griffiths and Mitchell (2008) also found that participants rated previously ignored items as less pleasant than either the previously attended or control condition items. Although these findings support the devaluation-by-inhibition account put forward

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[12] Note that a subset of the participants in this task did not show the preview benefit in their search performance. These participants also failed to show any difference in their evaluation of previewed and non-previewed distractors, confirming the importance of inhibition to both search performance and devaluation effects in this task.

by Raymond and colleagues (2003; 2006), the authors propose a different interpretation to their findings. Instead, Griffiths and Mitchell (2008) explain their results in terms of perceptual fluency. They argue that negative priming interferes with the processing fluency of previously ignored stimuli, and that this interference slows response times, produces errors, and is experienced as feelings of unpleasantness. This is counter to a devaluation-by-inhibition explanation that would instead attribute the reduced pleasantness of ignored stimuli as a direct result of attentional inhibition (see Figure 27).

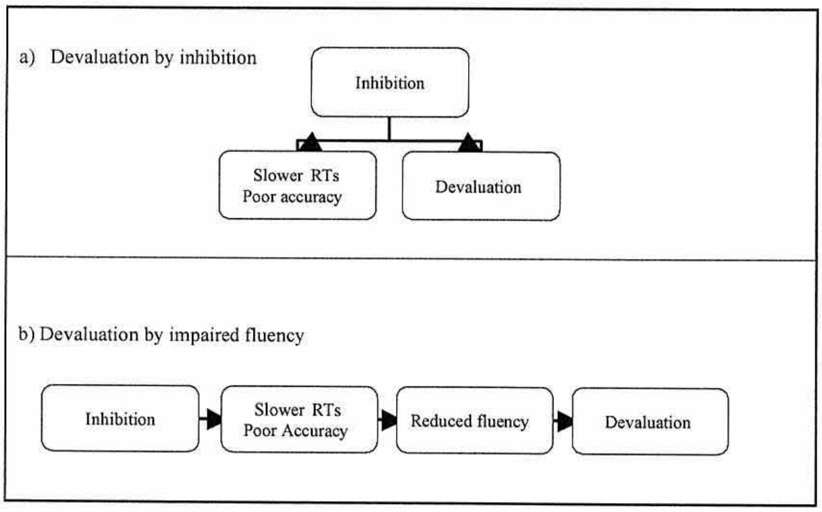

Figure 27. Accounts of devaluation. Raymond et al. (2003) propose parallel effects of inhibition on behavioural and emotion responding (a). Griffiths and Mitchell (2008) advocate a linear modulation of devaluation where inhibition interferes with processing fluency that results in stimulus devaluation (b).

Do the previous devaluation findings (Fenske et al., 2004; Raymond et al., 2003) serve as evidence to support a perceptual fluency account of the consequences of selective attention on emotional evaluations? This would certainly be parsimonious. In situations where objects are fluent, as in repeated exposure, stimuli are favoured.

However, when this fluency is disrupted, via inhibition for example, stimuli are no longer favoured. Considering the seminal devaluation article alone (Raymond et al., 2003), this fluency explanation falls short. Non-fluent items (i.e., the novel items) were rated more positively than the previously seen, and therefore fluent, distractor items (Figure 26). Note also that target stimuli were rated equivalently to novel stimuli. A fluency account would predict in this case that repeated exposure to a stimulus (i.e., the target) would enhance its perceived fluency and liking, in comparison to the single occurrence of a novel item, essentially being non-fluent. However, no difference between targets and novel items were found. Further evidence to negate the role of fluency as an explanation of devaluation effects can be drawn from the preview-search data collected by Fenske et al. (2004). Previewed distractors were devalued, in contrast to non-previewed distractors, even though these stimuli were seen for longer, encouraging fluency (e.g. Reber et al., 1998). Consequently, it seems unlikely that a fluency account can explain the existing findings presenting devaluation effects.

The devaluation-by-inhibition hypothesis postulates that top-down inhibition is associated with stimulus identity and / or location, and when that stimulus is re-presented, the inhibition is reinstated, suppressing emotional value. Evidence that inhibition can be encoded with object identity comes from negative priming studies (e.g. Tipper, 1985), and also from studies of object-based IOR (Morgan et al., 2005; Morgan & Tipper, 2007; Tipper et al., 1991; 1994; 2003). Specifically, Tipper et al. (2003) demonstrated that it was possible to extend the longevity of IOR from seconds to minutes using a stop-action task. Participants were presented with pairs of faces, with the identity of one of the faces in the pair being associated with a stop-action cue (i.e., to withhold responding). When targets were later presented for detection, responding was slower to targets superimposed over faces previously associated with the stop-action cue. These results suggest that the cue to withhold responding was encoded with the identity of that face, and when the face was presented a second time, the inhibition was reinstated, slowing responses (up to 13 minutes post-cue onset in some trials).

Long-term IOR effects using face stimuli prompted Fenske et al. (2005) to explore whether face stimuli associated with inhibitory cues would subsequently be devalued in a similar task. Again, pairs of face stimuli were presented together, and one face in each pair was cued to indicate whether participants should respond to the cue location (a go trial) or to withhold responding to the cue location (a no-go trial). After a filler trial, the face pair was re-presented, and participants were asked to choose which face in the pair they thought was either (a) less trustworthy, or (b) more trustworthy. Faces previously associated with no-go cues were rated as less trustworthy than their uncued counterparts, with uncued faces rated as more trustworthy than their cued counterparts. These ratings of decreased trustworthiness are consistent with the devaluation of cued faces, i.e., faces that were specifically associated with a cue to withhold responding. This was also the first demonstration that top-down inhibition has consequences for the social-emotional judgements of meaningful stimuli, in addition to the emotional judgements of less meaningful stimuli previously observed (Fenske et al., 2004; Griffiths & Mitchell, 2008; Raymond et al., 2003).

A final point of interest in this study by Fenske et al. (2005) was that two further ratings were taken using a perceptual response scale. Participants selected which face in each pair they thought was on either (a) a lighter background, or (b) a darker background. In both cases there was an equivalent bias to select the uncued face, suggesting a reluctance to respond to the cued face, consistent with IOR effects (e.g., Klein & Taylor, 1994). This finding is especially important because biases to select the uncued face when making social-emotional judgements only occurred when participants selected a face that was 'more trustworthy'. When selecting a 'less trustworthy' face, any response bias was overcome to select the face associated with the no-go cue. This experiment in particular suggests a role for IOR in the modulation of emotional evaluations of visual stimuli.

IOR, as well as inhibition more generally, can be encoded in both object and location-based frames of reference as discussed in the introduction to this thesis (e.g., Posner & Cohen, 1984; Tipper et al., 1991; 1994). An interesting question is how these two frames of reference contribute to devaluation effects. Raymond, Fenske, and Westoby (2005) investigated this notion using a complex visual search task. After each search array, participants rated either a previously seen target or a previously seen distractor item (Mondrians). These items to be rated were presented in either the same location they had occupied during the search task, or in a central location. The central presentation of items to be rated removed any modulation of evaluation by location-based processes, allowing purely object-based processes to be examined. Consistent with the devaluation-by-inhibition hypothesis, distractors presented in their original search locations were devalued in contrast to targets, replicating the previous findings of Raymond and colleagues (Fenske et al., 2004; 2005; Raymond et al., 2003). However, distractor items presented centrally for evaluation did not differ from evaluations of centrally presented target stimuli, failing to show any consequence of inhibition on evaluation. At first glance, these results suggest a role for purely location-based inhibition modulating emotional evaluations. However, in the previous devaluation studies, encoding of distractor identity has been crucial in supporting the devaluation-by-inhibition account. For instance, Raymond et al. (2003) presented stimuli in new locations for evaluation and found robust devaluation effects. Devaluation of previously cued faces found by Fenske et al. (2005) also depended upon encoding stimulus identity with the inhibitory cue to withhold responding. Therefore it seems unlikely that location-based processes act alone in mediating devaluation effects.

A more sensitive measure to examine any contribution of object-based effects was then adopted by Raymond et al. (2005) where the proximity of each distractor item to target item was factored into their analysis. Target-proximity effects in other behavioural tasks have suggested that regions of inhibition may be stronger nearer to the target stimulus than further away, presumably as stimuli nearer to the target produce a greater interference effect on target detection (Caputo & Guerra, 1998; Cave & Zimmerman, 1997; Cutzu & Tsotsos, 2003; Mounts, 2000). Indeed Raymond et al. (2005) found that distractor evaluations, when presented in both central and original search array locations, were modulated by their distance from the target. Stimuli near to the target were evaluated more negatively than stimuli which were presented further away from the target during the search task, converging with this notion of a region of inhibition surrounding target stimuli (e.g., Caputo & Guerra, 1998; Cave & Zimmerman, 1997; Cutzu & Tsotsos, 2003; Mounts, 2000). This finding is particularly important because it confirms the role of an object-based contribution to emotional evaluations in this study: Distractor identity had to be encoded at some level for target-distractor proximity effects to be evident in the evaluations of centrally presented distractors. Further, in a third experiment, this proximity effect was replicated, and in fact more pronounced, when using more meaningful distractor stimuli (faces as opposed to Mondrians). Encoding image identity was probably less demanding owing to the superior expertise humans are believed to have with faces (e.g., Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999), strengthening devaluation effects.

The findings of Raymond et al. (2005) indicate a role for both location and object-based inhibitory processes in determining the emotional value of previously seen stimuli in a visual search task. Location-based inhibition seems the stronger of the two mechanisms in producing devaluation effects; however, encoding object identity also appears important in the manifestation of devaluation. Interestingly, these visual search devaluation findings also converge with studies of object and location-based IOR. Tipper et al. (1994) found larger object-based IOR effects when stimuli were presented nearer to the locations they were originally cued than when presented further away from the initially cued location. Summation of object and location-based inhibitory processes is advantageous, especially in dynamic environments. Indeed Tipper et al. (1994) hypothesise that these mechanisms may compete, with the more dominant process reflecting the needs of the current task demands. In visual search studies where the task is to locate a target amongst a fixed array of distractors, location-based inhibitory tagging is probably more important than object-based tagging, perhaps explaining the stronger location-based devaluation effects observed by Raymond et al. (2005).

In this section of my thesis, I was specifically interested in whether attentional inhibition generated through spatial cuing would modulate the emotional evaluations of visual stimuli. Although IOR has not been directly manipulated or measured in the studies discussed here, there is evidence to suggest an IOR-like mechanism may exist in these tasks (Fenske et al., 2005; Raymond et al., 2006). And as considered earlier, IOR itself may be function to reduce the salience of stimuli in the visual environment (Itti & Koch, 2000; 2001; Itti et al., 1998), and reducing emotional salience may be one way these IOR mechanisms act. In the studies presented here, the consequences of both object-based and location-based IOR effects on stimulus evaluation were measured. As previously described here, it is likely that both object- and location-based inhibitory processes contribute to the previously observed devaluation effects (Raymond et al., 2003; 2005).

A secondary interest was whether emotionally valenced stimuli could be devalued. All the previous devaluation studies have used affectively neutral stimuli (words, line drawings, Mondrians, and faces) showing these stimuli are evaluated more negatively in the presence of inhibition. Does inhibition function to always negate stimulus value, or does it instead suppress ratings toward a mean value? The only way of answering this question is to use stimuli with an inherent emotional value (positive or negative) and measure the effect of top-down attentional inhibition on their evaluation. If a negative stimulus is evaluated more negatively following inhibitory tagging, then this would support the former hypothesis that inhibition functions to negate stimulus value. However, if a negative stimulus is instead evaluated more positively following inhibitory tagging, then it would suggest that stimulus ratings are instead suppressed towards a mean value. An alternative (null) hypothesis may be that the value of emotional stimuli (positive and negative) may remain unchanged following inhibitory tagging, overcoming any top-down modulations of their emotionality in order to maintain their saliency in visual encounters.

Finally, it is worth considering an additional hypothesis wherein value learning would predict greater devaluation effects at the uncued, rather than the cued, location. In cued trials, the cue correctly predicts the location of the target (and the location of the subsequent item to be rated, described in the following methods section). In contrast, the cue does not correctly predict the subsequent target's location in uncued trials. Consequently, the predictive value of the cue may result in more positive evaluations of cue items in cued trials than uncued trials, and thus the devaluation of negative, positive, and neutral items presented at uncued relative to cued locations. Note that this is different from a devaluation-by-inhibition hypothesis, which would instead predict devaluation effects (which may or may not be in a negative direction, dependent upon stimulus valence and the true nature of devaluation) at the cued location.

To investigate these issues, I report five experiments exploring whether the inhibitory mechanisms underlying IOR have consequences for the emotional evaluation of visual stimuli. The basic procedure was the same throughout: In each trial participants responded to the location of a target preceded by a brief spatial cue, and then completed a ratings task. In Experiment 12, I presented items to be rated blocked as a function of stimulus valence (negative, positive) in a between-groups design. In the remaining experiments, stimulus valence (negative, neutral) was mixed within participants. In Experiment 13, I investigated whether any inhibition encoded at the level of the cue would produce devaluation effects in the ratings data. Finally, Experiments 14-16 were designed to measure the emotional consequences of stimuli presented at previously cued and uncued locations, exploring both location-based and object-based inhibitory processes on evaluation.

Experiment 12

Experiment 12 was designed to explore the generation of IOR using emotional images as spatial cues to investigate whether object or location-based processes modulate the subsequent evaluations of these stimuli. Cue items were either spiders (negative) or sweet foods (positive) followed by a simple target (open circle) that required localisation. After target localisation, previously seen cue items or their novel counterparts (items never seen before but belonging to the same category as the cue) were presented in either previously cued or uncued locations for evaluation.

If inhibition is encoded with the identity of the cue, differences in evaluations between cue and novel items may be observed. However, if purely a location-based inhibitory mechanism modulates stimulus evaluations, ratings for cue and novel stimuli would only differ as a function of rate location (cued and uncued). Note also that a value learning hypothesis would predict differences in evaluations between rate locations, but in the opposite direction to a devaluation hypothesis, with ratings of items at uncued locations being more negative than ratings of stimuli at cued locations. Contributions of both location and object-based inhibitory processes in determining stimulus evaluations would be indicated by differences in evaluations between cue and novel items with the added contribution of rate location (cued, uncued).

A difference in the direction of any modulation of evaluative responding by inhibition would depend upon the nature of devaluation effects. If devaluation functions to reduce stimulus value, spiders and food items will be rated more negatively in the presence of inhibition. However, if devaluation instead reflects a mechanism that acts to suppress stimulus value, spiders will be rated more positive, with food stimuli instead being evaluated as more negative. Prior exposure to these stimuli when making judgments about cues may also produce a positive bias in their evaluation, in contrast to novel items, consistent with a mere exposure effect.

Methods

Participants

Fifty experimentally naïve adults (16 males; mean age 22 years) were recruited, and half were randomly assigned to each stimulus valence condition. Participants in the negative cue (spider) condition were low fearful of spiders, assessed by a brief fear of spiders questionnaire (see Appendix C). Any individuals assessed as being high fearful did not participate. Participants assigned to the positive cue (sweet foods) condition were instructed to abstain from eating or drinking anything but water for five hours before the experimental session to encourage a positive affective response to the food stimuli.

Apparatus and Stimuli

The apparatus and stimuli were as described in Chapter 4, with the following exceptions. An open circle served now served as a target (5.2° by 4.8°) in all conditions. Cues and items to be rated were either 120 spider images (6.61° by 6.61°) or 120 food images (6.61° by 6.61°) sourced from the Internet. 80 of these images in each category served as cue items and 40 images served as novel items to be rated. Food images depicted sweet finger foods such as cupcakes, doughnuts, strawberries, and cookies. All images were full colour photographs, and exemplars from each stimulus category are presented in Appendix A. Different spider and food images were used in the practice trials, and no stimulus (spider or food) was presented in more than one trial.

Procedure

The sequence of trial events is illustrated in Figure 28. A "get-ready" prompt was presented at the beginning of each trial for 4000ms. A central fixation cross was then presented on a blank screen, which remained on throughout the trial. After 1000 ms, a cue (either a spider or a food item) appeared for 85 ms, either 3.53° degrees left or right of fixation. After cue offset, the central fixation cross brightened for 15 ms to encourage central orienting. The target was then presented 3.53° to either the left or right of fixation for 200 ms, in the previously cued or uncued location. The SOA was 1500 ms. Participants were instructed to indicate the target's location as quickly and accurately as possible using the appropriate key. The "z" key (left index finger) and the "m" key (right index finger) were used to report target location as being left or right, respectively. Half the participants responded to targets preceded by a negative cue (spider), whereas remaining participants responded to targets preceded by a positive cue (sweet food).

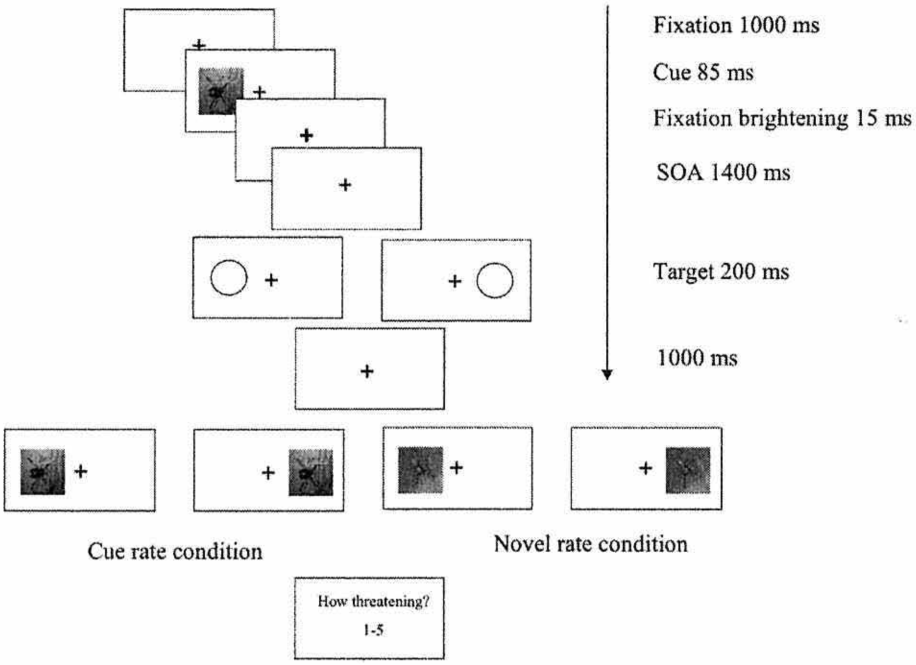

Figure 28. Trial sequence for Experiment 12. Here the task was to evaluate previously seen cue spiders or novel spiders at cued and uncued locations.

