Affective influences on top-down visual attention

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Declaration

I declare that this thesis is my own original work and has not been submitted, in whole or in part, in any previous degree award. The thesis is presented in the alternative format including ten articles that are either published, currently under review or in preparation. I confirm that appropriate credit has been given below in respect of multiple author publications.

Signed,

R. Bendall

Robert C. A. Bendall

Paper contributions

Chapter One

Bendall, R. C. A., & Thompson, C. (2015). Functional near-infrared spectroscopy: An emerging neuroimaging technique successful in studying the interaction between emotion and cognition. *PsyPAG Quarterly*, 96, 14-17.

RB conceived and designed research, manuscript preparation and manuscript editing. CT manuscript editing.

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RB review concept, verification of analytic methods, main conclusions, article drafting. PE verification of review concept, conclusion verification, proof reading. CT verification of review concept, verification of analytic methods, conclusion verification, article drafting.

Chapter Two

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Chapter Four

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Chapter Five

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Chapter Seven

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RB conceived and designed research, drafted manuscript, edited and revised manuscript.

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Abbreviations

AB – attentional blink

ANOVA – analysis of variance

BD – bipolar disorder

Deoxy-Hb – deoxygenated-hemoglobin

dlPFC – dorsolateral prefrontal cortex

EEG – electroencephalography

ER – emotion regulation

FEF – frontal eye field

fMRI – functional magnetic resonance imaging

fNIRS – functional near-infrared spectroscopy

IAPS – International Affective Picture System

ISI – inter-stimulus interval

MDD – major depressive disorder

mPFC – medial prefrontal cortex

MRPFC – medial rostral prefrontal cortex

NEO-PI-R – Revised NEO Personality Inventory

NIRS – near-infrared spectroscopy

nm – nanometers

oxy-Hb – oxygenated hemoglobin

PANAS – Positive and Negative Affect Schedule

PFC – prefrontal cortex

RT – reaction time

SAD – social anxiety disorder

vlPFC – ventrolateral prefrontal cortex

WM – working memory

Abstract

The mechanisms supporting emotional processing and the allocation of visual attention share common neural substrates and both draw upon limited top-down resources. Attention is biased towards emotional stimuli and these biases are suggested to be a key mechanism in the development of psychopathology. The aim of this thesis was to investigate the impact of affective influences on visual attention. This was achieved using three different approaches: exploring the impact of emotion, the effects of stimuli valence, and the contribution of inter-individual differences in affective traits. Across five experiments, two experimental paradigms incorporating real-world scenes were utilised: a change detection flicker task, and a visual search task. In two experiments prefrontal cortex activity was recorded using functional near-infrared spectroscopy. Overall, when considered in isolation, induced emotion had no impact on attention. However, negative emotion did influence prefrontal cortex activation. Moreover, induced emotion was shown to interact with extraversion and cognitive reappraisal to influence attention. In addition, when considering stimuli valence, accuracy to identify targets was reduced in task-irrelevant positively-valenced real-world scenes, and target identification was slower in negatively-valenced real-world scenes, suggesting that negative and positive emotional valence impact attention in different ways. Moreover, higher trait levels of extraversion, cognitive reappraisal and expressive suppression were shown to improve visual search performance. These findings suggest that emotion may not have a direct influence upon attention conflicting with theoretical models that argue for the impact of emotion on attention. Additionally, the findings reveal direct and interactive effects of affective traits on visual search, supporting the argument that inter-individual differences influence the competition between emotion and attention for top-down resources. These findings are discussed in relation to models of emotion-attention interactions. They provide novel insights into the attentional processing of healthy individuals and have implications for clinically focussed research investigating the psychopathology of affective disorders.

Chapter One: General Introduction

1.1. Overview of Chapter One

Our visual attention is essential in allowing us to conduct every day perceptual tasks. Of great interest to both fundamental and clinically focussed psychologists is the relationship between emotion and visual attention, as our affective experiences influence what information we focus on and how we interact with our visual world. Emotion can impact whether we focus on the individual trees or the forest as a whole (Fredrickson & Branigan, 2005), whilst our attention influences our ongoing affective experience and our interactions with emotional information within our environment (Ochsner et al., 2009). Emotion can impact our well-being and alter the availability of cognitive resources which may in turn compound the detrimental effect of emotion on our psychological health. Consequently, it is important to understand how emotion influences cognition, including visual attention, so these mechanisms can be accounted for and potentially mitigated. The work presented within this thesis addresses affective influences on attention.

Definitions of emotion are still debated by researchers (e.g. Gross, 2015; Lindquist et al., 2013; Panksepp, 2007). Within the literature the terms emotion and mood are used interchangeably, although they can be distinguished from one another. Emotions such as happiness, anger and sadness are often intense and short-lived produced by events that result in specific behavioural response tendencies (Gross, 2015). In contrast, moods such as feeling grumpy have a longer duration as well as reduced intensity and are infrequently caused by a specific event (Beedie et al., 2005; Larsen, 2000; Vanlessen et al., 2016). Moreover, compared to moods, emotions are more closely associated with physiological responses such as changes in heart rate and neural activity (Dolcos, Katsumi, et al., 2020). Affect can be conceptualised as an umbrella term for psychological states involving value-based discrimination/subjective feelings (positive/good or negative/bad) for which both emotions and moods are included (Gross, 2015). The literature describing affective influences on visual attention describes both emotions and moods, and often uses these terms interchangeably. Therefore, the literature discussed throughout the thesis includes research related to emotions and moods. Due to the current thesis investigating both behavioural changes in selective visual attention and simultaneous changes in neural activation, within the context of brief manipulations of psychological states within the laboratory, the term emotion is used to describe these momentary changes in psychological states in relation to their influences upon selective visual attention.