After 1000 ms, a second image was presented for 200 ms in the same location as the previous target. This image could either be the same as the previously seen cue, or a novel image. In the negative cue condition, evaluations were made in terms of "How threatening was the spider?" using a 5-point likert scale, where "1" represented "Not at all threatening" and "5" represented "Very threatening". In the positive cue condition, evaluations were made in terms of "How appetising was the image?", where "1" represented "Not at all appetising" and "5" represented "Very appetising". Participants were instructed that there were no correct responses to evaluations, with emphasis being on their initial or "gut" reactions to the stimuli. It was also emphasised that speed of evaluation response was not being measured, but to not spend an extended amount of time deciding upon this value. The trial ended with a space bar response to the onset of a red fixation cross to initiate the next trial.

There were 5 trials for each combination of variables: Cue location (left, right), target location (left, right), and item to be rated (previously seen cue, novel item). This made a total of 80 experimental trials. The cue and target always appeared in randomly determined locations, with the sole constraint that on half of trials the target was validly cued and on the remaining trials the target was invalidly cued. Each experimental session began with 8 practice trials. The experimental session lasted no longer than 25 minutes.

Data Analysis

Only RTs from trials with a correct target localisation response were analysed. Accuracy (98% for both groups) was not modulated by cue valence, $t(37) = -1.34$, $p = .19$. A mixed effects ANOVA using cue validity as a within-subjects factor (cued, uncued), and cue valence (positive, negative) as a between-group factor were performed on the RT data. Ratings were also analysed using a mixed effects ANOVA, specifying rate location (cued, uncued) and novelty (rate cue, rate novel item) as within subjects factors, and stimulus valence (spider, sweet food) as a between-group factor. Note that in all the experiments reported here, unless where otherwise stated, I conducted additional analyses on the ratings data as a function of IOR magnitude (small, large). Although this analysis was not always informative owing to the small number of participants in some cases limiting statistical power, I felt it was worth reporting. Data analysis was otherwise as previously described in Chapter 4.

Results and Discussion

RT Data

Participants were slower to localise targets presented at previously cued locations in contrast to uncued locations, $F(1,48) = 16.86, p < .001$, confirming the presence of IOR. In trials presenting spiders as cues, localisation responses were 395 ms (S.E. = 14) at the cued location compared to 385 ms (S.E. = 15) at the uncued location. In trials instead presenting sweet foods as cues, localisation responses were 395 ms (S.E. = 15) at the cued location compared to 377 ms (S.E. = 15) at the uncued location.

Cue valence did not modulate RTs, $F < 1$, and cue valence did not interact with cue validity, $F(1,48) = 1.21, p = .28$. These findings confirm previous research (Avila & Parcet, 2002; Lang et al., 2008; Stoyanova et al., 2007) and the finding of Section 4 that IOR is blind to cue valence. This observation has now been demonstrated for both social and non-social emotionally charged stimuli in this thesis.

Ratings Data

I first analysed the ratings data collected in response to both positive and negative images. Therefore, it was necessary to reverse scale the spider ratings to match the affective direction of the scale when rating sweet foods to make these two data sets comparable.

Evaluative ratings as a function of novelty and rate location are presented in Figure 29 for spider images, and Figure 30 for food images. Participants rated previously seen cue items as more positive than novel items, *F*(1,48) = 15.12, $p < .001$. This exposure effect did not interact with stimulus valence, $F < 1$, indicating prior exposure enhanced image ratings, irrespective of image valence (positive, negative). Rate location did not modulate stimulus evaluations, $F < 1$, and neither the interaction between rate location and stimulus valence, *F*(1,48) = 2.36, $p = .13$, or the interaction between rate location and novelty, *F*(1,48) = 2.52, $p = .12$, reached significance. The three-way interaction between stimulus valence, novelty, and rate location was also non-significant, $F < 1$.

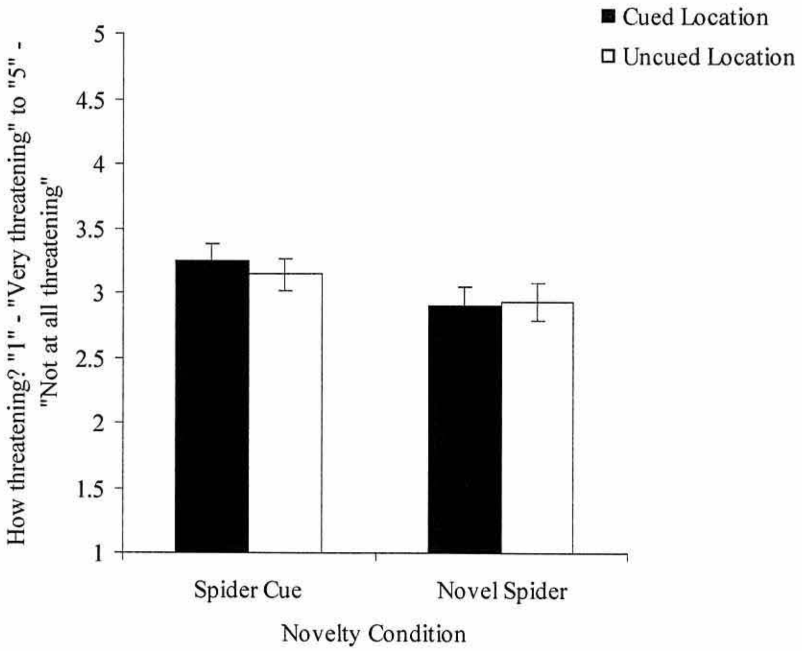

Figure 29. Mean ratings of spider images as a function of novelty condition and rate location. Vertical error bars indicate +/-1 S.E.

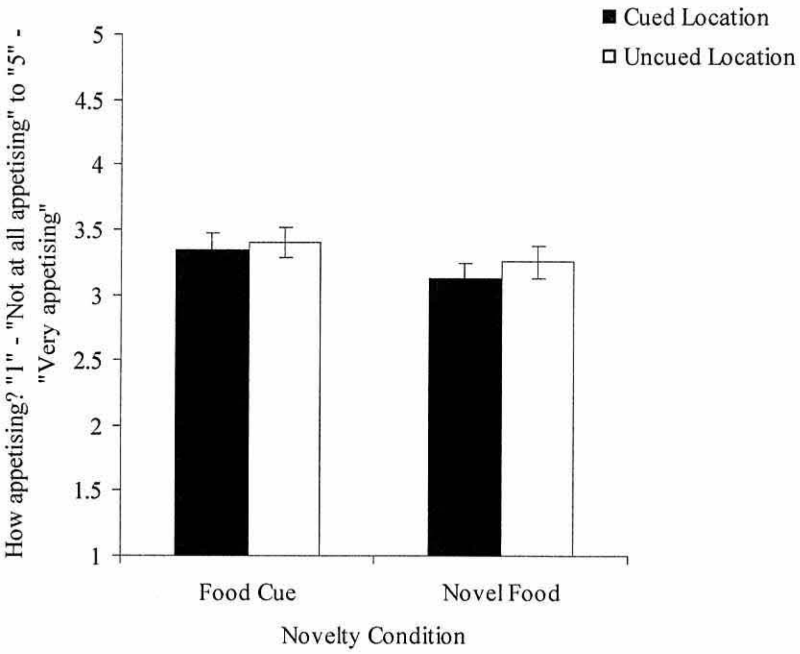

Figure 30. Mean ratings of sweet food images as a function of novelty condition and rate location. Vertical error bars indicate +/-1 S.E.

At first blush, my finding that previously seen spiders were rated as less threatening, and previously seen food stimuli were rated as more appetising, is consistent with a perceptual fluency account of prior exposure to stimuli enhancing liking. However, it was not clear whether the mechanisms underlying devaluation would have suppressed the affective intensity of negative stimuli, making the spiders less threatening (as observed here), or instead resulted in the spiders being rated as more threatening. Therefore, it is unclear from the present results whether the mechanism underlying the more positive evaluation of spider cue items is related to inhibitory processing, or instead reflects perceptual fluency. To explore this notion further, I analysed ratings for spiders and sweet foods separately, examining the contribution of IOR to these ratings. If a relationship could be established between ratings and IOR, this would suggest a contribution of inhibitory mechanisms, supporting a devaluation rather than a fluency account modulating the evaluation of spider cues. This latter analysis also enabled an exploration of whether any contribution of IOR to stimulus ratings was masked by individual differences (not all participants in this experiment showed an IOR effect). Finally, in the spider data, I also repeated this analysis excluding participants who showed no fear response to spiders on the pre-test questionnaire, in case an absence of emotional response to these stimuli created unnecessary variance in the ratings data obtained.

Spider Ratings

I repeated the analysis reported above including only the ratings from the spider condition. Consistent with the only main effect of the global analysis, previously seen spiders cues were rated as less threatening than novel spiders, $F(1,24) = 12.46, p < .01$. As described above, this finding of a positivity bias in ratings to a repeated stimulus event is consistent with a mere exposure effect. However, the suppression of stimulus value may instead indicate encoding of top-down inhibition with cue identity, reflecting the devaluation of cue spiders in contrast to novel spiders. If this difference in novelty ratings is related to inhibition, then we may see modulation of ratings by location too. Although there was no main effect of rate location modulating the evaluation of spider images, $F < 1$, the rate location and novelty interaction trended toward significance, $F(1,24) = 3.27, p = .08$. There was a hint in the data that spider cues presented at previously cued locations were rated as less threatening than spider cues presented at uncued locations, $t(24) = -1.78, p = .09$. However, rate location in no way modulated the evaluations of novel spider stimuli, *t* < 1. Although, not statistically significant, these results tentatively suggest that both location and object-based processes may modulate evaluations here (a purely location-based process would modulate the evaluations of both cue and novel items). Repeating this analysis with the removal of six participants reporting no fear of spiders did not affect the pattern of results. Moreover, removal of participants not showing any behavioural evidence of IOR did not improve any contribution of rate location, *F*(1,17) = 2.38, *p* = .14, or the interaction between novelty and rate location, *F*(1,17) = 3.00, *p* = .10, on evaluative responding here (see Table 6). Although this novelty and rate location interaction term did not reach significance in this latter IOR analysis, spiders cues were rated as less threatening at previously cued versus uncued locations, *t*(17) = 2.37, *p* <.05, an effect absent in the novel spider ratings, *t*<1.

Table 6. Emotional evaluations for spider stimuli as a function of rate location for participants showing IOR (n=18). Note the response scale ranged from "1" – "Very threatening" to "5" – "Not at all threatening" and S.E. is presented in parentheses.

	Cued location	Uncued Location
Spider Cue Rates	3.24 (0.2)	3.08 (0.2)
Novel Spider Rates	2.87 (0.2)	2.86 (0.2)

A final IOR exploratory analysis was to sort the latter group of participants into a large IOR effect group (n=11) and a small IOR effect group (n=7), based on the group mean IOR value (-22 ms). However, this variable did not modulate spider ratings, *F*<1, or interact with rate location and / or novelty, *F*'s<1.

Sweet Food Ratings

Analysis then focused on the sweet foods rating data. Consistent with the global ANOVA, previously seen food cues were evaluated as more appetising than novel food cues, $F(1,24) = 4.22$, $p = .05$. If devaluation results in more negative evaluations of stimuli, then food cues encoded with inhibition should have been evaluated as less appetising than their novel counterparts. In contrast, this data suggests an enhancement of preference toward the food cues, which would be predicted by perceptual fluency. Further, there was no evidence that novelty and rate location interacted to modulate evaluations, $F < 1$. Evaluations of food cues, $t < 1$, and novel food stimuli, $t(24) = -1.28$, $p = .21$, were unaffected by rate location.

I then repeated this analysis excluding data from four participants who did not show a behavioural indication of IOR, with data presented for the remaining IOR participants presented in Table 7.

Table 7. Emotional evaluations for sweet food stimuli as a function of rate location for participants showing IOR (n=21). Note the response scale ranged from "1" – "Not at all appetising" to "5" – "Very appetising" and S.E. is presented in parentheses.

	Cued location	Uncued Location
Food Cue Rates	3.23 (0.1)	3.31 (0.1)
Novel Food Rates	3.03 (0.1)	3.16 (0.1)

Neither the main effect of novelty, $F(1,20) = 3.00$, $p = .10$, or rate location, $F(1,20) = 1.88$, $p = .19$, were significant. The interaction between these variables was also non-significant, $F<1$. The evaluations of sweet food cues, $t < 1$, and novel food stimuli, $t(20) = -1.26$, $p = .22$, remained unaffected by rate location. Division of participants into large (n= 8) and small (n= 13) IOR effect groups also did not reveal any differential effects of IOR on sweet food evaluations, *F*'s < 2.53, *p*'s > .26.

These results present two important findings from the current experiment. First, IOR was successfully generated in both positive and negative cue conditions, and is further evidence that the mechanisms underlying IOR are unaffected by cue valence. Second, the emotional evaluations of sweet food and spider images were enhanced by prior exposure to the stimuli as peripheral spatial cues. However, it is unclear in the latter case whether this enhanced positivity of spiders reflects a consequence of perceptual fluency or inhibitory suppression of affective value. The indication that location-based processes enhanced this positivity bias does not necessarily indicate that this reflects an inhibitory modulation of spider evaluations; it is plausible that both fluency of objects and the location in which they are presented in enhances preference. Indeed, parsimony would predict that the same mechanism underlies both the modulation of spiders and sweets foods. Perhaps processes of fluency and inhibition are occurring in parallel, and in the spiders data this fluency effect is in the same direction as value suppression. This positivity bias at cued locations for cue spiders would also support a value coding hypothesis, with cues correctly predicting target locations rated more positively then cues incorrectly predicting target locations.

The design of this experiment would have benefited from including a neutral cue condition as a baseline to confirm the insensitivity of IOR to cue valence. Moreover, this was a between-groups design where any underlying differences in ratings could have been influenced by group differences. Making comparisons between the two data sets is also problematic because of the differences in affective state, with individuals in the positive condition being food-deprived versus participants in the spider condition who were normally sated, but experienced sustained exposure to negative images. The findings from Section 2 highlight the need for control over affective state when exploring IOR effects.

Further, the ratings questions used here, although stimulus appropriate, would benefit the comparability of ratings analyses if the same response scale was used. Teasing apart the object and location-based effects on evaluation here is also difficult, with rating responses always occurring at the previously attended or unattended locations. In the previous studies by Raymond and colleagues (2003; 2005) stimuli were presented centrally to measure the putative contribution of object-based processes, and this is a necessary condition to be included in the subsequent experiments. A final point to improve in future designs addresses the stimuli used themselves. Although each image was only seen once (with the exception of cues which were repeated in the rating task), stimuli were not counterbalanced between cue and novel conditions, and although there is no *a priori* reason to consider any stimulus differences contributed to emotional evaluations, this should be amended in future designs (and these stimuli should have also been pre-tested to validate their emotionality). These issues will all be addressed in Experiments 13 – 16.

Experiment 13

Experiment 13 was designed to address whether object-based inhibitory processes would modulate the emotional evaluation of visual stimuli. Items were presented in the centre of the screen for evaluation, removing any effects of prior cue or target location. Items to be rated were the previously seen cue, a novel item belonging to the same category as the cue, or a novel item belonging to a different category as the cue. This allowed the following four hypotheses to be tested. First, if inhibition is encoded at the level of the exemplar, then same cue items may be rated differently in comparison to novel items. Second, if inhibition to the cue is generalised to within category items, difference in evaluation may be observed for both cue and novel items belonging to the same category, in comparison to novel items belonging to a different category as the cue. Third, no difference in evaluations across each rate category would suggest object-based processes are not sufficient alone to modulate the emotional evaluation of visual stimuli. Given that these stimuli are presented centrally for evaluation, trial type (cued, uncued) should not modulate ratings. Fourth, a value learning hypothesis predicts that ratings may be more positive when the cue correctly predicts target onset, and this may result in a positivity bias in favour of stimuli evaluated following a cued versus an uncued trial.

There are two further important methodological differences between this experiment and Experiment 12. The first was the change to the stimuli sets used. Here (and in Experiments 14 -16), the cue and rate stimuli employed were either negative (spiders) or neutral (leaves), and were presented pseudorandomly to a single group of participants in each Experiment. Leaf stimuli replaced the previously used sweet food stimuli for three reasons. First, leaves provided a neutral baseline to contrast RTs, IOR magnitude, and evaluative responding with an emotional stimulus condition. Second, leaves co-occur in similar environments to spiders, and in the case of palmate leaves, are visually similar. Third, using leaves instead of sweet foods also removed any contribution of motivational state (i.e., hunger) as a source of variance in this task.

The second methodological difference was a change to the evaluation task instruction. Participants rated both negative and neutral stimuli in terms of pleasantness, allowing direct comparisons to be made between the evaluations for each stimulus valence under the same rating criteria.

Method

Participants

Twenty-five experimentally naïve adults (19 females; mean age 22 years) were recruited as before.

Apparatus and Stimuli

The apparatus and stimuli were the same as previously described, with the following exceptions. An open circle served as a target (5.2° by 5.3°) in all conditions. Cues and items to be rated were full colour photographs consisting of 200 spider images and 200 leaf images (6.9° to 6.9°) sourced from the Internet. A single leaf or spider was present in each image, and was clearly visible. The backgrounds of the stimuli varied in colour. Prior to Experimentation, 18 different participants (10 females, mean age 19 years) were presented with 492 images (245 leaves, 247 spiders) and were asked to rate each image on a 7-point likert scale where "1" represented "Very Positive", "4" represented "Neutral", and "7" represented "Very Negative". From these ratings, 200 images of each stimulus type were selected, removing images where they were considered outliers (for example, rating spider images as very positive) and images of sub-standard quality. Mean ratings for leaves were 3.13 (S.E = .04) and spiders 5.54 (S.E. = .04), and these image ratings were significantly different, $t(199) = -44.04$, $p < .001$.

Each image was only seen once, unless the image was repeated within the same trial as an item to be rated. Images were all counterbalanced across participants to ensure that each image was seen in every cue and rate position. A different set of spider and leaf images were used in the practice trials.

Procedure

The sequence of the trial events is illustrated in Figure 31. The procedure was the same as before with the following exceptions. First, the item to be rated was the previously seen cue, a novel item belonging to the same category as the cue, or a novel item belonging to a different category as the cue. Second, evaluations were made in terms of "How pleasant was the image?" using a 1 – 5 likert scale, where "1" represented "Not at all pleasant" and "5" represented "Very pleasant", enabling the same response question to be used for both stimulus sets.

Third, there were now 10 trials for each combination of variables: Cue type (spider, leaf), cue location (left, right), target location (left, right), and rated item (cue, novel, novel-different category). This made a total of 240 experimental trials. Each experimental session began with 12 practice trials. The experimental session lasted no longer than 60 minutes.

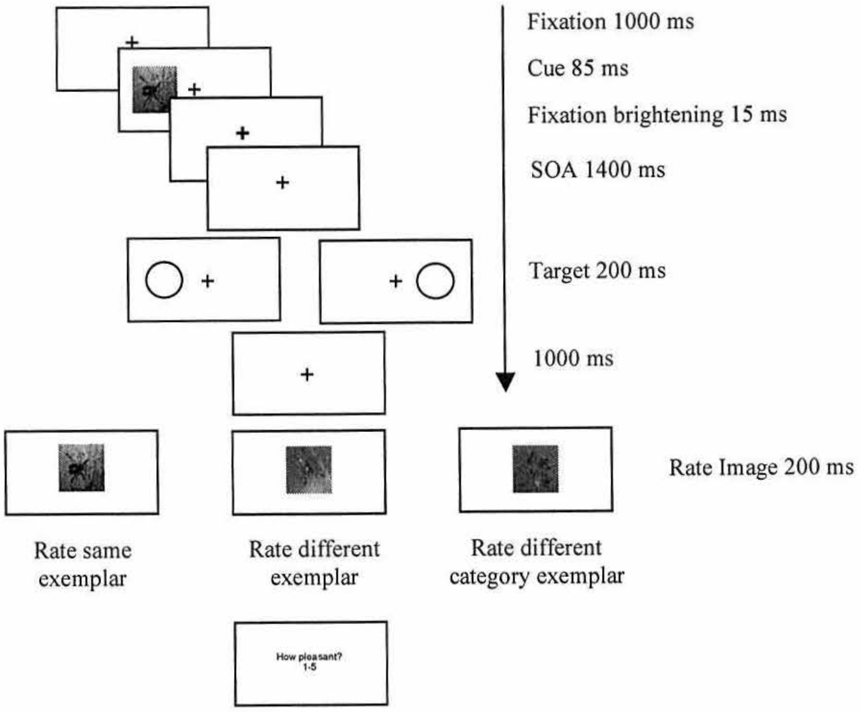

Figure 31. Trial sequence for Experiment 13. Note items to be rated were always presented centrally.

Data Analysis

Error rates were low (<2%) in this task, and were not modulated by cue content, *t*<1. However, the data from one participant was removed owing to poor performance (accuracy being less than 10%). Trials in which participants responded before target onset (3%) were also removed. Examination of the ratings data also revealed that time taken to rate each stimulus was highly variable (up to 13 seconds in one case). Therefore, a lower time limit (200 ms) and an upper time limit (4000 ms) response window was employed to remove any ratings that were anticipatory, or unlikely to reflect initial or "gut" responses to these stimuli, respectively. This led to the removal of 3% of stimulus ratings. On this and all subsequent experiments, rating scores for each participant were first explored using box plots, and identifying any outlier participants who responded outside of the normal distribution of ratings. This led to two participants being removed from the final data set owing to extreme rating responses.

Analysis of RT and rating data were conducted separately. A repeated measures ANOVA specifying cue type (spider, leaf) and cue validity (cued, uncued) was conducted on the RT data. Ratings data was also analysed using a repeated measures ANOVA, specifying trial type (cued, uncued), stimulus valence (spider, leaf), and novelty (cue, novel, novel-different category) as within group factors[13]. Note novel-different category describes the condition where the cue and rate item belong to different image categories (e.g., spider cue, leaf rating).

Results and Discussion

RT Data

Localisation responses were slower to targets presented at cued versus uncued locations, F (1,21) = 14.62, p <. 01, indicating IOR. In trials presenting spiders as cues, localisation responses were 382 ms (S.E. = 13) at the cued location compared to 363 ms (S.E. = 12) at the uncued location. In trials presenting leaves as cues, localisation responses were 378 ms (S.E. = 13) at the cued location compared to 368 ms (S.E. = 13) at the uncued location. Although cue content did not modulate RTs, F < 1, there was a significant interaction between cue content and cue validity, F (1,21) = 4.34, p = .05. In trials where spiders were used as cues the IOR effect was -19 ms (S.E. = 5 ms); however,

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[13] Note that this ratings analysis was also conducted excluding participants not reporting any emotional response to spiders. This did not influence or change any of the main effects or interactions described below.

this effect was smaller and measured at -10 ms (S.E. = 4 ms) when leaves were used as cues, $t(21) = -2.08$, $p = .05$. This is the first time in this thesis that an experiment has shown evidence that cue valence has modulated IOR. To test the reliability of this effect, a meta-analysis of RTs and IOR from the spider and leaf conditions will be reported in the Section Discussion.

Ratings Data

Mean ratings for spiders are presented in Figure 32, and mean ratings for leaves are presented in Figure 33. The first point to note here is that leaves were evaluated as more pleasant than spiders, $F\,(1,21) = 89.41$, $p <. 001$. This demonstrates the participants in this task were employing the rating scale correctly. Secondly, unlike Experiment 13, there was no effect of novelty, $F < 1$, in modulating the evaluation of the images presented here. Even when comparing only cue and novel spider and leaf ratings, there was still no effect of novelty, F's < 1, on ratings, indicating these categories were rated equivalently. Trial type also did not modulate ratings, $F<1$, and there were also no significant interactions between stimulus valence and novelty, $F < 1$, stimulus valence and trial type, $F < 1$, and novelty and trial type, $F\,(2,42) = 1.25$, $p = .30$. However, the third point of interest here was that the three-way interaction between stimulus valence, trial type, and novelty reached significance, $F\,(2,42) = 7.59$, $p <. 01$. I then examined each valence condition separately to understand this interaction.

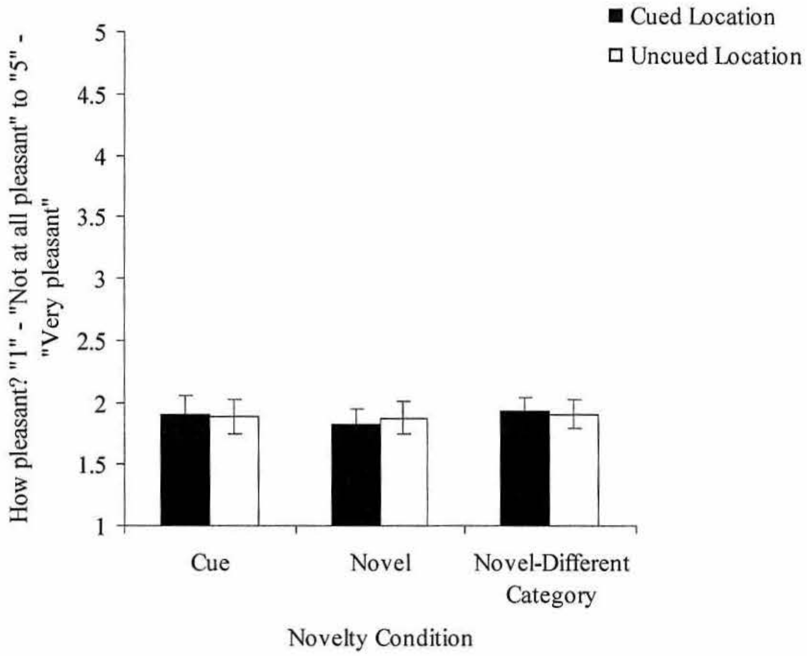

Figure 32. Mean pleasantness ratings for spider images. Note vertical error bars indicate +/- 1 S.E.

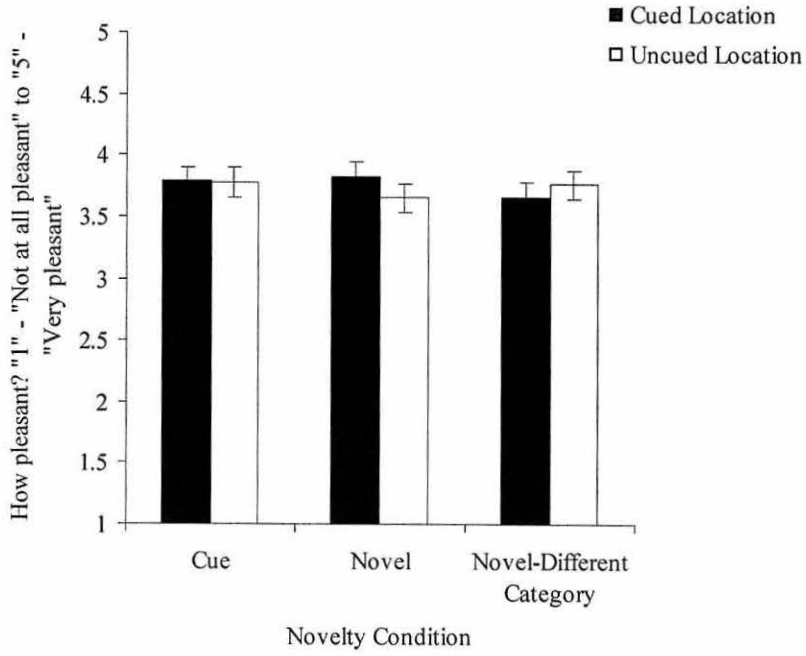

Figure 33. Mean pleasantness ratings for leaf images. Note vertical error bars indicate +/- 1 S.E.

Spider Ratings

Analysis of the spider rating data revealed the main effects of novelty and trial type, as well as their interactions, in no way influenced the evaluation of spider images, *F*'s < 1. To be sure that no object-based effects contributed to spider evaluations, I repeated this analysis including data from only the cue and novel-different category rating conditions (i.e., the cue was a leaf). I found that novelty, trial type, and the interaction between these variables were all non-significant, *F*'s <1, indicating no object-based processes contributed to the modulations of spider evaluations here.

Leaf Ratings

When rating leaf images, there was no main effect of novelty or trial type, *F*'s < 1. However, the interaction between these two variables was significant, *F* (2,42) = 5.63, $p <.01$. This interaction can be understood by examination of the mean ratings of leaf images in the novel leaf conditions (Figure 33). Novel leaf images were rated as more pleasant following a cued trial than an uncued trial, $t(21) = 2.74, p < .05$. However, novel-different category images (i.e., when the cue was a spider) tended to be evaluated less pleasantly following a cued than an uncued trial (although this difference did not reach significance, $t(21) = -1.81, p = .09$). This contribution of trial type to novel leaf evaluations, explains the three-way interaction between stimulus valence, novelty, and trial type observed in the global analysis of ratings data, *F* (2,42) = 7.59, $p <. 01$.

I also isolated the conditions rating cues and novel-different category images to explore putative object-based processes. Importantly, this revealed no effect of novelty, *F*<1, influencing ratings here. Therefore, leaves were rated equivalently, irrespective of any prior exposure. There was also no main effect of trial type, *F*<1; however, a marginally non-significant novelty and trial type interaction, *F* (1,21) = 3.55, *p* =.07, was present in this data. Trial type did not modulate ratings of cues, *t*<1, but ratings of novel-different categories trended towards significance, *t*(21) = -1.81, *p* = .09, as identified in the analysis above.

The results described here suggest that the evaluation of centrally presented visual images are equivalent, regardless of whether they were previously presented as a peripheral spatial cue, or if they belonged to the same or different category as a spatial cue image. This suggests that purely object-based inhibition encoded with the identity of the cue was not sufficient to modulate the emotional evaluations of cue items, or items belonging to the same category as the cue. This was true for evaluations of both negative and neutral images. The only exception to this observation was in the case of novel leaf evaluations where there was a benefit to pleasantness ratings when the trial prior to the rating was a cued trial. This result was not present in the spider equivalent condition, and is difficult to explain. One possibility is that this positivity bias reflects a trial condition where the cue correctly predicted the location of the target, consistent with a positive evaluative outcome predicted by a value coding hypothesis. However, this bias was limited only to the novel leaf condition, and was not replicated further in the other ratings conditions.

A final comment here is that I did not examine stimulus ratings as a function of IOR in this particular experiment. RT measures indexed the summation of both location and object-based inhibition on responding, and therefore it was not possible to isolate a measure of purely object-based IOR here to accurately examine stimulus evaluations as a function of object-based processes. Furthermore, I could not divide participants as a function of their overall mean IOR effect (obtained from spiders and leaves RTs), owing to the unexpected significant difference in IOR between the cue valence conditions. In order to compare object-based (cue rating) and non-object-based (novel-different category) processes, the two ratings categories would have consisted of data obtained from some of the same individuals but also of data from different individuals. This problem did not occur in Experiments 14 – 16, enabling a better understanding of the relationship between IOR and stimulus evaluations to be obtained.

Experiment 14

After determining there were no putative object-based contributions to emotional evaluations in the previous experiment, Experiment 14 was designed to explore whether location-based inhibition would instead modulate stimulus evaluations. Although there may be an object-based component contributing to evaluative conditions involving the cue, the previous null effects of object-based inhibition in Experiment 13 suggests this is unlikely to influence responding.

Therefore, in this experiment items were presented in either the previously cued or uncued target locations for evaluation. Four hypotheses were tested here. First, evidence for location-based modulation of stimulus evaluations would be indicated by differences in stimulus ratings as a function of rate location. Specifically, leaves would be evaluated as less pleasant at the cued location. Spiders might also be rated as less pleasant at these locations, although if the ratings effects of Experiment 12 were correct, spiders may instead be evaluated as more pleasant (reflecting a suppression of affective intensity) when presented at inhibited versus novel locations. Second, if there is an object-based contribution to stimulus ratings, this would be evident by differences in pleasantness ratings between cue and novel items (belonging to the same and different category as the cue). Third, an interaction between object and location-based processes would be evident in rate location modulating cue but not novel stimulus evaluations. Fourth, a value learning hypothesis would predict more positive stimulus evaluations (leaves and spiders) at cued versus uncued locations, regardless of rate condition.

Methods

Participants

Twenty-five naïve adults (17 females; mean age 19 years) were recruited as before.

Apparatus and Stimuli

The apparatus and stimuli were the same as before.

Procedure

The procedure was the same as before with one important exception. Items to be rated were now presented in the previous target location for evaluation, as illustrated in Figure 34.

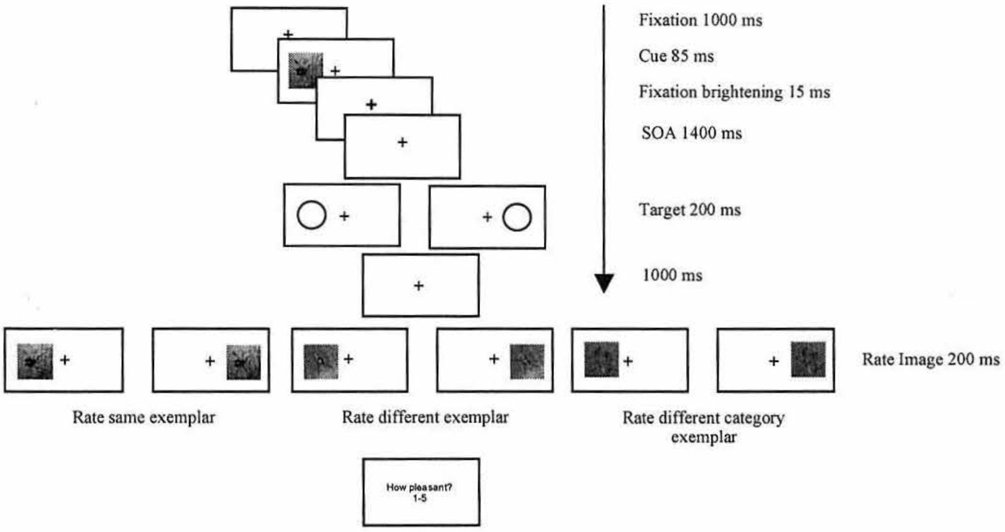

Figure 34. Trial sequence for Experiment 14. Note items were always rated in previous target locations.

Data Analysis

Only data from trials in which participants correctly detected the target were analysed. Error rates were again low (2%), and there were no differences in errors made between negative and neutral cue trials, $t<1$. Less than 1% of trials were removed owing to pre-target responding. Three participants were removed owing to extreme rating responses, and 2% of ratings were removed owing to outlier timing when making ratings. A further two participants were removed from the analysis owing to slowed responding in the cuing task.