The focus of the current thesis concerns affective influences on top-down selective visual attention. More specifically, the author will investigate the impact of emotion on selective visual attention, that is, whether the emotional state of an individual impacts top-down selective visual attention. Secondly, the influences of the emotional content of real-world scenes on selective visual attention will be investigated. Additionally, the possible mitigating role of affective individual difference traits on the relationship between emotion and/or emotional stimuli during top-down selective visual attention will be considered, as well as the involvement of the prefrontal cortex (PFC) during emotional top-down selective visual attention. To introduce these topics the current chapter will provide a detailed review of the relevant literature. Initially, this will include an overview of selective visual attention. Following this, the review focuses on research that has investigated the role of emotion in selective visual attention in relation to a key theoretical framework – the broaden-and-build theory. Subsequently, research concentrating on the ability of emotional stimuli to bias selective visual attention will be discussed. Next, the neural mechanisms underpinning visual attention will be introduced. The current thesis is presented in the alternative/journal format and includes ten papers. The first two papers are included in this introductory chapter. The first paper provides a review of the suitability of functional near-infrared spectroscopy (fNIRS) as a neuroimaging technique to study emotion-cognition interactions. The second paper provides a review of recent fNIRS research that has investigated emotional processing. Subsequently, the main aims and objectives of the thesis will be presented, followed by a summary of the contents of each Chapter.

1.2. Emotional influences on selective visual attention

1.2.1. Selective visual attention

Due to the complexity of the visual world it is impossible to attend to all items and areas of the visual field simultaneously. Therefore, priority is given to the most relevant areas or objects within a scene enabling ongoing adaptive behaviour and survival (Driver & Baylis, 1989; Schneider & Shiffrin, 1977). This ‘biasing’ of attentional resources away from task-irrelevant information and towards task-relevant information is known as selective visual attention, and it is subject to a range of influences. Attention is dependent upon top-down processing (endogenous attention) characterised by goal-directed behaviour including the allocation of attention to stimuli matching target-defining properties as well as the inhibition of distractors (Posner, 1980; Schneider & Shiffrin, 1977). Conversely, bottom-up processing (exogenous attention) is characterised by the automatic capture of attention by salient information in the environment regardless of ongoing task requirements (e.g. Itti & Koch, 2000; Jonides & Yantis, 1988). However, it should be noted that it has also been suggested that all attentional processing cannot be sufficiently explained solely by traditional top-down and bottom-up processing (Awh et al., 2012; Failing & Theeuwes, 2018; Theeuwes, 2019; Zhao et al., 2013). For instance, it is suggested that attention can be biased by statistical irregularities learned over time that are unable to be explained by either top-down or bottom-up processing (Zhao et al., 2013). Additionally, it has also been argued that selective attention is influenced by learned associations between stimuli and rewards resembling a value-driven mechanism of attentional selection (Anderson, 2013). Moreover, a history-driven selection process has also been proposed whereby previous selection biases can influence future selective attention (Theeuwes, 2019).

When individuals experience an emotional situation, or are presented with emotional information, it is argued that top-down processing and bottom-up processing strategies are also evident. For example, emotion and emotional stimuli may influence attention in a bottom-up manner, whilst simultaneously top-down cognitive control mechanisms may be initiated by individuals to direct resources towards emotion regulation (ER; Buhle et al., 2014; Ochsner et al., 2009; Ochsner et al., 2012). It has therefore been argued that emotion interacts with top-down and bottom-up processing and presents a further influence on selective visual attention.

1.2.2. Influences of emotion on selective visual attention

Despite most individuals being aware of the pleasant experience that positive emotion confers, much less well known are the effects of positive emotion on a range of resources. For instance, positive emotion increases psychological resources (Fredrickson et al., 2003; Tice et al., 2007), intellectual resources (Isen, 1993; Isen et al., 1987; Leslie, 1987), physical resources (Burton & King, 2009; Danner et al., 2001) and social resources (Aron et al., 2000; Berry & Hansen, 1996). The processing of emotional information helps us to encode sensory information as well as modify perception and alter ongoing behaviour, and it has been argued that the benefits of positive emotion are a consequence of a broadened attentional scope (Fredrickson, 2001; Fredrickson et al., 2003; Xu et al., 2015).

One of the most influential theoretical models in this area is the broaden-and-build theory (Fredrickson, 1998, 2001). It proposes a framework whereby the many influences of positive emotion on cognition and behaviour, including visual attention, can be accommodated. The theory posits that positive emotions, such as love, pride, joy, interest and contentment, can create a broadening of ‘‘thought-action repertoires’’ and ‘‘build’’ individual’s ‘‘enduring resources’’. Such resources include those mentioned above, although the focus within this thesis relates specifically to attentional resources. The broaden-and-build theory proposes that, over time, the experience of positive emotion has a cumulative impact allowing an individual to become more creative, knowledgeable, resilient, socially integrated and healthy, thus providing resources that can be used when necessary in the future. Whilst the theory is mainly focussed on the influence of positive emotion, Fredrickson postulates that negative emotions have the opposite effect, preventing an individual from broader thinking and the development of lasting psychological reserves. However, the theory focuses on the beneficial impact of emotion. For example, Fredrickson and Branigan (2005) propose that the experience of positive emotions have an evolutionary advantage over time as they increase available resources, whereas negative emotions confer an evolutionary advantage ‘‘in the moment’’ as they permit an individual to focus on a threat and their subsequent behavioural response.