Analysis of the RT data was the same as before. Analysis of the ratings data was again conducted using a repeated measures ANOVA, but instead specifying image type (spider, leaf), novelty (cue, novel, novel-different category), and rate location (cued, uncued) as within subject factors[14].

Results and Discussion

RT Data

Participants were slower to localise targets presented in previously cued locations than targets presented in uncued locations, confirming the presence of IOR, *F* (1,19) = 28.05, $p <. 001$. In trials presenting spiders as cues, localisation responses were 377 ms (S.E. = 19) at the cued location compared to 357 ms (S.E. = 19) at the uncued location. In trials instead presenting leaves as cues, localisation responses were 373 ms (S.E. = 18) at the cued location compared to 360 ms (S.E. = 17) at the uncued location. Cue content (spider, leaf) did not modulate RTs, $F < 1$, and there was no significant interaction between cue content and target location (cued, uncued) as observed in Experiment 13, *F* (1,19) = 1.60, $p = .22$. Therefore, IOR was unaffected by cue valence in this task.

Ratings Data

Participants again evaluated leaves to be more pleasant than spiders, *F* (1,19) = 85.93, $p < .001$. Although there was no main effect of novelty, $F < 1$, or rate location, $F<1$, there were significant interactions between stimulus valence and novelty, *F* (1,20) = 4.67, $p < .05$, and novelty and rate location, *F* (2, 38) = 3.41, $p < .05$, modulating evaluations. The three-way interaction between stimulus valence, novelty, and rate

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[14] I repeated the ANOVA reported below removing data from a single participant who showed no fear to spiders on the pre-test questionnaire. This did not change the pattern of main effects or interactions reported.

location did not reach significance, F (2,38) = 1.70, p = .20. I then analysed ratings data for each stimulus valence separately to understand the interactions described above.

Spider Ratings

Analysis first focused on the spider rating data, which is presented in Figure 35. Rate location did not modulate stimulus evaluations, F (1,19) = 1.53, p =.23; however, novelty and rate location did significantly interact to influence the evaluation of spider stimuli, $F(1,27) = 5.34, p < .05$. Planned comparisons then explored the difference between ratings at target locations for each rating category. Previously seen spider cues were not evaluated any differently between cued and uncued locations, $t(19) = 1.60, p = .13$. In contrast to this however, the noteworthy finding of this second experiment is that novel spiders presented at cued locations were rated as less pleasant, than novel spiders presented at uncued locations. This rating location difference was true for when the novel item was preceded by a spider cue, $t(19) = -2.68, p = .02$, and when the novel spider was preceded by a leaf cue, $t(19) = -2.35, p = .03$. This results is consistent with the location-based devaluation by inhibition hypothesis. Interestingly, this devaluation effect was in the opposite direction to the possible devaluation effect presented in Experiment 14, where there was tentative evidence spiders were evaluated as less threatening (i.e., more positive) at cued versus uncued locations. This would suggest that the inhibitory mechanism underlying devaluation reduce stimulus value rather than suppressing the affective intensity of stimuli in this task (spiders were in fact becoming more negative when presented at cued locations).

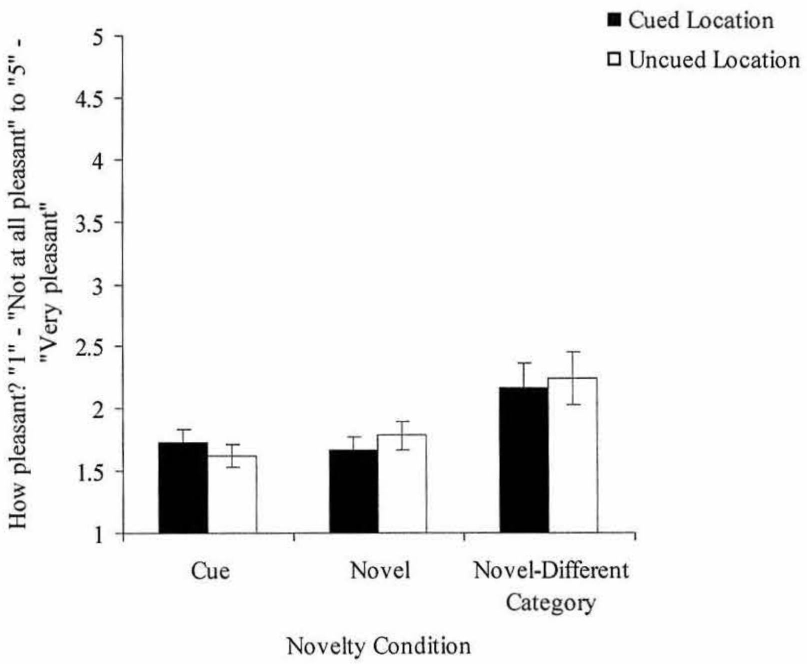

Figure 35. Mean pleasantness ratings for spider images. Note vertical error bars indicate +/- 1 S.E.

Also present in the analysis of the spiders rating data was a main effect of novelty, $F(1,23) = 5.02, p < .05$. As illustrated in Figure 35, spiders were rated as more pleasant when they were preceded by a leaf cue, than when they were preceded by a spider cue. This modulation of spider ratings by prior cue content is consistent with affective priming (Fazio, Sanbonmatsu, Powell, & Kardes, 1986), and this finding will be considered further in the Section Discussion. I compared these ratings statistically in the two novel ratings conditions, which confirmed this emotional cue effect on novel stimulus ratings, $F(1,18) = 4.95, p < .05$. This analysis also revealed a significant main effect of rate location, $F(1,19) = 9.19, p <.01$, consistent with the devaluation effects observed when rating the pleasantness of novel spider stimuli presented at cued versus uncued locations described above.

Leaf Ratings

Analysis then focused on the evaluations of leaves, which are presented in Figure 36.

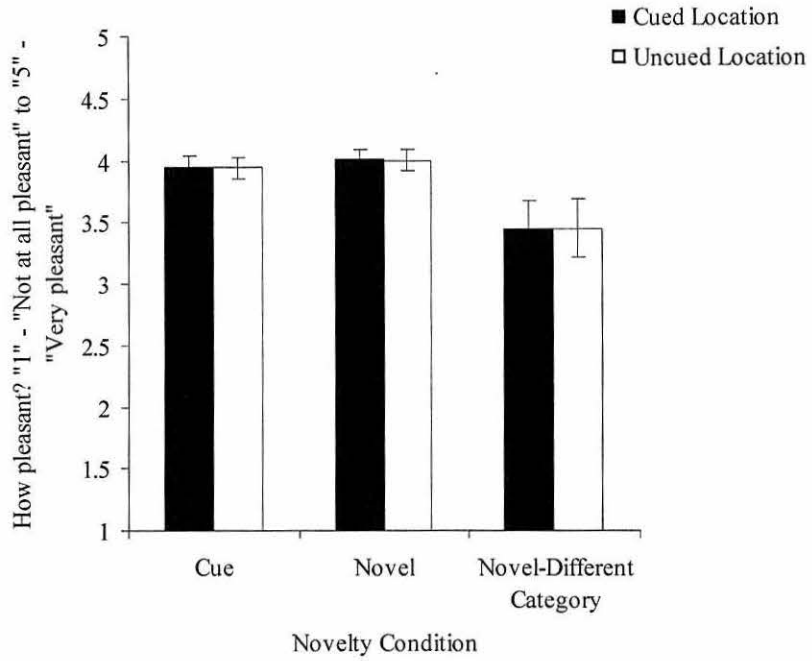

Figure 36. Mean pleasantness ratings for leaf images. Note vertical error bars indicate +/- 1 S.E.

Leaf ratings were unaffected by rate location, $F<1$, and rate location did not interact with novelty to modulate responding here, $F<1$. These results suggest that any inhibition at the level of the cue or present at prior target locations did not modulate the emotional evaluations of neutral stimuli. However, there was a marginally significant main effect of novelty, *F* (1, 20) = 3.94, $p = .06$. I then compared ratings of novel spiders in conditions preceded by a leaf cue and preceded by a spider cue (removing data from when the cue was rated and therefore any contribution of fluency), which revealed a significant modulation of ratings by prior cue valence, *F* (1,19) = 4.60, $p <.05$. Leaves were rated as less pleasant when preceded by a spider cue than when preceded by a leaf cue, consistent with affective priming (Fazio et al., 1986). This effect was not influenced by rate location, $F<1$, or any interaction between rate location and novelty, $F<1$.

IOR and stimulus ratings

To explore the relative contribution of IOR to stimulus evaluations, I re-analysed the data here, excluding participants who did not show a behavioural index of IOR[15]. This re-examination of the data presented the same pattern of effects as previously reported; however, the strength of the statistics improved. Leaves were still rated as more pleasant than spiders, $F(1,17) = 68.91, p < .001$, and affective modulation of ratings by cue valence was still present, indicated by the stimulus valence and novelty interaction, $F(2,34) = 4.84, p < .05$. Although the main effect of rate location was not significant, $F<1$, the interaction between novelty and rate location was highly significant, $F(2,34) = 6.06, p < .01$. Therefore, I have reported the data analysis for these IOR individuals as a function of stimulus valence below.

Spider Ratings. The mean ratings data for participants showing IOR are presented in Table 8. Stimulus evaluations were modulated by rate category, $F(1,22) = 5.46, p <$

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[15] My first analysis here divided participants into an IOR and non-IOR group defined by the overall mean IOR effect of all participants. However, the latter group contained participants showing IOR, which seemed inappropriate for a non-IOR group.

.05, with novel-different category stimuli (rating spider following a leaf cue) being rated as more pleasant than the cue spider and novel spider ratings. Although rate location did not modulate evaluations, $F<1$, the interaction between novelty and rate location was significant, $F(2,34) = 6.77, p < .01$.

Table 8. Pleasantness evaluations for spider stimuli as a function of rate location for participants showing IOR (n=18). Note pleasantness scores ranged from "1" – "Not at all pleasant" to "5" – "Very pleasant", and S.E. is presented in parentheses.

	Cued location	Uncued Location
Spider Cue Rates	1.72 (0.1)	1.60 (0.1)
Novel Spider Rates	1.69 (0.1)	1.78 (0.2)
Novel-Different Spider Rates	2.25 (0.3)	2.32 (0.3)

I then explored the ratings for each novelty category as a function of rate location. Spiders cues were rated as marginally more pleasant at cued versus uncued locations, $t(17) = 2.06, p = .06$. In contrast with this, ratings of novel spiders, $t(17) = -2.30, p = .03$, and novel-different category spiders, $t(17) = -2.28, p = .04$, were rated as less pleasant at cued versus uncued locations. The decrease in pleasantness ratings of novel stimuli at previously cued locations is consistent with a location-based devaluation effect. The contrasting effect observed when rating previously seen spider cues perhaps suggests that this condition was reflecting more the perceptual fluency of repeating a stimulus presentation in the same spatial location, enhancing pleasantness ratings (consistent with Experiment 12).

To probe whether the size of the IOR effect was important in the devaluation measures reported here, I repeated the analysis described above, including an additional between group factor of IOR magnitude, determined by dividing participants into two groups based around the size of their IOR effect in relation to the mean IOR effect of the group (large IOR n=8, small IOR n=10). This factor did not interact with rate location, $F(1,16) = 1.02$, $p = .33$, or the three-way interaction between novelty, rate location, and IOR magnitude, $F < 1$.

Leaf Ratings. I then re-examined the evaluations of leaves when only including IOR participants. The mean ratings for each novelty category are presented in Table 9. The main effect novelty did not reach significance, $F(1,18) = 3.73$, $p = .07$, although descriptively, leaves were rated as less pleasant when preceded by a spider cue than a leaf cue. The main effect of rate location, and the interaction between novelty and rate location were also non-significant, F's<1, suggesting that mechanisms subserving IOR did not modulate the evaluations of leaf stimuli in this experiment. This was further confirmed by an absence of any modulation of ratings by IOR magnitude (large, small) interacting with rate location F<1, or the three-way interaction between IOR magnitude, novelty, and rate location, $F(2,32) = 1.69$, $p = .20$.

Table 9. Pleasantness evaluations for leaf stimuli as a function of rate location for participants showing IOR (n=18). Note pleasantness scores ranged from "1" – "Not at all pleasant" to "5" – "Very pleasant", and S.E. is presented in parentheses.

	Cued location	Uncued Location
Leaf Cue Rates	3.93 (0.1)	3.88 (0.1)
Novel Leaf Rates	4.00 (0.1)	3.98 (0.1)
Novel-Different Leaf Rates	3.37 (0.3)	3.39 (0.3)

There were four important points to report from the experiment presented here. First, the magnitude of IOR was unaffected by cue valence (negative, positive). Second, as revealed in the global ratings analysis, the valence of the cue influenced stimulus ratings. Leaves were evaluated as less pleasant when preceded by a spider cue than a leaf cue, and spiders were evaluated as more pleasant when preceded by a leaf cue than a spider cue. This apparent affective priming (Fazio et al., 1986) of cue valence on stimulus ratings will be further considered in the Section Discussion. Third, when rating spider stimuli, pleasantness ratings of novel spiders were affected by prior target location. Novel spiders were rated as less pleasant at cued versus uncued locations, and this seemed to be common across participants regardless of the magnitude of IOR that was measured. This suggests a location-based mechanism may modulate stimulus evaluations, with novel stimuli, related and unrelated to the preceding cue, being devalued. However, the absence of this effect in the spider cues data was curious, and perhaps suggests that prior exposure to a stimulus negates evaluative consequences of inhibition (in essence mere exposure and devaluation cancel each other out). Evidence that both processes may be co-occurring can be drawn from the analysis including only

IOR participants, where rate location contributed (marginally) to rating spider cues as more pleasant at cued versus uncued locations. Fourth, no devaluation effects were observed when rating leaf stimuli. This was somewhat unexpected, based on the previous research by Raymond and colleagues (2006) where neutral stimuli are consistently devalued. I further explored the reliability of this observation (and the devaluation of spider stimuli) in the next experiment by instructing participants to now rate the unpleasantness of these stimuli, enabling any contribution of potential response biases on stimulus evaluations to be explored.

Experiment 15

The novel finding of Experiment 14 was the modulation of emotional evaluations by rate location. Novel spiders were rated as less pleasant at cued locations in contrast to novel spider ratings at uncued locations.

In this next experiment I was interested in whether the response scale contributed to this pattern of devaluation. Perhaps rating the pleasantness of spiders was more sensitive to measuring devaluation effects than rating pleasantness of leaves. Therefore, in this next experiment, participants instead rated the unpleasantness of leaf and spider stimuli. If the response scale measure is contributing to devaluation effects, by asking participants to rate the unpleasantness of these stimuli, devaluation may no longer be observed for spider stimuli, but may emerge for neutral stimuli. However, if devaluation in these experiments is modulated by the affective content of stimuli, then I would expect to replicate the devaluation of novel spider stimuli observed in Experiment 14.

Methods

Participants

Twenty-six naïve adults (22 females, 8 males; mean age 21 years) were recruited as before.

Apparatus and Stimuli

The apparatus and stimuli were the same as before.

Procedure

The procedure was the same as Experiment 14 with one important exception: Evaluations were instead made in response to "How unpleasant was the image?", again using a 5-point likert scale, where "1" represented "Not at all unpleasant" and "5" represented "Very unpleasant".

Data Analysis

Only data from trials in which participants correctly detected the target were analysed. Error rates were again low (< 2%), and were not modulated by cue valence, $t<1$. Less than 1% of trials were excluded owing to pre-target responding. Data from one person was removed owing to extremely slow RTs, and another person was removed owing to extreme rating responses. 1% of ratings data was excluded owing to anticipatory or slowed responding[16].

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[16] Again I repeated the ANOVA removing data from three participants who showed no fear to spiders on the pre-test questionnaire. This did not change the pattern of main effects or interactions reported below.

Results and Discussion

RT Data

Consistent with IOR, participants were slower to localise targets presented in previously cued locations than targets presented in uncued locations, *F* (1,23) = 31.01, *p* <.001. In trials presenting spiders as cues, localisation responses were 372 ms (S.E. = 12) at the cued location compared to 359 ms (S.E. = 11) at the uncued location. In trials instead presenting leaves as cues, localisation responses were 383 ms (S.E. = 13) at the cued location compared to 363 ms (S.E. = 12) at the uncued location. Participants were faster to respond in trials preceded by a spider cue than a leaf cue, *F* (1,23) = 6.14, *p* <.05; however, IOR was unaffected by cue valence, *F* (1,23) = 1.96, *p* = .18.

Ratings Data

The ratings data for spiders is presented in Figure 37, and the ratings data for leaves is presented in Figure 38. Participants evaluated spiders as more unpleasant than leaves, *F*(1,23) = 83.84, *p* < .001, confirming correct use of the response scale. There was no main effect of novelty, *F* < 1, rate location, *F*(1,23) = 1.58, *p* = .22, or the interaction between these two variables, *F*<1. Stimulus valence did not interact with novelty, *F*(1,34) = 1.20, *p* = .30, and the interaction between stimulus valence and rate location did not reach significance, *F*(1,23) = 3.01, *p* = .10. The three-way interaction of stimulus valence, novelty, and rate location was also non-significant, *F*<1. Although there was no statistical evidence in the data reported here of devaluation by inhibition, I examined each stimulus valence separately and subsequently explored any contribution of IOR to this.

Spider Ratings

Analysis first focused on the spider rating data, which are presented in Figure 37. In direct contrast to Experiment 14, there was no evidence that novelty, rate location, or their interaction (all *F*'s < 1) modulated the emotional evaluations of spider stimuli.