Initial research investigating the proposed impact of emotion on the breadth of attention adopted the global-local processing task (Navon, 1977, 2003). This task involves the presentation of large letters (global stimuli) that are composed of smaller letters (local stimuli) where participants are required to respond to either the global or local feature. Experiments using this task frequently show a global-precedence effect demonstrating faster responses at the global level. Additionally, response times are slowed when local features are incompatible with the global feature. Research has shown that negative moods promote a local processing style, whereas positive moods lead to a global processing style being adopted (Basso et al., 1996; Derryberry & Tucker, 1994; Fredrickson & Branigan, 2005; Gasper & Clore, 2002). Additionally, whilst individuals with lower levels of depression show the expected global processing bias, individuals with higher levels of depression show a reduced global processing bias (de Fockert & Cooper, 2014). These findings are argued to show that positive emotion broadens attentional resources. However, the global precedence effect suggests that a global processing style is the preferred processing style (Fiske & Taylor, 1991). Secondly, additional resources are required to process information at a local level, and this does not fit with the premise that the scope or breadth of attention expands due to positive emotion. Moreover, the use of a global-local task does not allow the investigation of any potential broadening or narrowing of *visuospatial* attention.

However, additional research supporting a broadening of attention due to positive emotion has been provided using different methods. For instance, when simultaneously presented with images in the centre and periphery of a display, participants induced in a positive mood state made additional fixations on the peripheral stimuli compared to individuals in a neutral mood state (Wadlinger & Isaacowitz, 2006). Whilst the authors interpret this finding as showing a broadened attentional scope due to positive emotion, the analytical framework failed to take account of fixations made to items located in the centre. The broaden-and-build theory proposes that positive emotion increases the resources available to an individual (rather than simply allocating information to the periphery at the expense of processing information presented centrally). Without the inclusion of centrally located comparisons it is not known whether positive emotion increased the amount of available resources overall, or biased attention to conduct peripherally based search at the expense of centrally focussed search. Moreover, the observation of increased fixations to peripheral stimuli in a positive mood was only evident when the stimuli in the periphery were also positive, showing a congruency effect.

Additional studies investigating a broadening impact of positive emotion on visual attention have adopted a modified version of the flanker task (Eriksen & Eriksen, 1974). In the flanker task participants are required to focus on a centrally located target whilst ignoring peripherally located distractors (flankers) located either side of the target. It is suggested that when the flankers are compatible with the target, they create less interference compared to when the flankers are incompatible (evidenced by changes in reaction time; RT). When in a positive mood, if attention is broadened, peripherally located distractors should have a greater impact (increased distraction and RTs) compared to when in a neutral mood. Rowe et al.

(2007) manipulated the distance of the flankers and showed that positive mood slowed RT to peripherally located targets when participants were in a positive mood compared to neutral and negative moods. This finding is complemented by the observation that experimentally inducing a broadening of attention has been shown to decrease (improve) sad and depressed mood in individuals (Gu et al., 2017). However, a number of studies adopting interference tasks such as the flanker task have subsequently shown no influence of positive emotion on selective visual attention (e.g. Jiang et al., 2011; Martin & Kerns, 2011; Wegbreit et al., 2015). Moreover, a precise replication of Rowe and colleagues' study failed to show any broadening of attention as a result of positive mood (Bruyneel et al., 2013). Therefore, it remains an ongoing debate as to whether positive emotion broadens visuospatial attention.

An alternative explanation accounting for the influences of positive emotion on attention has been suggested by Huntsinger (2012, 2013). Participants initially completed a global-local priming task followed by a traditional flanker task and a modified flanker task. It was demonstrated that the links between mood and attentional focus are not related to either a broadening of attention under positive mood or a narrowing of attention under negative mood. Instead, it was suggested that the link between mood and attentional focus reflects the current momentary focus of the individual. Specifically, when a global focus was primed in participants, individuals in positive moods displayed a broadened attentional focus whilst those in a negative mood showed a narrowed attentional scope in the flanker task. Conversely, when a local focus was dominant, this relationship was the opposite with individuals in a positive mood displaying a narrowed attentional focus and those in a negative mood showing a broadened attentional focus. Moreover, when neither a global or local focus was superior there was no relationship between mood and attentional scope. These findings add to idea that the influences of emotion on attention are not as simple as the broaden-and-build theory suggests.

One aspect related to the study of emotional influences on attention which has received surprisingly little research focus is visual search. Grubert et al. (2012) presented participants with a stimuli array consisting of green vertical bars. Target items differed to the array items in respect of their colour (a red or blue vertical bar) or their orientation (a green bar rotated by 45 degrees). Participants in a negative mood displayed slower RTs to identify search targets compared to individuals in a positive or neutral mood. Moreover, participants in neutral and positive moods, showed dimension-based but not feature-based intertrial effects. It is argued that the difference observed in feature-related search on the basis of participant mood can be explained by the level of information processing; that is, participants in a positive mood based their responses on the presence of a salient difference, whilst individuals in a negative mood used the identity of the target item to guide their response. The findings suggest that mood influences processing depth during visual search via the mechanisms of feature-based attentional selection, and support earlier studies suggesting that negative mood may lead to a narrower attentional focus (e.g. Derryberry & Tucker, 1994; Rowe et al., 2007).