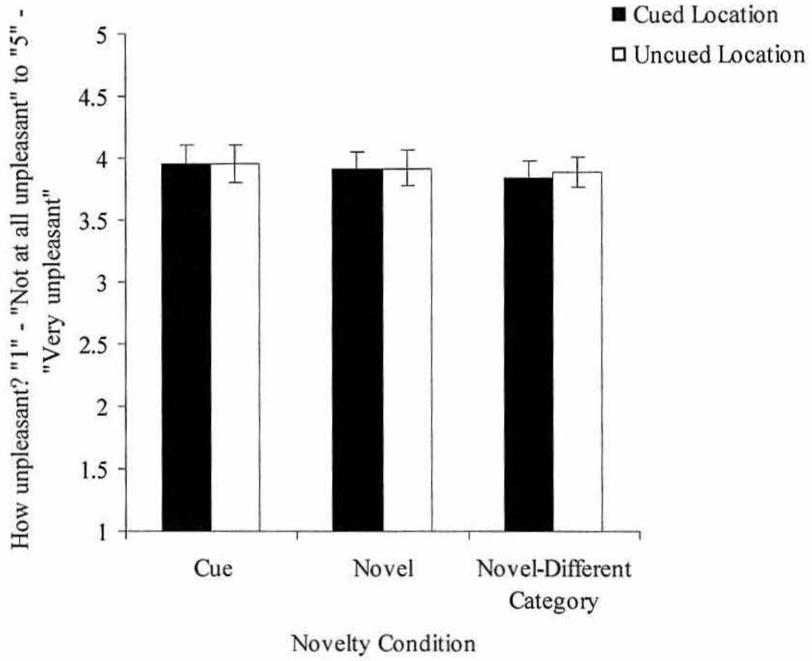

Figure 37. Mean unpleasantness ratings for spider images. Note vertical error bars indicate +/- 1 S.E.

Leaf Ratings

Analysis then focused on the evaluations of leaves (Figure 38). There was no effect of novelty, *F* (1,29) = 1.42, *p* = .25, and novelty did not interact with rate location to determine responding, *F*<1. However, a main effect of rate location was present in the data, $F(1,23) = 4.81, p < .05$. Across all novelty conditions, leaves were rated as more unpleasant at cued locations than at uncued locations. Post-hoc comparisons suggested this effect was not owing to the differences in ratings between any specific novelty categories at cued and uncued locations, with evaluative differences between rate locations being (marginally) significant only for previously seen cues, $t(23) = 1.99, p = .06$, and not reaching significance for novel, $t<1$, or different category exemplars, $t(23) = 1.46, p = .12$.

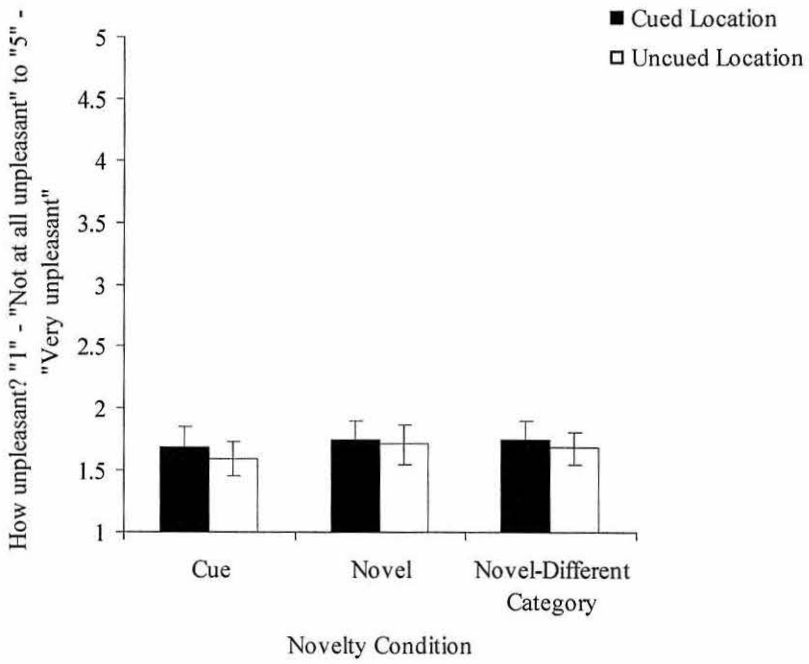

Figure 38. Mean unpleasantness ratings for leaf images. Note vertical error bars indicate +/- 1 S.E.

IOR and stimulus ratings

I then re-examined the unpleasantness ratings data, excluding data from four participants who did not show a behavioural manifestation of IOR. As found in the initial global analysis, the only significant main effect reflected the higher unpleasantness ratings of spider versus leaf stimuli, F (1,19) = 58.20, $p < .001$. Novelty and rate location did not modulate stimulus ratings, F's < 1. Moreover, there were no significant interactions between the stimulus valence, novelty, and rate location variables, F's < 1.05, p's > .36. The stimulus valence and rate location interaction also did not reach significance, F (1,19) = 2.05, p = .17. Nevertheless, I also examined stimulus valence separately, with devaluation effects reported above only emerging for leaf stimuli once these data were analysed separately from the spider stimuli.

Spider Ratings. Mean spider ratings for each novel category are presented in Table 10. Novelty, rate location, and the interaction between these variables did not modulate the evaluation of spiders in this task, F's < 1.

Table 10. Unpleasantness evaluations for spider stimuli as a function of rate location for participants showing IOR (n=20). Note unpleasantness scores ranged from "1" – "Not at all unpleasant" to "5" – "Very unpleasant", and S.E. is presented in parentheses.

	Cued location	Uncued Location
Spider Cue Rates	3.89 (0.2)	3.87 (0.2)
Novel Spider Rates	3.81 (0.2)	3.83 (0.2)
Novel-Different Spider Rates	3.78 (0.1)	3.83 (0.1)

I then again divided participants into two groups, based on the group mean magnitude of IOR to explore whether this may contribute to the pattern of data. This led to 7 participants forming the large IOR effect group, and 13 forming the low IOR effect group; however, this seemed an unfair comparison, and I also examined the data when the groups were more evenly matched (10 participants in each group). The principal results were the same, with one exception described below, and so I will report the analysis from unequal group analysis to parallel the equivalent analysis conducted in Experiment 14.

IOR magnitude as a factor included in this analysis did not interact with rate location, $F<1$, or novelty, $F\ (1,26) = 2.69, p = .10$. However the three-way interaction between these variables was significant, $F\ (2,36) = 3.37, p = .05$. In participants showing greater IOR effects, novelty ($F<1$) and rate location ($F<1$), and their interaction, $F\ (2,12) = 2.73, p = .11$, did not modulate spider ratings. Note that this interaction did reach significance when the sample size was increased to 10, $F\ (2,18) = 3.49, p = .05$, with novel (3.74 versus 3.79) and novel-different category spiders (3.76 versus 3.91) tending to be evaluated as less unpleasant (i.e., more positive) at cued than uncued locations, respectively, with spider cues showing the reverse effect (3.76 versus 3.61). However, analysis of just novel spiders failed to reveal a significant modulation of ratings by rate location, $F\ (1,9) = 4.13, p = .07$, weakening the claim that rate location may modulate emotional evaluations in this group. However, note that this non-significant ratings trend is in the same direction as ratings effects in Experiment 12.

In the low IOR magnitude group, no modulation of ratings by rate location, $F<1$, or the novelty and rate location interaction, $F<1$, was observed. However, the main effect of novelty was significant, $F\ (2,24) = 3.93, p < .05$. This novelty effect can be explained by spider cues being rated on average as more unpleasant (4.08), than novel spiders (3.93), or novel-different category spiders (3.84).

Leaf Ratings. Mean ratings for each leaf rating category are presented in Table 11. There was no main effect of novelty, *F* (1,24) = 1.18, *p* = .30 modulating evaluations. Moreover, the previously significant main effect of rate location, was now non-significant, *F* (1,19) = 3.17, *p* = .09. The novelty and rate location interaction was also non-significant, *F*<1.

Table 11. Unpleasantness evaluations for leaf stimuli as a function of rate location for participants showing IOR (n=20). Note unpleasantness scores ranged from "1" – "Not at all unpleasant" to "5" – "Very unpleasant", and S.E. is presented in parentheses.

	Cued location	Uncued Location
Leaf Cue Rates	1.69 (0.2)	1.59 (0.2)
Novel Leaf Rates	1.75 (0.2)	1.71 (0.2)
Novel-Different Leaf Rates	1.72 (0.2)	1.70 (0.2)

I again analysed this data in respect of the magnitude of IOR shown by participants (large, small). The principal results were the same for unequal and equal grouping of participants, and so I will report the analysis from unequal group analysis to parallel the equivalent analysis conducted in Experiment 14. Interestingly, the factor of IOR group trended toward interacting with rate location, *F* (1,18) = 3.54, *p* = .08, although this factor did not interact with novelty, or the three-way interaction between these variables, *F*'s <1. Therefore, I examined the ratings for the high and low IOR groups separately. Surprisingly, ratings in the high magnitude IOR group were not affected by novelty, rate location or their interaction, *F*'s <1. However, in the low magnitude IOR group, the main effect of rate location was significant, *F* (1,12) = 6.50, *p*

< .05, with the main effect of novelty, *F*<1, and the interaction between novelty and rate location, *F*<1, being non-significant. In this low IOR group, leaf stimuli were rated as more unpleasant at previously cued versus uncued locations when previously seen as cues (1.71 versus 1.57; *t*(12) = 2.37, *p* = .04), with this effect descriptively but not statistically present for novel (1.81 versus 1.71; *t*(12) = 1.49, *p* = .16), and novel-different category (1.76 versus 1.70; ; *t*(12) = 1.21, *p* = .25) conditions.

There were three main findings to reported from this experiment. First, consistent with the previous experiments reported here, the magnitude of IOR was unaffected by cue valence (negative, positive). Interestingly, cue valence did modulate response times in this task, although this did not interact with the magnitude of IOR. Second, there was some evidence of the devaluation of leaf stimuli, although this was not statistically strong enough to manifest in the global analysis across stimulus valence conditions, and analysis of only individuals showing a behavioural IOR effect removed this devaluation by rate location effect. This would suggest that participants not showing IOR influenced this apparent modulation of stimulus evaluations by rate location. Indeed this hypothesis was strengthened by the observation that individuals showing a smaller magnitude of IOR were more likely to devalue leaves presented at cued versus uncued locations. Third, there was no evidence that spiders were devalued in this experiment or that cue valence modulate emotional evaluations of novel-different category stimuli as previously observed (c.f. Experiment 14).

In sum, the data provided here does not provide convincing evidence that IOR is linked to emotional evaluations when evaluating the unpleasantness of negative and neutral stimuli. There was some evidence that emotional evaluations of neutral images were affected by rate location, although this was not statistically strong. Participants did correctly dissociate leaf and spider stimuli in terms of unpleasantness, but perhaps rating unpleasantness is a more crude or insensitive measure of potential IOR and emotional evaluation interactions. Thus, in the final experiment reported here, the affective response question was removed, and instead a nominal rating scale was employed.

Experiment 16

The main methodological difference between Experiment 16 and the previous experiments is the nature of the emotional response required. Here participants rated images on an 11-point likert scale, preventing any contribution of the emotional response question in biasing or influencing emotional evaluations.

Method

Participants

Thirty-one naïve adults (23 females; mean age 20 years) were recruited as before.

Apparatus and Stimuli

The apparatus and stimuli were the same as before.

Procedure

The procedure was the same as Experiment 15 with one critical difference. Participants were asked to "Rate that image!", and were presented with an 11-point likert scale where "-5" represented "negative", and "+5" represented "positive".

Data Analysis

Only data from trials in which participants correctly detected the target were analysed. Error rates were again low in spider cue trials (<3 %) and leaf cue trials (3 %), and this error rate difference did not reach statistical significance, $t(22) = 1.85$, $p = .08$. Less than 2% of trials were excluded owing to pre-target responding, and 5% of trials were removed owing to anticipatory and slow ratings responding. Data from one participant was removed owing to extremely slow RTs, and two further participants were removed owing to extreme rating responses. Note that in this Experiment, five participants reported no fear response to spider stimuli. I analysed the data with both these participants included and excluded. The exclusion of the participants provided more sensitivity in measuring differences in emotional responding, so the analysis reported below excludes data from these participants.

Results and Discussion

RT Data

Participants were slower to localise targets presented in previously cued locations than targets presented in uncued locations, $F(1,22) = 30.61$, $p < .001$, indicating IOR. In trials presenting spiders as cues, localisation responses were 385 ms (S.E. = 14) at the cued location compared to 364 ms (S.E. = 14) at the uncued location. In trials instead presenting leaves as cues, localisation responses were 384 ms (S.E. = 13) at the cued location compared to 365 ms (S.E. = 13) at the uncued location. RTs and IOR were unaffected by cue valence, F's < 1.

Ratings Data

This new scale was used successfully with spiders being rated as more negative than leaves, *F*(1,22) = 446.79, $p < .001$. The mean ratings for leaves as a function of novelty and rate location are presented in Figure 39, and the mean ratings for spider stimuli for the same variables are presented in Figure 40.

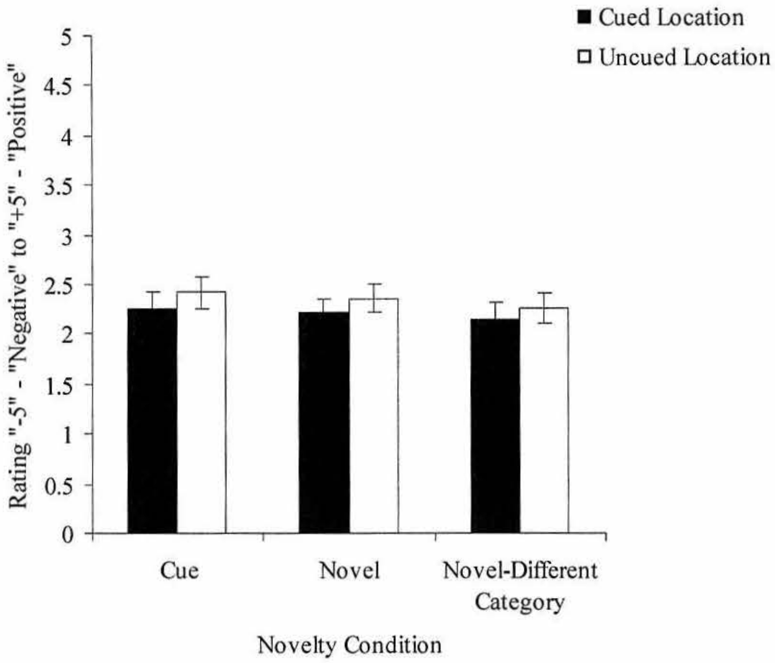

Figure 39. Mean ratings for leaf images. Note vertical error bars indicate +/- 1 S.E.

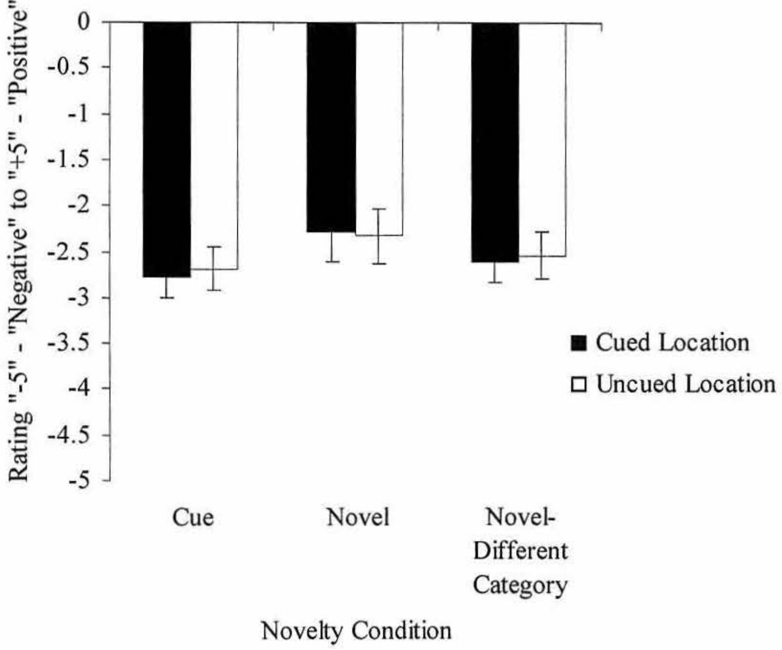

Figure 40. Mean ratings for spider images. Note vertical error bars indicate +/- 1 S.E.

The noteworthy finding of this analysis was that rate location significantly modulated stimulus evaluations, $F(1,22) = 6.92, p < .05$. Across stimulus categories, images presented at cued locations were evaluated as more negative than images presented at uncued locations. Moreover, rate location did not interact with novelty, $F<1$, or stimulus valence, $F(1,22) = 1.32, p = .26$. The three-way interaction between these variables was also non-significant, $F<1$, confirming the generality of this devaluation effect present in the ratings data. The main effect of novelty was non-significant, $F(2,44) = 1.72, p = .19$, and this did not interact with stimulus valence to influence emotional responding, $F(2,44) = 1.99, p = .15$.

Although rate location modulated image evaluations, indicated by a main effect of this variable on responding, visual examination of Figures 39 and 40 suggest this modulation of evaluation may be mediated by rating differences in the leaves rather than the spiders data. Thus, I examined each stimulus valence condition separately in the analysis reported below.

Spider Ratings

Consistent with the visual inspection of Figure 40, rate location did not modulate evaluations of spider images, $F<1$. Furthermore, novelty, $F(2,36) = 2.09$, $p = .15$, and the interaction between novelty and rate location, $F<1$, did not modulate ratings here. These results suggest that the emotional evaluation of spiders was equivalent, regardless of their relatedness to the cue, or the spatial location of evaluation.

Leaf Ratings

The main effect of rate location was highly significant in determining the emotional evaluations of leaf stimuli, $F(1,22) = 10.03$, $p < .01$. However, leaf evaluations did not statistically differ between novel categories as function of rate location, t's< -1.8, p's > .09, suggesting a general devaluation response to images presented in the cued location. Note that novelty, $F<1$, and the interaction between novelty and rate location, $F<1$, were also non-significant.