A recent study that has also investigated emotional influences on visual search adopted an experience sampling procedure. Here, participants self-reported their happiness levels before completing two visual search tasks on their smartphone (Maekawa et al., 2018). The first task was a replication of that used by Treisman and Souther (1985) to investigate the feature integration theory where ability to search for items that 'pop out' is suggested to remain unaffected by the number of distractor items (Treisman & Gelade, 1980). Maekawa et al. (2018) initially replicated these initial findings using their experience sampling methodology. In their second experiment, a serial visual search task was used, where a target was presented with differing numbers of distractor items (10, 20 or 30 distractors). Findings revealed that for trials where 10 or 20 distractor items were present no difference in performance based on happiness levels was observed. However, for trials when 30 distractor items were present, individuals with low levels of happiness performed worse than individuals self-reporting higher levels of happiness (indexed by an increase in RT). This finding demonstrates that naturalistic mood (happiness) interacts with task difficulty within a visual search task to influence visual search performance, suggesting happiness may only have an impact on visual search when task difficulty is high.

It is therefore clear that, to date, the research investigating either a broadening of attention under positive emotion conditions or a narrowing of attention because of negative emotion conditions presents many conflicting findings. The past research suffers from a range of flaws, for example studies often claim to investigate possible broadening or narrowing of attention because of emotion, however instead they measure processing style. Moreover, studies do not always include both a positive emotion condition and a negative emotion condition which makes detailed conclusions regarding emotions impact on attention problematic. There are very few studies that have attempted to directly investigate any broadening or narrowing of visuospatial attention due to emotion, as well as a lack of studies that have adopted visual search tasks, and consequently it is still unknown whether emotion exerts either a broadening or narrowing influence upon selective visual attention during visual search tasks.

Laboratory investigations testing the influence of emotion on visual attention (and psychological functioning in general) have used different methods to successfully induce emotional states in participants. Such approaches include presenting participants with emotional images, playing emotional music or auditory stimuli, providing participants with rewards, guiding the recall of autobiographical memories, and the use of mental imagery relating to specific situations or experiences (e.g., Anderson et al., 2011; Gable & Harmon-Jones, 2008, 2010; Huntsinger, 2012; Lench et al., 2011; Lindquist et al., 2013; Siedlecka & Denson, 2018; Westermann et al., 1996; Yang et al., 2013; Zhang et al., 2014). The choice of emotion induction procedure is crucial when designing experiments and involves several considerations.

Firstly, some emotion induction procedures are more effective at eliciting desired emotional states. For instance, two meta-analyses compared the effect sizes of different emotion induction procedures when inducing happiness (a positive emotion), anger, sadness, and anxiety (negative emotions). Music was found to be the most successful, followed by the presentation of images, use of films, mental imagery, behavioural techniques, and lastly, recall inductions (Lench et al., 2011; Lindquist et al., 2013). A further example comes from Siedlecka and Denson (2018) who critiqued the effectiveness of various emotion induction procedures. They reported that situational emotion induction procedures, involving the creation of a social situation aimed at eliciting a target emotion, were more successful than music at inducing anger, disgust, surprise, and fear. In contrast, music was more effective than situational techniques at inducing happiness and sadness. This suggests that some procedures are more effective than others, but their effectiveness can depend upon the emotion being induced.

A further consideration is that some procedures are unable to induce specific emotions. For example, gift giving as a form of reward has been shown to be successful at inducing happiness and positive affect, yet it cannot be used to induce anger or negative affect (Gable & Harmon-Jones, 2010). Therefore, gift giving would not be suitable for use in experiments investigating positive and negative affect. Moreover, procedures such as gift giving may also alter levels of approach motivation therefore introducing an additional confound (Vanlessen et al., 2016). It is also possible that some emotion induction procedures are susceptible to demand characteristics such as when participants are aware of the aims of an emotion induction procedure (Västfjäll, 2002). It has also been suggested that some emotion induction procedures are more susceptible to accidental experimenter influences. For instance, it has been suggested that this is more problematic for emotion induction procedures that rely on experimenter input such as when the experimenter guides participants to focus their attention towards previous situations or experiences (Siedlecka & Denson, 2018). Additionally, some emotion induction procedures may be more susceptible to the individual abilities of participants (e.g., memory capacity, memory detail, or the emotional content of situations recalled).

Given the limitations of various emotion induction procedures discussed above, together with extensive research showing that visual stimuli has been shown to be effective in inducing positive affect/happiness and negative affect/sadness (e.g., Lench et al., 2011; Lindquist et al., 2013; Siedlecka & Denson, 2018; Westermann et al., 1996), the experiments in this thesis used emotional images to induce positive, neutral, and negative emotional states in participants. Another consideration in the use of images as an emotion induction technique in the current thesis was the experimental setup. Participants were required to complete several tasks during the experimental sessions in the laboratory: 1) engage with an emotion induction procedure, 2) provide self-report data to enable the success of the emotion induction procedure to be assessed, 3) complete a visual attention task, and 4) provide self-report data on affective individual difference traits. Additionally, in some experiments participants were also required to wear a fNIRS headband to permit the collection of haemodynamic data to provide a measure of changes in brain activity. Research has also shown that using a combination of emotion induction procedures can be more effective than using only a single method. For example, using visual images and music simultaneously has been shown to be more effective than either approach individually (Baumgartner et al., 2006), however it is important not to overburden participants and cause experimental fatigue. As participants were required to complete a computerised visual attention task, embedding an emotion induction technique that used visual images was easy to effectively include within the experimental procedure without overwhelming participants. Using images to induce emotion in participants also permitted closer comparison with the existing literature as the use of images is more common compared to other procedures such as the use of emotional music (Yang et al., 2018).

A further advantage of using images to induce emotional states in the laboratory is that existing databases are available. The experiments presented in this thesis used the International Affective Picture System (Lang et al., 2008) which is commonly used in image-based emotion induction procedures and was specifically designed for experimental research investigating emotion and attention. The use of such databases provides several advantages. Firstly, as these databases provide normative ratings (e.g., for valence and arousal) they provide greater control and objectivity in the selection of images used within experiments. Secondly, their use helps to facilitate the comparison of studies conducted across different laboratories. Lastly, such databases permit the precise replication of studies investigating emotion and attention. Further information regarding the use of the IAPS within an image-based emotion induction procedure is discussed in Chapter Seven – General Discussion.

1.2.3. Influences of stimuli valence on selective visual attention

It has been well documented that affective stimuli including threat-related images (e.g. snakes, spiders, angry faces) comprise a special category of stimuli able to influence selective visual attention in a bottom-up manner (for reviews see Carretié, 2014; Pourtois et al., 2013). Additionally, research has also demonstrated the ability of positively valenced stimuli to influence selective visual attention (for reviews see Carretié, 2014; Gupta, 2019; Pool et al., 2016). Research has shown that emotional targets are detected quicker and more accurately across different experimental tasks including visual search tasks (Eastwood et al., 2003; Hahn & Gronlund, 2007; Williams et al., 2005). Additionally, emotional distractors have an increased ability to capture attention more than neutral distractors (Carretié, 2014).

However, it has also been shown that bottom-up processing of emotional stimuli can be moderated by top-down processing, such as attentional control (Pessoa, 2008; Pessoa & Adolphs, 2010). Moreover, it has been suggested that in order to fully understand how emotional information guides spatial attention it is necessary to understand voluntary (top-down) attentional shifts towards visual search targets (Mohanty & Sussman, 2013). For example, it has been shown that whilst threatening faces capture attention when they are operationalised as targets within visual search tasks (Hahn & Gronlund, 2007; Williams et al., 2005), the same stimuli do not capture attention when they are not related to the current task (Mohanty & Sussman, 2013). Within the emotion-attention literature, the role of emotional stimuli when they are not operationalised as task-relevant (e.g. target stimuli) or as distractors is much less well understood and this is an avenue for future research.

Most of the research investigating the impact of emotional stimuli on selective visual attention has used emotional faces or employed tasks that use stimuli arrays incorporating emotional targets and/or distractors. Much less focus has been given to the investigation of selective visual attention using more naturalistic stimuli or emotional visual scenes. One study that did use natural scenes demonstrated that visual search performance was poorer for negative stimuli compared to neutral stimuli (Simpson et al., 2000). In this experiment stimuli consisted of images taken from the IAPS (Lang et al., 2008). Participants were required to decide how many humans were in a visual scene and it was shown that RTs were slower when the visual scene was negative compared to neutral. Additional research adopting free viewing paradigms has also shown an effect of emotion. When participants were instructed to naturally view neutral and emotional real-world scenes, individuals made a greater number of fixations as well as longer fixations when the scenes were either positive or negative compared to neutral (Bradley et al., 2011; Kaspar et al., 2013; Kuniecki et al., 2017). Recently it has also been shown that the emotional content of stimuli during the free viewing of natural images modulates attention (Astudillo et al., 2018). Here mosaics of nine images (taken from the IAPS) containing three negative images, three neutral images and three positive images were presented to participants, with the instruction to freely inspect the mosaics. It was shown that dwell times increased for emotional stimuli compared to neutral stimuli, and that this difference was greater for negative images. These studies adopting free viewing paradigms can reveal information about the voluntary (top-down) mechanisms supporting orientation and selective visual attention to emotional real-world scenes. Free of any specific goal-directed instructions individuals appear to allocate their attention towards emotional stimuli more than neutral stimuli.

Few studies have investigated the interaction between the emotional content of stimuli used within tasks measuring aspects of visual attention and an individual's emotion. Initially, it was shown that positive emotion broadens attention to positive stimuli, but not neutral stimuli, suggestive of a congruency effect (Wadlinger & Isaacowitz, 2006). It has also been demonstrated that the relationship between emotion, stimuli characteristics and individual differences can be complex. Grol and De Raedt (2014) presented participants with facial stimuli varying in emotional expressions (happy, sad, and neutral) followed by a target that was presented at varying distances from the facial stimuli. Participants also completed a measure of depressive symptoms and were also induced into either a positive or neutral mood. The findings suggest that stimuli valence (happy, sad or neutral faces) and mood (positive or neutral) had no direct impact on attentional breadth. However, participants who scored higher in levels of depressive symptoms showed 1) a greater narrowing of attention under positive mood conditions, and 2) increases in positive mood were related to attentional narrowing for positive (happy) stimuli conditions. Whereas, individuals with low levels of depressive symptoms showed a broadening of attention corresponding to increases in positive mood. These findings suggest that individual differences and stimuli valence can influence the effect of emotion on visual attention.