IOR and stimulus ratings

I then examined the ratings data from leaves and spiders, and explored whether IOR magnitude contributed to the pattern of data obtained. This analysis resulted in the exclusion of two participants who showed no behavioural index of IOR. As reported in the global analysis, spiders were evaluated more negatively than leaves, *F*(1,20) = 391.28, $p < .001$, and the main effect of rate location was still significant, *F*(1,20) = 7.65, $p < .05$. Rate location again did not interact with novelty, stimulus valence, and the three-way interaction between these variables was also non-significant, *F*'s<1. Novelty also did not modulate responding, *F*(2,40) = 1.97, $p = .15$, or interact with stimulus valence, *F*(2,40) = 1.88, $p = .17$. I then looked at each stimulus valence separately as a function of IOR.

Spider ratings. Spider ratings for participants showing IOR in their RT data is presented in Table 12. Novelty, *F*(2,40) = 2.22, $p = .12$, rate location, *F*<1, and the interactions between these variables, *F*<1, did no modulate image evaluations here. I then included the between group factor of IOR magnitude (large, n = 9; small, n = 11) in this analysis. This factor did not modulate ratings, *F*<1, or interact with any variables to modulate stimulus evaluations, *F*'s <1. These results are conclusive that IOR did not modulate the emotional evaluation of spiders presented in this task.

Table 12. Emotional evaluations for spider stimuli as a function of rate location for participants showing IOR (n=21). Note the response scale ranged from "-5" – "Very negative" to "+5" – "Very positive" and S.E. is presented in parentheses.

	Cued location	Uncued Location
Spider Cue Rates	-2.77 (0.2)	-2.65 (0.2)
Novel Spider Rates	-2.24 (0.3)	-2.25 (0.3)
Novel-Different Spider Rates	-2.60 (0.2)	-2.15 (0.3)

Leaf ratings. Leaf ratings for participants showing IOR in their RT data is presented in Table 13.

Table 13. Emotional evaluations for leaf stimuli as a function of rate location for participants showing IOR (n=21). Note the response scale ranged from "-5" – "Very negative" to "+5" – "Very positive", and S.E. is presented in parentheses.

	Cued location	Uncued Location
Leaf Cue Rates	2.20 (0.2)	2.38 (0.2)
Novel Leaf Rates	2.19 (0.2)	2.31 (0.1)
Novel-Different Leaf Rates	2.11 (0.2)	2.22 (0.2)

Similar to the spiders data, novelty, *F*<1, and the novelty and rate location interaction, *F*<1, did not modulate emotional evaluations of leaf stimuli. However, the main effect of rate location was highly significant, *F*(1,20) = 8.50, *p* < .01, consistent with the global ANOVA. Again leaf evaluations did not statistically differ between novel categories as a function of rate location, *t*'s< -1.86, *p*'s > .08.

I then re-analysed this data including the between group factor of IOR magnitude (large, small); however, IOR magnitude did not modulate evaluations, *F*<1, or interact with novelty and / or rate location, *F*<1, to modulate evaluative responding. Therefore, this devaluation effect observed in the leaves data appears to represent a general bias to evaluate leaves more negatively at the cued location, and is not inherently linked to the magnitude of IOR, consistent with the devaluation effects of spiders found in Experiment 14, and leaves in Experiment 15.

In this final experiment, I removed any possible contribution of response bias in the data presented here by using a nominal scale of negative to positive, with no emotional question posed to guide evaluative ratings. No evidence of devaluation effects was observed when participants rated spider stimuli, suggesting that the emotional value of negative stimuli were not affected by IOR. However, I did find evidence that leaves were devalued when presented at previously cued locations versus uncued locations, and this was unrelated to the magnitude of IOR measured in participant responses.

Chapter 12: Section Discussion

In this final experimental section of my thesis, I reported five experiments that were designed to explore whether the mechanisms underlying IOR would influence the emotional evaluation of visual stimuli. Computational models of visual attention have employed IOR as a mechanism to reduce location saliency (Itti & Koch, 2000; 2001; Itti et al., 1998), and a recent behavioural study has proposed that IOR may influence stimulus selection (Ivanoff & Taylor, 2006). Indeed, inhibitory effects reducing stimulus saliency have previously been reported, expressed as a devaluation of stimulus value (Fenske & Raymond, 2006). If the IOR effect does reflect changes in stimulus saliency and selection, the experiments reported here probed whether this could be measured in the emotional response system. Visual images were presented as spatial cues and were later presented for evaluation at locations associated either with inhibition or at novel locations not associated with inhibition. Images related to the identity of the spatial cues were also presented for evaluation. Although no consistent evaluative response effects were found, evidence that visual stimuli (emotional and non-emotional) were devalued by inhibitory processes was present in the data. For parsimony, I will discuss the results of the experiments reported here in terms of object-based processes, location-based processes, affective priming, and IOR sensitivity to cue valence. I will finish with considering directions for future research.

Object-based evaluation effects

Experiment 13 was specifically designed to address whether inhibition encoded at the level of the exemplar (i.e., the cue identity) would result in changes to its emotional value when it was re-presented at a novel spatial location for evaluation. Moreover, whether changes in the evaluations of other visual items belonging to the same category as the cue as a function of inhibition was also investigated in this experiment. The items to be rated were always presented in the centre of the screen for evaluation, preventing any influence of prior cue and target location on subsequent ratings. Pleasantness evaluations of spider stimuli were equivalent, regardless of the novelty of the spider. However, pleasantness evaluations of leaf stimuli were a little less clear cut, with trial type influencing the evaluation of novel leaves. Importantly though, in both spider and leaf conditions, there was no evidence of object-based inhibition modulating the emotional evaluation of these stimuli.

Previous studies exploring the contribution of attentional inhibition to emotional evaluations have highlighted the importance of encoding stimulus identity with inhibition in the manifestation of devaluation. Indeed object-based devaluation effects have been previously observed (Fenske et al., 2005; Raymond et al., 2003; 2005). In the seminal devaluation article (Raymond et al., 2003) for instance, distractor devaluation was observed when these stimuli were presented in a central location for evaluation, away from the position they had occupied in the previous attention task. This raises an interesting issue as to why object-based inhibitory effects were not measured in the data reported here. One possible explanation may be that there was insufficient exposure to previous cue stimuli, preventing the formation of a robust stimulus representation that could be encoded with inhibition. Cue images were presented very briefly (85 ms) in the experiments reported here. In the original Raymond et al. (2003) study, stimuli were presented for a relatively short duration still (100 ms); however, these stimuli were more simpler visual images consisting of circles or squares, in contrast to the complex contents of photographs used in these experiments. Subsequent devaluation experiments using more complex visual stimuli have used longer exposure durations (e.g., 200 ms, Fenske et al., 2004), and the more pronounced object-based devaluation effects observed by Raymond et al. (2005) occurred with more meaningful stimuli (faces), which were also exposed for a longer duration in the visual search task. Therefore, the failure to demonstrate object-based modulations of evaluation in the experiments reported here may be owing to insufficient exposure duration to the cue items.

Although the experiments reported here were principally interested in the emotional consequences of inhibition, a related object-based effect is mere exposure. Experiment 12 demonstrated that prior exposure enhanced the appetising value of sweet food images previously seen as spatial cues. In this experiment, cue images were presented for the same amount of time as cue images in Experiment 13, and evaluative consequences were still found. This suggests that the mechanisms underlying devaluation and mere exposure are very different. Indeed, subliminal exposure can enhance the emotional value of a visual stimulus when it is later re-presented for evaluation (Zajonc, 2001). Perhaps complete formations of object-based representations are not required for a fluency benefit on evaluations to be observed, a criterion required to observe devaluation effects. This would suggest a more cortical mechanism subserving object-based devaluation effects, and this would converge with the notion that object-based IOR effects also have a cortical locus (Tipper et al., 1997).

Finding a less threatening evaluation of previously seen cue spiders (versus novel spiders) in Experiment 12 is also consistent with mere exposure modulating emotional evaluations. Although it was unclear whether this was truly a consequence of fluency or inhibition, finding that spiders were rated more negatively in Experiment 14 suggests that a fluency account of the more positive ratings of these spider cues is a more viable interpretation. However, it is also plausible that both fluency and inhibitory mechanisms were acting in parallel in this task to exert control over stimulus evaluation; the contribution of these two effects cannot be dissociated here.

Location-based evaluation effects

Experiments 13 – 16 explored the contribution of both object and location-based processes in contributing to stimulus evaluations in a spatial cuing task. Indeed evidence supporting devaluation-by-inhibition was found in conditions where stimuli were evaluated as more negative when presented at cued locations (associated with inhibition) than when presented at uncued locations. Indeed, this effect of rate location influenced the rating of leaves when no loaded emotional rating instruction was employed (Experiment 16), with some evidence that leaves were also rated as more unpleasant at cued versus uncued locations in Experiment 15. Decreases in pleasantness ratings of spiders consistent with devaluation by location-based inhibition were also observed (Experiment 14). Interestingly, the magnitude of IOR did not appear to be related to the presence (or size) of devaluation. In the spatial cuing task used here, IOR magnitude reflects a summation of location and object-based inhibition; therefore, to establish any relationship between IOR magnitude and devaluation, tasks would need to be employed to tease apart location and object-based inhibition and devaluation effects. Currently, the data suggests that the mere presence of IOR is sufficient to generate a devaluation effect between stimuli at cued and uncued locations.

It was interesting to note the dissociation between Experiments 15 and 16 in terms of which stimuli set showed evidence of devaluation. When rating pleasantness, spiders were devalued but leaves were not. In contrast when rating unpleasantness, there was some evidence that leaves were devalued, but there was no evidence that spiders were also devalued. By removing any affective task instruction, devaluation effects were observed only with leaves, consistent with the devaluation of neutral stimuli typically measured in these tasks (Fenske & Raymond, 2006). This would suggest that the framing of the emotional rating instruction can create response biases when making emotional evaluations of visual stimuli. Previous devaluation studies have incorporated emotional question frames where participants have rated “cheery” versus “dreary” as well as “trustworthy” versus “untrustworthy”, failing to find any evidence of a response bias between these rating terms. Apart from the obvious experimental design differences, the Experiments reported here included stimulus valence (negative, neutral) as an additional experimental manipulation that previous devaluation studies have not yet investigated. Perhaps the presence of emotional stimuli may interfere with the emotional response system.

Support from this proposal is drawn from a recent study that demonstrated planning an emotional response interferes with the concurrent evaluation of an emotional stimulus, when response and stimulus share the same valence. Eder and Klauer (2007) presented participants with an emotional word (S1), which they had to categorise as being positive or negative (R1). Whilst preparing to initiate this categorisation response, a second emotional word was presented (S2), which participants also had to categorise (R2). The relevant finding here was that if R1 was emotionally compatible to S2, R2 categorisation performance was significantly impaired. However, if R1 was emotionally incompatible to S2, R2 categorisation performance was unaffected. More simply, categorisation of positive words was impaired if the preceding categorisation was positive. Similarly, categorisation of negative words was impaired if the preceding action was to categorise a negative word. Eder and Klauer (2007) termed this *action-valence blindness*, proposing that the mechanisms encoding stimulus and response valence are similar, and may overlap or co-exist within a common representation. Therefore, simultaneous activation of stimulus and response (e.g., positive response, positive stimulus) impairs performance in this task. Assuming that leaves may be more positive than neutral (and this is hinted at in the pre-testing rates of these stimuli, Experiment 14), perhaps evaluative response mechanisms are impaired when the stimulus valence and response valence are compatible. This would explain why leaves and not spiders were devalued when rating their unpleasantness, and why spiders and not leaves were devalued when rating their pleasantness. In Experiment 16, by removing the emotional framing of the response question, only leaves were devalued.

Devaluations of neutral stimuli are consistent the devaluation-by-inhibition account originally proposed by Raymond et al. (2003). Moreover, when spider stimuli were devalued, they were rated as less pleasant at cued versus uncued locations

(Experiment 14). This evaluative consequence of inhibition negated the value of spiders rather than suppressing their affective intensity (this would have resulted in more pleasant ratings at cued locations). This is consistent with the existing devaluation findings of neutral stimuli, which are evaluated as more negative in the presence of inhibition.

It is perhaps not surprising that the emotional value of spider stimuli were not suppressed in this final experiment when potential response biases were removed. Spiders are an example of a phylogenetic threat-relevant stimulus, which are believed to be prioritised during visual processing (Öhman & Mineka, 2001). Although the mechanisms subserving IOR may function to reduce the saliency of visual locations (Itti & Koch, 2000; 2001; Itti et al., 1998), these mechanisms did not affect the emotional saliency of negative stimuli in the final experiments reported here (Experiments 15 and 16). If the saliency of emotional stimuli were malleable to subtle attentional manipulations, this may hinder their detection during visual encounters. Nevertheless, failures to find emotion perception in the absence of attention and awareness (Okon-Singer et al., 2007; Pessoa, 2005; Pessoa et al., 2002; Silvert et al., 2007) suggest that the emotional saliency of a stimulus may not always facilitate its detection.

Finally, it is worth considering why location-based rather than object-based devaluation effects were observed in the experiments reported here. Perhaps the stronger location-based effects were consistent with the component mechanism of IOR required to complete the task. Tipper et al. (1994) hypothesised that object and location-based IOR mechanisms may be in competition, with current task demands determining which mechanism is the more dominant. In a localisation task such as the one presented in the experiments here, mechanisms subserving location-based IOR would be more beneficial in facilitating target responding. Therefore, stronger location-based devaluation effects may reflect the dominance of location-based IOR in influencing responding here. Indeed a task that engages the need for object-based IOR may reveal object-based devaluation, an effect absent in tasks geared to measure visual orienting to locations.

Affective priming

An interesting observation from Experiment 14 was the modulation of ratings in the novel-different category conditions. Leaves preceded by a spider cue were rated as less pleasant than leaves preceded by a leaf cue. Similarly, spiders preceded by a leaf cue were rated as more pleasant than spiders preceded by a spider cue. The modulation of emotional evaluations by the preceding cue stimulus suggests that the emotional cue primed the emotional evaluation of the item to be subsequently evaluated.

Affective priming studies traditionally involve the presentation of a positively or negatively valenced image (~200 ms), followed by the presentation of a positive or negative target (positive-negative, negative-positive; Fazio et al., 1986). Target responses typically involve an evaluative response made to the valence of the stimulus (e.g., target categorisation as positive or negative). Responding is faster when the prime and target share the same valence (positive-positive, negative-negative) than when they are differently valenced. Affective priming has also been observed in evaluation tasks. For example, participants rated neutral stimuli (Chinese ideographs) as more negative when preceded by very briefly (4 ms) presented angry face primes, and more positive when preceded by happy face primes (Murphy & Zajonc, 1993).

This apparent affective priming influence on ratings by cue items in Experiment 14 was somewhat surprising, considering the transient nature typically attributed to affective priming measures. Indeed, a recent analysis of the time course of affective priming indicates the effect is maximal with a 0 ms SOA, and declines with increasing SOAs of 150 – 300 ms (Hermans, De Houwer & Eelen, 2001). The ratings here occurred after 2500 ms (1500 ms SOA and a 1000 ms delay screen) well outside this time window affective priming is believed to operate. Interestingly, Raymond et al. (2003; Experiment 1) also found evidence of affective priming in their study, with two affective primes presented at the beginning of each trial prior to the localisation and ratings task. The delay here was also relatively long between prime onset and rating task (at least 1850 ms). Nevertheless, in Experiment 14 it is possible that the mechanisms found modulating responding are not the same that underlie affective priming, and the failure to replicate this effect across all experiments casts some doubt to its reliability.

IOR sensitivity to cue valence

Experiment 13 provided the first indication across all the experiments reported in this thesis that the mechanisms subserving IOR were modulated by emotion. Specifically, IOR was larger when the cue was negative (a spider) than when it was neutral (a leaf). This was an unexpected effect, considering the results from Section 4, as well as the remaining experiments in this present Section. I therefore conducted a meta-analysis of IOR reported across Experiments 13 – 16 (N=89) to explore the reliability of this cue valence modulation of IOR. In this analysis, localisation RTs in cued and uncued trials containing spider and leaf cues were specified as within subjects factors, and experiment was specified as a between-group factor. There was of course a significant IOR effect, $F(1,85) = 98.38, p < .001$. Importantly, IOR did not interact with cue valence, $F(1,85) = 1.09, p = .30$. The mean IOR effect generated in response to spider cues was -18 ms, and the mean IOR effect generated in response to leaf cues was -16 ms. Moreover, the three-way interaction between cue valence, IOR, and experiment was not significant, $F(3,85) = 2.07, p = .11$. This analysis indicates that across four experiments there was no reliable modulation of IOR by cue valence, and this finding continues to support the underlying theme of this thesis that the mechanisms underlying IOR are blind to the emotional content of visual stimuli.

Future Considerations

The noteworthy finding of this final section of my thesis was demonstrating that the mechanisms underlying IOR may modulate the emotional quality of visual stimuli. This is an important theoretical point, furthering our understanding of the possible functional nature of the mechanisms underlying the effect. Traditionally, IOR is conceptualised as a reflexive component of visual orienting, with little research addressing the consequences of IOR beyond the slowed responding that has been shown to characterise the effect. Here I have demonstrated that the mechanisms subserving IOR may reduce the saliency of visual stimuli presented at locations subject to inhibition. This would be advantageous in preventing stimulus selection at locations that have previously been the subject of visual scrutiny, preventing erroneous and unnecessary responding there (Ivanoff & Klein, 2006; Ivanoff & Taylor, 2006; Klein & Taylor, 1994;

Terry et al., 1994). Indeed this converges with a previous claim by Ivanoff and Taylor (2006) that the mechanisms underlying IOR may facilitate stimulus selection.