Additional studies have supported the notion of an emotion-stimuli interactive influence on attention. For instance, it has been shown that performance on an emotional Stroop task was influenced by state negative affect and trait negative affect (Crocker et al., 2012). Specifically, higher levels of state negative affect were correlated with longer RTs when responding to emotional words compared to neutral stimuli, as well as more errors. In contrast, trait levels of negative affect were not correlated with RT or the numbers of errors made. Importantly, there was an interaction between trait negative affect and state negative affect suggesting that increased levels of trait negative affect were correlated with poorer task accuracy but only when levels of state negativity were also increased. Conversely, when levels of state negative affect were low, and trait negative levels were high, this combination led to decreased task-related errors. The findings suggest that state negative affect and trait negative affect can have both separate and combined influences on attentional processing.

In a similar study, adopting a word-colour Stroop task, participants were induced into positive, neutral, and negative emotional states and had levels of trait negative affect recorded. Whilst there was no direct effect of emotional state on behavioural performance, individuals with high levels of trait negative affect demonstrated poorer performance during negative mood states compared to positive and neutral mood states (Hur et al., 2015). Although not directly related to the emotion or mood of an individual per se, recent evidence also suggests that one's awareness of their feelings (measured via a self-report questionnaire assessing attention to and clarity of one's feelings) is associated with attention to emotional (but not neutral) images during a free viewing task (Bujanow et al., 2020). Additionally, attention to one's feeling was also correlated with increased dwell times when viewing positive images. The studies discussed in this section demonstrate that early work has begun to reveal some of the interactions between the emotion of participants and the emotional valence of task-related stimuli and their relationship with top-down selective visual attention. However, this area of investigation is at an early stage and the research conducted thus far is unable to specifically test the predictions made by the broaden-and-build theory relating to a broadening or narrowing of visuospatial attention as a result of emotion and/or emotion-stimuli valence interactions.

1.3. Neural basis of selective visual attention

As well as developing our understanding of the cognitive processes involved in selective visual attention, it is also important to consider the neural mechanisms underpinning selective visual attention, emotional processing, and emotion-attention interactions. For instance, developing our understanding of the neural correlates of selective visual attention and the way in which they are impaired will help to develop more effective treatments for a range of clinical conditions (e.g. affective disorders including depression as well as attention deficit hyperactivity disorder). Top-down processing (voluntary) and bottom-up processing (automatic) mechanisms appear to be underpinned by both shared and unique neural networks including regions of the frontal cortex, parietal cortex, temporal cortex, occipital cortex, as well as thalamic and midbrain structures (Buschman & Kastner, 2015; Corbetta et al., 2008; Corbetta & Shulman, 2002; Driver, 2001; Hopfinger et al., 2000; Miller & Cohen, 2001; Posner & Petersen, 1990). This broad fronto-parietal network, responsible for mediating selective visual attention, ensures that information is quickly shared throughout the brain. Early research supporting the assertion that selective attention is underpinned by a distributed network throughout the brain was provided by neuropsychological studies investigating visuospatial hemineglect (Adair & Barrett, 2008; Parton et al., 2004). More recently, functional neuroimaging and electrophysiological research has furthered our understanding of the neural mechanisms supporting selective visual attention and the involvement of the fronto-parietal network.

The visual cortex located in the occipital lobe is the first region to receive and process visual information from the retinas via the lateral geniculate nucleus, and is commonly divided into five regions (V1, V2, V3, V4 and V5). Due to their excellent temporal specificity, electrophysiological techniques have been used to investigate the temporal dynamics of attentional processing following stimuli presentation. Visually evoked potentials, including P1 (a positive deflection around 80-130 milliseconds post stimulus) and N1 (a negative deflection around 120-180 milliseconds) were the first visually evoked potentials suggested to be influenced by spatial attention mechanisms (Hillyard et al., 1998; Luck et al., 2000). It has also been shown that when attention is directed towards a specific location, activity in the visual cortex relating to the area of the visual field no longer the focus of attention is decreased (Smith et al., 2000), suggesting that fronto-parietal networks are able to bias initial sensory representations originating in the visual cortex (Long & Kuhl, 2018). Additionally, when participants locate their attention in anticipation of a stimulus, increases in activity within the fronto-parietal network are observed including within the superior parietal lobule, intraparietal sulcus, frontal eye field (FEF) and supplementary eye field (Buschman & Kastner, 2015), and this observation is consistent across a range of different tasks (Kastner & Ungerleider, 2000). Furthermore, in the absence of visual stimulation, increases in activation are seen in the FEF and V4 when allocating attention to a peripheral target location (Kastner et al., 1999). The FEF as well as the superior colliculus have long been known to be involved in the control of eye movements demonstrated by evidence showing that direct stimulation of these regions causes saccades (Robinson, 1972; Robinson & Fuchs, 1969)[1]. It has also been demonstrated that selective visual attention to specific features of stimuli is able to modulate activity in specific regions of the extrastriate cortex responsible for the processing of the same specific features (Corbetta et al., 1991).

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[1] Although non-human primate research such as direct in vivo electrophysiological studies have provided valuable information regarding the role of brain structures involved in attention, such studies are not the focus of the current thesis and are therefore not discussed in detail. Any research presented that describes such findings are included due to their importance to the overall discussion and should not be viewed as a comprehensive review of this field of research.

Whilst the fronto-parietal network has shared mechanisms supporting both top-down and bottom-up attentional processing, evidence also suggests that different regions may support specific elements. For example, using a multiple neurophysiological recording technique, when a salient stimulus captured a monkey’s attention, suggestive of bottom-up attentional processing, this was initially reflected in the lateral intraparietal area, followed by FEF neuronal firing (Buschman & Miller, 2007). This suggests that information moved from parietal regions to the frontal cortex. Conversely, when attention was guided by a memory of a target stimulus, suggestive of top-down attentional processing, neural activity was initially demonstrated in the frontal cortex before subsequently being observed in the parietal cortex. Further, using electrophysiological recordings, similar results have been shown in humans (Li et al., 2010). Moreover, using functional connectivity analyses, it has also been argued that the fronto-parietal network can be divided into two separate subsystems. Here, one system is connected to the default network and involved in introspective processes, whilst a second system is connected to the dorsal attention network responsible for supporting perceptual attention (Dixon et al., 2018). These observations suggest that frontal and parietal regions are involved in different aspects of attention supporting top-down and bottom-up processing. To summarise, it is evident that the fronto-parietal network is involved in selective visual attention and can modulate the activity of brain regions involved in perceptual processes such as the visual regions of the occipital cortex. Moreover, top-down processing and bottom-up processing appear to recruit both distinct and overlapping brain networks.

Cognitive control refers to the intentional process of adopting executive functions such as working memory, attention, and the selection of thoughts and behaviours based on current task demands as well as the suppression adverse habitual behaviours (Miller & Cohen, 2001). As such it is likely that cognitive control-related brain regions will exert an influence on selective visual attention. Indeed, neuroimaging findings suggest that cognitive control is underpinned by activity in dorsal anterior cingulate, dorsolateral prefrontal cortex (dlPFC), medial prefrontal cortex (mPFC) and the dorsal and posterior parietal cortex, indicating the involvement of both frontal and parietal brain regions (Breukelaar et al., 2017). Moreover, areas of the PFC supporting cognitive control are also involved in selective visual attention (Curtis & D’Esposito, 2003; Gray et al., 2002; Miller & Cohen, 2001; Rossi et al., 2009). There is also overlap between cognitive control-related networks and brain regions associated with emotional processing and the regulation of emotion including the PFC (e.g. Buhle et al., 2014; Ochsner et al., 2012).

An aim of the current thesis was to investigate the neural mechanisms underpinning selective visual attention and emotion. One approach was to utilize fNIRS. Having reviewed the neural mechanisms underpinning selective visual attention, the following sections present two papers that discuss the suitability and benefits of fNIRS as a neuroimaging technique in measuring emotional processing and interactions between emotion and cognition including attention. Research that has utilised fNIRS is reviewed and findings relating to PFC neural activation during emotional processing are highlighted.

1.4. Functional near-infrared spectroscopy: An emerging neuroimaging technique successful in studying the interaction between emotion and cognition[2]

Functional near-infrared spectroscopy (fNIRS) is a non-invasive neuroimaging technique that measures hemodynamic concentration changes in the brain. The first fNIRS studies were published in 1993 (e.g. Chance et al., 1993) and since then the technique has become increasingly popular in the area of cognitive neuroscience.

1.4.1. How does fNIRS work?

Like functional magnetic resonance imaging (fMRI), fNIRS measures changes in deoxygenated-hemoglobin (deoxy-Hb) in the brain that result from neural activity. Whereas fMRI uses the differing paramagnetic properties of deoxy-Hb to infer neural activation, fNIRS uses the differing light absorption properties of oxygenated-hemoglobin (oxy-Hb) and deoxy-Hb in the near-infrared range (650-1000 nanometers (nm)) to infer neural activation changes. The relationship between neural activity and vascular response is termed *neurovascular coupling* and is described elsewhere (Villringer & Dirnagl, 1995).

A typical fNIRS setup involves placing optical fibres on the forehead and/or scalp. Light sources emit light in the near-infrared range at two differing wavelengths (e.g., 730nm and 850nm). Light in this range, introduced at the scalp, is either scattered through biological tissue or absorbed by hemoglobin. Light detectors temporally measure the amount of light

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[2] Bendall, R.C.A., & Thompson, C. (2015). Functional near-infrared spectroscopy: An emerging neuroimaging technique successful in studying the interaction between emotion and cognition. *PsyPAG Quarterly*, 96, 14-17.

absorbed by hemoglobin at the two wavelengths. Concentration changes in oxy-Hb and deoxy-Hb are normally measured temporally in relation to specific experimental manipulations (generally behavioural or cognitive tasks) and are compared to baseline data collected before commencing the experimental procedure. Stimulus presentation software is employed to permit both the controlled design and manipulation of experimental variables, as well as allowing the precise mapping of experimental stimuli to simultaneous hemodynamic data.

1.4.2. Comparing fNIRS and fMRI

Cui et al. (2011) have demonstrated that fNIRS signals are correlated with fMRI data suggesting that fNIRS is also a good marker of neuronal activity. This finding indicates that it may be possible to compare results from fMRI and fNIRS experiments (albeit with caution). An important benefit of fMRI is that it can provide detailed anatomical and spatial information. fNIRS is only able to record hemodynamic concentration changes in the cortex at a depth of roughly 1-2cm and lacks the ability to show precisely where these signals originate from.