These results provide a fruitful avenue for future research exploring the interaction between mechanisms underlying IOR and the emotional response system. The initial steps would be to replicate the current finding with a more streamlined design using different neutral stimuli, and a more conservative response scale. Evidence from Experiment 13 suggests it is unlikely that inhibition encoded at the exemplar level modulates subsequent emotional evaluations; however, extending the cue exposure duration to allow sufficient processing time of these stimuli would certainly rectify this issue. Furthermore, designing the experiment such that object-based IOR would be the dominant inhibitory process may also reveal devaluation effects otherwise absent in experiments dominated by location-based inhibition.

A second design adaptation would be to present meaningless stimuli as both cues and targets, and measure evaluation responses to meaningful stimuli presented in cue-target locations after the localisation task. This is advantageous as it removes any effects of prior exposure of cue content on emotional evaluations, which from the presence of affective priming in Experiment 13 and fluency effects in Experiment 12 may be an issue. On a related note, altering the cue-target interval to measure both attentional facilitation (short interval) and attentional inhibition (long interval) would be beneficial, enabling the relative contribution of the cue-target delay to stimulus evaluations to be investigated. Here I only investigated the effects of cuing on performance when the time interval was sufficient to generate IOR, and to be sure that IOR is responsible for the devaluation effects measured here, shorter cut-target intervals would be necessary.

The experiments reported here highlight the importance of using sensitive and unbiased response scales when probing the emotional response system. Although Likert scales have widely been used in devaluation studies, developing more sensitive measures of evaluation are important. Although there are several response scales that are available to measure emotional responding, including the Self-Assessment Manikin (Lang, 1980) and the Pleasure-Arousal-Dominance dimensions (Mehrabian & Russell, 1974), the employment of less overt measures may be more rewarding. One approach could be to measure facial EMG activity to accompany self-report measures of emotional responding. For example, previous research has demonstrated that self-report measures indicating more positive evaluations of fluent stimuli are accompanied by increasing activity in zygomatic facial muscles (Winkielman & Cacioppo, 2001). Ideally any emotional response scale should be accompanied by a non-emotional (e.g., perceptual) response scale, to differentiate general biases in responding from genuine attention-emotion interactions (see Fenske et al., 2004, for evidence of this).

In summary, the experiments reported here investigated whether the mechanisms underlying IOR would influence the emotional evaluations of visual stimuli. Evidence for the devaluation of both neutral and emotional stimuli was found, and appeared to be mediated by a location-based inhibitory effect. Moreover, the mechanisms underlying IOR were again demonstrated as being blind to emotional content of spatial cues. Taken together, these results suggest that the generation and measurement of IOR is unaffected by the emotional content of the visual world. However, once initiated, the mechanisms underlying IOR can influence the emotional evaluations of visual events.

Section 6: General Discussion

General Discussion

Inhibition of return (IOR) is an effect of visual orienting, characterised by slower responding to previously examined locations and objects. The experiments reported in this thesis investigated whether the mechanisms underlying IOR are sensitive to the emotional content of visual stimuli. Further, whether the mechanisms subserving IOR would influence the emotional evaluations of visual stimuli was also investigated. In this General Discussion I will first re-state the principal hypotheses tested in this thesis, followed by a review of the empirical chapters in respect of their support for these hypotheses. I will then discuss how these results are informative about the functional nature of the mechanisms subserving IOR, as well as emotion perception and visual orienting generally.

IOR: Adaptive versus reflexive hypotheses

In Chapter 3, I presented two competing hypotheses describing the nature of the IOR effect and their predictions for the generation and measurement of IOR in the presence of emotion. I will begin by re-visiting the literature that led to the development of these hypotheses prior to discussing the results of this thesis within their framework.

IOR as an adaptive consequence of visual orienting posits monitoring of visual locations, preventing responding there (Terry et al., 1994), as well as facilitating adaption of behaviour 'online' to meet the demands of the environment (Ivanoff & Taylor, 2006). Evidence to support this adaptive notion can be drawn from the observation that participants make fewer false alarms at cued locations (Ivanoff & Klein, 2001), and participants are also better able to override prepotent response tendencies to targets presented at these previously cued locations (Ivanoff & Taylor, 2006). Moreover, finding IOR effects in visual search studies developed the principal that the mechanisms underlying IOR serve to facilitate visual foraging (Klein, 1988; Klein & MacInnes, 2001; MacInnes & Klein, 2003; Müller & von Mühlenen, 2000; Thomas et al., 2007). By extrapolating the findings and claims from the studies described above into an *adaptive hypothesis* of IOR, I proposed that the mechanisms underlying the effect are sensitive to the emotional content of visual stimuli. Consequently, encounters with emotion would facilitate adaptive behavioural responding, changing the time course and magnitude of IOR in contrast to measures of responding in the presence of non-emotional (i.e., neutral) stimuli.

In contrast to this adaptive account of IOR is the presumed reflexive nature in generating and measuring the effect. That is, any peripheral onset of an irrelevant spatial cue and involuntary orienting to its location, with a sufficient cue-target interval, will produce IOR effects in responding (e.g., Tipper & Kingstone, 2005). This approach conceptualises IOR as a ballistic mechanism, biasing vision to novelty even with appetitive and aversive stimuli employed as cues and targets. Therefore, I presented a *reflexive hypothesis* of IOR that predicts the mechanisms underlying the effect would remain unaffected by the presence of emotional stimuli. This hypothesis also received support from previous research finding the mechanisms underlying IOR as being blind to cue and target content when it was socially relevant (Taylor & Therrien, 2005; 2008), employing a methodology comparable to the experiments reported here.

I will now summarise the main findings from each of the empirical sections, and report whether they support the adaptive or reflexive hypothesis of IOR described above.

In Experiments 1 through to 6, emotional stimuli were presented as targets to be localised in a spatial cuing task. Repeated exposure to emotional stimuli reduced the magnitude of the IOR effect in contrast to repeated exposure to affectively neutral stimuli. However, when emotional stimuli were intermixed with neutral target stimuli, IOR was equivalent irrespective of target content. Further, by systematically varying the emotional content of target stimuli in a series of mini-blocks of trials, I was able to demonstrate that the emotional modulation of IOR resulted from changes in affective contextual state associated with repeated exposure to these stimuli, rather than any perceptual processing of emotional content when the target onset. These results demonstrate that the stimulus-driven emotional content of target stimuli does not modulate the IOR effect, supporting the reflexive hypothesis of IOR.

The emotional content of target stimuli was also manipulated in Experiments 7 through to 10, with the emotional compatibility of the response mode included as the critical variable of interest. Emotional compatibility between target and response facilitated responding in both cued and uncued trials. However, the magnitude of IOR remained unchanged by the emotional content of target stimuli in this task, and more importantly, the IOR effect did not interact with emotional compatibility between target and response. These results were true when emotional targets were presented in blocks keeping valence constant (Experiment 9), as well as when emotional targets were intermixed amongst neutral targets (Experiment 10). The failure to replicate IOR sensitivity to emotion in the blocked design was attributed to the temporal delay between successive target exposures. Nevertheless, these results converge with the findings of Experiments 1 through to 6 in supporting a reflexive account of the IOR effect.

In Experiment 11, a novel value learning procedure was introduced to control the saliency of stimuli presented as peripheral spatial cues in a task designed to generate both attentional facilitation and IOR. Although attentional facilitation was only measured in the neutral cue condition, IOR remained unaffected by cue content, irrespective of its value (neutral, high or low probable gain and loss). Interestingly, cue value interfered with target processing at cued locations in both attentional facilitation and IOR trials. Nevertheless, the unchanged magnitude of IOR across the cue value conditions further supports its role as a reflexive consequence of visual orienting. Finally, converging with this null finding of Experiment 11, the emotional content of cue stimuli (spiders, sweet foods, leaves) was also manipulated in Experiments 12 through to 16, producing no reliable modulation of IOR by cue content.

Taken together, the results from the 16 experiments reported in this thesis support the reflexive hypothesis of the mechanisms underlying IOR: The generation and measurement of IOR is unaffected by the presence of emotional and motivational events in the visual scene. Note that these findings typically represent null effects of emotional content on IOR. This does not mean that emotion was not being processed, and there is evidence throughout this thesis supporting the influence of emotional content on performance in the experiments reported here. Examples of this include affective modulation of IOR in Section 2 and the presence of emotional compatibility effects in Section 3. Moreover, speeded responding was observed for emotional versus non-emotional target conditions in the experiments reported throughout the first and second sections of this thesis. Additionally, the influence of expected value in cued trials on facilitation, IOR, and performance in the face localisation task in Experiment 11 supports the processing of stimulus content in these tasks. Nevertheless, the principal finding of thesis converges with existing studies that have demonstrated the mechanisms underlying IOR are blind to the content of stimuli present in the visual environment (Avila & Parcet, 2001; Lange et al., 2008; Taylor & Therrien, 2005; Stoyanova et al., 2007).

Attentional or motoric IOR?

IOR has been conceptualised as having both an attentional and a motoric locus (Hunt & Kingstone, 2003; Kingstone & Pratt, 1999; Sumner, 2006; Sumner et al., 2004; Taylor & Klein, 2000). Recall that the traditional view of IOR is an attentional one, with IOR generated by visual attention orienting to and withdrawing away from the location of a non-predictive spatial cue. However, the motoric view instead posits IOR as reflecting a reluctance or inhibition to respond to a cued location or object. Hunt and Kingstone (2003) demonstrated that these two flavours of IOR could be dissociated at the level of the response mode: IOR is evident in the attentional system when a manual response is required; however, IOR is manifested through the motor system when a saccadic response is required (see also Kingstone & Pratt, 1999; Taylor & Klein, 2000).

In the experiments reported here, a manual response was always employed to localise target stimuli. This would suggest that IOR was generated through the attention system. However, although participants were instructed not to move their eyes and to maintain central fixation, eye-movements were not otherwise constrained in the experiments reported here. Indeed, when the eyes are free to move, it is more likely that

IOR reflects a reluctance to respond rather than the inhibition of attention (Taylor & Klein, 2000). The decision not to restrict eye-movements in the experiments reported here was advantageous in one sense, being more representative of natural viewing conditions and increasing the ecological validity of the results obtained. However, there was no objective confirmation that participants did not move their eyes, adding variance to these results. Compensating for this was two design details employed to dissuade eye-movements. The first approach was the inclusion of multiple SOAs (short and long) in the majority of the experimental designs, providing no temporal information regarding target onset. Thus, eye-movements toward the cue location would disadvantage performance in the shorter SOA conditions. The second approach was to ensure cue and target stimuli remained in relatively close spatial proximity to central fixation, rendering eye-movements unnecessary to localise the target stimuli. Nevertheless, eye-movement restrictions were also not employed by previous studies exploring the sensitivity of IOR to biologically and emotionally relevant stimuli, studies that found both sensitivity (Fox et al., 2002; Yiend & Mathews, 2001) and insensitivity (Avila & Parcet, 2001; Lange et al., 2008; Taylor & Therrien, 2005; 2008) in measuring IOR to cue and target content. However, to be confident in the locus of IOR generated across all these experiments (in this thesis and in published research), conditions under which manual (eyes fixed) and saccadic (eyes move) responses are employed in the presence of emotional stimuli would be required.

The nature of IOR

Irrespective of whether the mechanisms underlying IOR in these experiments were attentional or motoric in nature, the results I report provide more detail to understanding the nature of the IOR effect and visual orienting more broadly.

The functional nature of IOR has been conceptualised as promoting novelty in vision, preventing the preservative processing of previously examined locations and objects (e.g., Handy et al., 1999; Klein, 1988; Posner & Cohen, 1984). Indeed, finding emotionally charged stimuli produced null effects on the magnitude of IOR converges with this principal: IOR biases vision toward novelty even in the presence of threat-relevant and appetitive stimuli presented as cues and targets. Therefore, these inhibitory mechanisms of visual orienting seem ballistic in their existence, functioning to guide vision towards novel locations and objects at the expense of not detecting emotionally significant information.

The absence of stimulus-driven emotional modulation of IOR is also consistent with the notion that pre-cuing a location or object changes the criterion to respond there in future encounters (Ivanoff & Klein, 2006; Ivanoff & Taylor, 2006; Klein & Taylor, 1994). Consequently, it would seem that once IOR is generated, a criterion to respond to the cued location is established. Only when sufficient information is accrued to confirm the target's presence can a response to its location be successfully executed. Evidence to support this notion comes from Sections 2 and 3. Emotional information present in the visual scene did not influence the IOR effect when presented in target stimuli requiring localisation during pseudorandom presentation amongst neutral target stimuli (Experiments 1 – 6). That is, once a criterion to respond is initiated from cue onset, not even emotionally relevant information can override its existence. Further, facilitated responding to emotionally compatible stimuli in the absence of any interaction with IOR indicates that once the target stimulus reaches this criterion necessary to respond, response related processes (such as response compatibility effects) can then occur as normal (Experiments 7 – 10).

These results are also of interest when considering the proposal that IOR facilitates foraging behaviour (Klein, 1988; Klein & MacInnes, 2001; Thomas et al., 2007). Recall that the inhibitory consequences of spatial cuing were believed to facilitate sampling of the visual environment, biasing vision toward novelty (Posner & Cohen, 1984). Subsequent research demonstrated IOR effects occurring in visual search tasks (notably Klein, 1988, but see also Klein & MacInnes, 2001; MacInnes & Klein, 2003; Müller & von Mühlenen, 2000; Thomas et al., 2007), developing the idea that IOR is more of an adaptive mechanism of real world search.

Although the experiments reported in this thesis did not set out to investigate this hypothesis, these results are informative to foraging accounts of IOR. At a very basic level, if the mechanisms underlying IOR serve to underscore visual foraging behaviour, then this hypothesis would predict modulation of the IOR effect measured in appetitive target conditions. Indeed, if an irrelevant spatial cue automatically oriented vision to a location where no food (target) was present, IOR should be larger than when the same cue oriented vision to a location when searching for a neutral target. This would encourage orienting to novel locations, increasing success of finding food, an irrelevant need when localising neutral stimuli. However, in disagreement with this were the results of Experiment 6, where successive exposure to appetitive stimuli instead reduced the magnitude of the IOR effect in contrast to neutral stimuli. Moreover, the size of the IOR effect was equivalent between conditions employing appetitive and neutral target stimuli in Experiment 9, when a temporal delay was introduced between successful target exposures. Therefore, the results presented here do not necessarily provide convincing evidence to support a foraging account of IOR. However, foraging for food is one example of where IOR sensitivity to stimulus content may be expected, and in the task reported here, finding (or localising) the food image did not constitute finding food. Indeed the mechanisms underlying IOR may reflect more foraging for novel visual information rather than for adaptive information (i.e., food and water sources, shelter), converging with the principal finding of this thesis that target content *per se* does not modulate IOR.

Attention, IOR, and emotion interactions

In Chapter 2, I described the literature suggesting that emotional stimuli are especially salient, modulating perceptual and attentional processes. Attention and emotion systems, although believed independent, interact and have overlapping neural substrates (Vuilleumier et al., 2003). The interaction between these two systems is advantageous, facilitating the prioritisation of visually important events. Indeed, multiple paradigms including the attention blink (Anderson, 2005; Anderson & Phelps, 2001), visual search (Brosch & Sharma, 2005; Eastwood et al., 2001; Fox & Damjanovic, 2006; Fox et al., 2007; Öhman et al., 2001), and dot-probe tasks (Armony & Dolan, 2002) have been employed to investigate the nature of interactions between attention and emotion. The conventional finding here is that emotionally relevant stimuli facilitate responding (accuracy and response times) in contrast to neutral stimuli. Prior exposure to emotional stimuli also serves to enhance perceptual processes (Dijksterhuis & Aarts, 2003; Phelps et al., 2006; Tipples et al., 2008; Zeelenberg et al., 2006).

Consistent reports that emotionally charged stimuli facilitate visual cognitive processes provided empirical support for the adaptive hypothesis of IOR presented here. Indeed, it seemed very likely that the mechanisms underlying IOR would be sensitive to both emotional cue and target stimuli. Consequently, the null effects of emotion on the magnitude of IOR reported in this thesis were surprising. Emotional information seemed unable to break through inhibitory tags at spatial locations when presented as targets, and emotional information did not influence the generation of IOR when presented as cues. In the former case, the nature of response to the target may be important (Geoff Cole, Carolina Pérez Dueñas, personal communications), with IOR and emotion interactions occurring only when target content is relevant to the task (as in a discrimination response). Therefore, it is not the presence of emotion that is important here, but the need to process emotion in order to be successful in the task. This raises an interesting theoretical convergence with the proposal that attention is required to process the emotional content of visual stimuli to reveal significant processing benefits, in contrast to non-emotional stimuli (Pessoa, 2005; Pessoa et al., 2002; Silvert et al., 2007).

In the case of emotional cues, perhaps any effect of their content dissipated with the long SOA (1500 ms) employed in the experiments reported here, and this would certainly explain the dissociation between the effects of motivational cues between the short and long SOA conditions in Experiment 11. Recall that these cues impaired cuing benefits, leaving IOR unaffected. Perhaps emotional cues would modulate the generation of IOR if the time interval between cue and target was reduced. Although Stoyanova et al. (2007) employed a range of SOAs (500 – 1500 ms); IOR did not change as a function of this time course manipulation. However, perhaps 500 ms is still too long after cue processing to observe any modulation of IOR by cue content. As described in Chapter 1, endogenously directing attention away from a cued location can reveal IOR at a very short SOA (50 ms; Danziger & Kingstone, 1999). Future research investigating IOR sensitivity to emotional cues would benefit from employing this endogenous cuing procedure with shorter cue-target intervals.

Although the mechanisms underlying IOR were found to be insensitive to the emotional content of visually presented stimuli, the findings of Experiments 12 – 16 suggest an interaction between the mechanisms underlying IOR and the mechanisms responsible for affective stimulus evaluation. Specifically, I found evidence that stimuli presented at previously cued locations were evaluated as more negative than stimuli presented at uncued locations, consistent with a devaluation by inhibition hypothesis (Fenske & Raymond, 2006). This devaluation effect may serve to reduce the saliency of stimuli presented at previously examined locations, preventing the return of attention there (Raymond et al., 2003). Further, finding emotional consequences of inhibition also converges with the notion that IOR may serve to influence stimulus selection processes (Ivanoff & Taylor, 2006), and devaluation effects may be representative of this. Consequently, the mechanisms underlying IOR appear to act on both the orienting system and the affective system, and do not necessarily function independently of emotion.

Finally, the principal finding of this thesis was the absence of stimulus-driven emotional content on the generation and measurement of IOR, with top-down contextual affect instead being crucial to the modulation of the IOR effect. As described in Chapter 6, the transient nature of this contextual influence on IOR unlikely reflects changes in mood; and with inconsistencies in speeded response times to emotional and neutral target stimuli and IOR effects, a purely arousal-based mechanism also seems an unlikely source of the IOR modulation reported here. This presents an interesting challenge for future research to probe the nature of this affective contextual phenomenon in influencing visual orienting. First, it would be necessary to establish whether changes in affective context in the absence of visual sources of emotion (i.e., emotional images) can influence the IOR effect; for example, by increasing the stress level of participants prior to, and during, visual orienting tasks.

Second, the link between affective context, arousal, and emotion would need to be concreted. It may well be the case that to observe changes in affective context, emotional stimuli need to be sufficiently arousing. That is, affective context is determined by both emotional valence (positive, negative) and arousal. Indeed, researchers such as LeDoux (1998) advocate that emotional stimuli should be termed affective stimuli, incorporating both the valence and arousal values these stimuli afford. This distinction is not only important to the research described here, but also any research involving manipulations of emotion. As stated previously (Chapter 2), performance related biases are typically observed during conditions employing negative or threat relevant stimuli, with less consistency in the influence of more positively valenced stimuli on task responding. Negative stimuli are generally more arousing than positive stimuli, and when more arousing positive stimuli are employed in tasks, equivalent biases are seen in performance between the two valences (relative to neutral; Anderson, 2005; Anderson et al., 2003). Therefore, precision in manipulating and measuring both the valence and arousal values of stimuli should be encouraged to further understand how these properties contribute to and interact with visual cognition.

Motivation and attention

Although this thesis employed emotional stimuli as cues and targets, the stimuli presented in Experiment 11 were also motivationally relevant. Participants learned the expected value of visually presented stimuli prior to their presentation in a spatial cuing task. Learning stimulus value is advantageous in providing an objective measure of stimulus saliency in experimental paradigms. Moreover, manipulating the expected value of stimuli may be reflective of existing neural codes that enable contrasts between stimulus selections and outcomes (Montague & Berns, 2002; Pessiglione et al., 2002). Although research in this area has primarily been interested in the neurophysiology of learning the expected value of stimuli (e.g., Gallagher et al., 1999; Knutson et al., 2001; 2005; Schoenbaum et al., 1998; Schultz et al., 1997), Experiment 11 and the study described by Raymond and O'Brien (under review) investigates the consequences of expected value to visual cognition. This approach enables direct comparisons to be made between the mechanisms underlying attention and the mechanisms underlying reward, and motivation more broadly.

Recently, Maunsell (2004) claimed that measures of reward and attention are frequently confounded, drawing support for this claim from single-cell recording studies that show similar patterns of results. For instance, Maunsell (2004) describes a study where activity was recorded in the lateral intraparietal (LIP) region whilst monkeys were cued to saccade to different spatial locations. Activity was greater in the LIP neurons when monkeys executed a saccade to stimuli associated with larger rewards than when executing a saccade to stimuli associated with smaller rewards. The authors of this study (Platt & Glimcher, 1999) interpreted their finding as evidence that LIP neurons encoded reward outcome. However, an alternative explanation highlighted by Maunsell (2004) is that more attentional resources may be allocated to locations that are more rewarding than locations likely to be less rewarding. Therefore, it is unclear whether increasing activation in the LIP recording study (Platt & Glimcher, 1999) reflected neural activity related to attention or reward. Indeed, Maunsell (2004) speculates that the neural mechanisms underlying reward and attention may be the same, if defining reward in a motivational sense. That is, if motivation is considered as encompassing focus to task-relevant locations, objects, and behaviours, all inherently rewarding in achieving the task at hand, then motivation and attention may be one in the same thing. This notion provides an interesting approach for future research and suggests a degree of caution when interpreting results in terms of processes underlying either reward or attention.

Future considerations

Although the experiments reported here are informative in exploring the sensitivity of IOR to emotion, I would embark on a number of additional studies to really concrete this research area. Although I have outlined specific details in each Section Discussion, more global considerations are needed here too.

First, at a paradigm level, further manipulation of the components in the spatial cuing task would be beneficial. A localisation task was employed throughout the experiments reported in this thesis, and only very recently were discussions about the nature of the response mode in changing the sensitivity of IOR to emotion held. Nevertheless, it would be necessary to replicate the experiments reported here using a discrimination response, in addition to the localisation response, to ascertain whether IOR is truly insensitive to the emotional content of target stimuli as the experiments reported here imply. In the context of this thesis, I found the mechanisms underlying IOR were unaffected by the presence of emotion; however, this principal may not hold when employing different response tasks, and it would be the goal of future research to establish any conditions where, and indeed why, IOR may be modulated by the emotional content of target stimuli in contrast to the results reported in this thesis. Related to this would be completing additional studies (using both localisation and discrimination responses) with the value learning paradigm, employing stimuli with controlled expected value as targets to further understand whether these stimuli influence IOR any differently to emotional stimuli. Moreover, although IOR was the principal interest here, these studies would also explore these issues employing both short and long SOA conditions to measure facilitation as well as inhibitory effects of spatial cuing on target responding.

Second, as described above, I would also run a series of studies employing motivational and emotional cue and target stimuli employing precise control over eye-movements. I would compare conditions under which saccades were executed as the task response, as well as when the eyes remained fixed and only manual responding was employed. This would be informative in understanding whether the attentional and occulomotor mechanisms of visual orienting are differentially affected in the presence of emotion.

Third, the studies reported throughout this thesis would benefit from additional measures of neurophysiology to accompany the interpretation of the behavioural data presented. For instance, to verify changes in affective contextual state during successive exposures to emotional stimuli (Sections 2 and 3), it would be interesting to simultaneously record potential neurophysiological indexes to accompany changes observed in the behavioural results. Moreover, I hypothesised that the apparent spatial interference effect of cue and target presentations in Experiment 11 may manifest in the OFC. To test this hypothesis, it would be necessary to record functional areas of activation under the same spatial cuing conditions that this experiment reveals measurable behavioural consequences of expected value.

Fourth, in this thesis, individual differences were not manipulated as a variable of interest. Although only low spider fearful individuals participated in experiments employing these stimuli, manipulations in this level of fear, as well as anxiety level when employing emotional faces, may prove fruitful in future research to look at the boundary conditions of the influence of emotion on visual orienting. However, to understand fully the contribution of these individual differences, it would be necessary to measure visual orienting in the absence of emotional stimuli, in addition to orienting behaviour in their presence.

In summary, this thesis investigated IOR as a consequence of visual orienting in the presence of emotion. Visual orienting is fundamental to interactions with the visual world, facilitating the prioritisation of task-relevant information. The apparent reflexivity of the inhibitory mechanisms contributing to visual orienting suggests that the drive to sample novel locations and objects takes priority over the drive to detect emotionally and motivationally significant events. This raises an interesting issue regarding stimulus salience, and to what extent emotional stimuli are prioritised for visual processing when they are task-irrelevant. Interestingly, these inhibitory mechanisms are not independent of the affective system, with evidence that inhibition to a location devalues the emotional quality of stimuli presented there. This converges with the functional nature of orienting inhibition, facilitating vision toward novelty by decreasing the saliency of stimuli and locations in previously examined regions of space.

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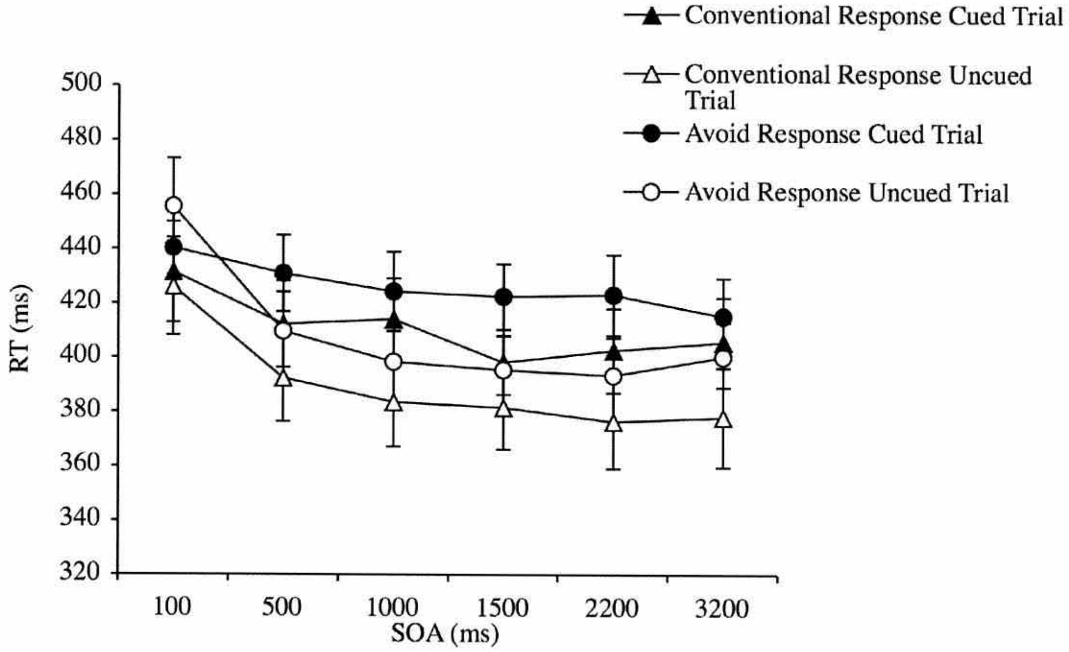
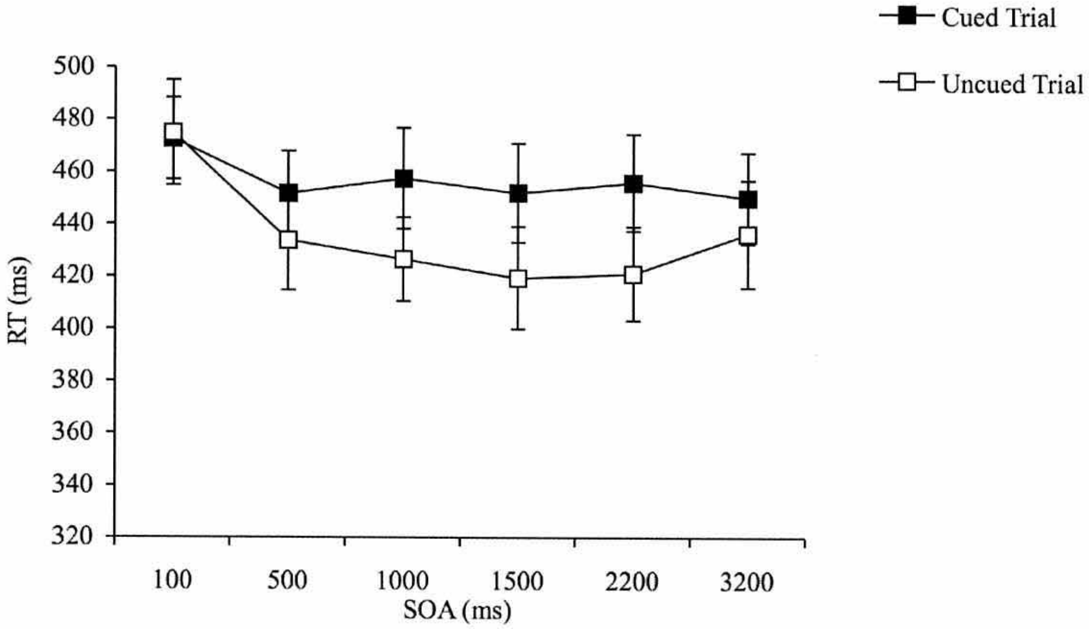
Appendix

Supplementary Figure 1



Supplementary Figure 1A. Group mean RT obtained in Experiment 7 for localising an asterisk target with either a conventional or avoidance key response, plotted as a function of SOA. Vertical error bars indicate +/- 1 S.E.

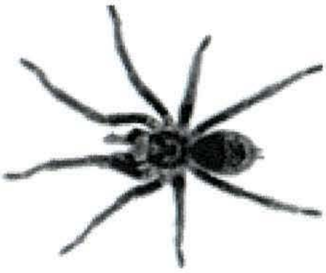


Supplementary Figure 1B. Group mean RT obtained in Experiment 7 for localising a complex target with an avoidance response, plotted as a function of SOA. Vertical error bars indicate +/- 1 S.E.

Appendix A: Examples of Stimuli

Experimental Sections 2 and 3

Spider Exemplars



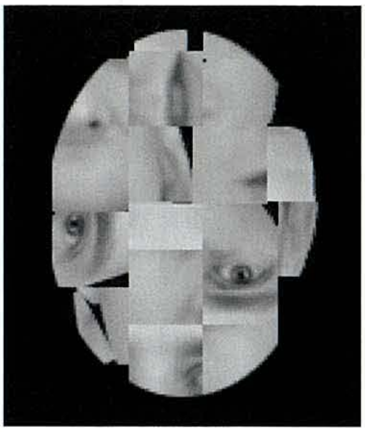
Object Exemplars

Sweet Food Exemplars (also used in Experiment 9 and 12)

Ekman Exemplars

Experimental Section 4

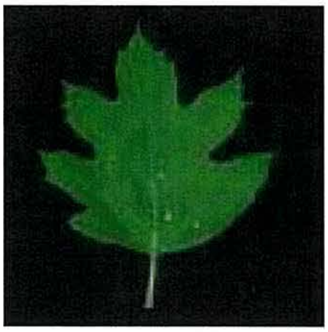
Value Learning Exemplars



Experimental Section 5

Spider Exemplars

Leaf Exemplars



Appendix B: Breakdown of methodological differences and results for the five studies described here exploring IOR sensitivity to emotional cue stimuli.

	Fox et al. (2002)	Yiend & Mathews (2001)	Stoyanova et al. (2007)	Lange et al. (2008)	Avilia & Parcet (2002)
Participant details	E2 = 48 25 high anxious 23 low anxious E2 = 48 25 high anxious 23 low anxious	N = 40 Group divided into high and low anxious groups, numbers not specified	E1 = 13 E2 = 29	E1 = 54 E2 = 23 Spider Fearful, 24 controls E3 = 18 high anxious 22 low anxious	N = 76 High and low anxious division, but not specified
Measures	STAI trait anxiety	STAI trait and state anxiety scale Beck Depression Inventory Social desirability questionnaire	No measures	Spiders = FSQ, SAS, BAT Anxiety = LSAS (used for grouping), STAI, SCL-90	Sensitivity to punishment and sensitivity to reward questionnaire
Cue stimuli	E1: Schematic face cues: angry, happy, neutral E2: Schematic face cues: angry, jumbled angry, neutral	60 threatening 60 non-threatening 60 filler pictures (all sourced from IAPS)	36 fear faces 36 neutral faces 36 luminance patches (all Ekman face stimuli)	Butterfly, cross, spider (one exemplar) Happy, angry, neutral photograph (one male and one female)	Eight threat-related words Eight neutral word
Target stimulus	Dot (in lower half of box)	Arrow heads pointing up or down	Square	Dot	Asterisk

(continued)	Fox et al. (2002)	Yiend & Mathews (2001)	Stoyanova et al. (2007)	Lange et al. (2008)	Avilia & Parcet (2002)
Task	Localisation (left/right)	Discrimination (Up / Down)	Localisation (left/right)	Detection (present/absent)	Detection
Cue exposure duration	300 ms	2000 ms Remained on throughout trial	300 ms	100 ms	1000 ms Remained on throughout trial
SOA	960 ms	2000 ms	E1 - 900 ms E2 - 500, 1000, 1500 ms	150, 250, 550 ms, only analysed 550 ms	100 ms, 500 ms
Cue instructions	Cue location is not predictive	Picture cue indicated most likely target location	Cue location and type were not predictive	Focus on centre	Varied conditions, but in IOR task, no instructions about cue validity
Results	E1: IOR reduced for angry face cues, no difference between high and low anxious groups E2: IOR reduced for angry and jumbled angry face in high anxious group	IOR disrupted by threat cues Occurred in both high and low anxious groups, seemed to be mediated by uncued trial differences	No modulation of IOR by emotion in either experiment	No modulation of IOR by emotion by any group or cue type	IOR unaffected by emotion

Abbreviations: E - Experiment, N - sample size, STAI - Speilberger State-Trait Anxiety Inventory, FSQ - Fear of Spiders Questionnaire, BAT - Behaviour Assessment Task, LSAS – Liebowitz Social Anxiety Scale, SCL-90 – Symptom Check List 90.

Appendix C: Spider Questionnaire

1.) Do you describe yourself as:
   (a) not at all fearful of spiders
   (b) low fearful of spiders
   (c) highly fearful of spiders
   (d) clinically phobic of spiders

2.) How do you feel if there is a spider in the same room as you?
   (a) it doesn't bother you, so you ignore it and stay in the room
   (b) you'd rather not have it in the room so remove it yourself
   (c) you feel uncomfortable and get someone else to remove it for you
   (d) you feel frightened and get someone else to remove it for you

3.) Have you any detailed knowledge of spiders?
   (a) yes
   (b) no

4.) Do pictures or photographs of spiders make you anxious?
   (a) yes
   (b) no

5.) Do you encounter many spiders, either in your house / workplace or outside?
   (a) yes
   (b) no

6.) Which word best describes how spiders make you feel:
   (a) petrified
   (b) frightened
   (c) uncomfortable
   (d) indifferent