However, fNIRS has a number of advantages when compared to fMRI. fNIRS possesses a higher temporal resolution than fMRI and importantly can be easily combined with other neuroimaging techniques including electroencephalography (EEG; Herrmann et al., 2008). The combination of fNIRS and EEG allows the investigation of hemodynamic and electrophysiological changes simultaneously. Further, fNIRS is considerably less expensive than fMRI and the optical fibre configurations can be applied quickly, substantially reducing experimental set up time. fNIRS is also portable, non-invasive and suffers less from environmental noise. This makes it an ideal tool for studying populations difficult to examine in an fMRI scanner, e.g., infants or the elderly. In addition, fNIRS lends itself well to studying aspects of cognitive neuroscience in less constrained environments. This increases the ecological validity of experimental findings compared to fMRI studies as well as decreasing the level of discomfort for participants.

1.4.3. fNIRS in emotion-cognition research

The study of emotion-cognition interactions often focuses around the amygdala (a deep brain structure associated with the processing of emotional information). It has been documented that the neural activity of emotion regulation involves interactions between the *hot* emotional system in limbic regions (e.g. the amygdala,) and the *cold*, higher order emotional systems located in prefrontal regions (Dolcos et al., 2011). According to the limbic model the amygdala forms part of the evolutionary *old* brain found in sub-cortical areas and is involved in the generation of primitive emotions (e.g. fear). Emotions are then elaborated in the advanced prefrontal cortex (PFC) neural circuits. Whilst it is not possible to measure neural activity from the amygdala using fNIRS due to its location within the brain, fNIRS provides an ideal tool for measuring activity in the PFC.

We know that there are direct and indirect anatomical connections between the *hot* and *cold* emotional systems. For instance, it has been demonstrated that connections exist between the PFC and amygdala (Fossati, 2012). Further, medial regions involved in the processing of emotional information are connected to lateral/dorsal areas implicated in higher order cognitive functioning (Fossati, 2012). For a detailed review of the anatomical connections within the PFC and between the PFC and amygdala see Ray and Zald (2012).

To date, studies utilising fNIRS have been successful in demonstrating the involvement of PFC regions in emotion-cognition interactions across a range of tasks. For instance, Ozawa et al. (2014) have found that emotional stimuli affected oxy-Hb changes in the medial prefrontal cortex (MPFC) with increased oxy-Hb during an n-back task. Kreplin and Fairclough (2013), who recorded a compound oxygenation measure (oxy-Hb – deoxy-Hb) also found increases in oxygenation in the medial rostral prefrontal cortex (MRPFC) during emotional introspection and external object identification of positively valenced stimuli (visual art), suggesting that the MRPFC is recruited during the evaluation of emotional information.

Aoki et al. (2011) have demonstrated that naturalistic mood is correlated with PFC activity during a working memory task; higher levels of negative mood displayed lower levels of PFC activity. The finding that naturalistic mood influences PFC activity is important as it suggests that the PFC is involved in emotion-cognition interactions in everyday situations. The use of fNIRS therefore allows for the investigation of real-world emotions and task performance, which would not be possible using more invasive techniques.

Altered PFC activity in response to emotional processing has also been observed in clinical populations. In an emotional Stroop task, a different pattern of PFC activity was observed in bipolar disorder (BD) patients and major depressive disorder (MDD) patients (in remission) compared to healthy control participants. Patterns of neural activity in response to positive stimuli also differed between BD and MDD patients, suggesting that different neural circuitry is involved during emotional processing in these two disorders (Matsubara et al., 2014).

Information processing models emphasise the importance of top-down and bottom-up processing, and both of these processing strategies are likely to be present during emotional-cognitive interactions. For example, Dolcos et al. (2011) have suggested that the effects of emotional distraction depend on interactions between neural systems that permit an individual to stay focussed on the task demands, and systems that are responsible for the processing of emotional information which compete for processing resources. Dolcos et al. (2011) propose that emotional distractors may result in bottom-up processing of task irrelevant information, therefore negatively affecting task performance. They argue that this deficit in performance can be avoided via top-down cognitive control processes, whereby systems are recruited to allow an individual to regulate emotional responses and therefore deal with emotional distraction. It is proposed that difficulty in utilising such processes to regulate emotion is a contributing factor in various psychopathologies including MDD and BD (Matsubara et al., 2014).

The exact role of the PFC in emotional processing remains unclear. For example, whilst Kreplin and Fairclough (2013) found that positive stimuli resulted in increased activity in the MRPFC, the same was not found for negative stimuli. Yet, Ozawa et al. (2014) have shown increases in oxy-Hb during both negative and neutral stimuli viewing. Differences in oxy-Hb are also evident during behavioural task conditions. For instance, Aoki et al. (2011) have shown that higher negative mood is correlated with lower PFC activity during a working memory task, whereas Ozawa et al. (2014) demonstrated increased activation during an n-back task after negative, but not neutral stimuli. Interestingly these two studies also provide differing findings when looking at behavioural task performance. Ozawa et al. (2014) found no effects of emotion on task performance whereas Aoki et al. (2011) found a correlation between negative mood scores and reaction times in a working memory task. In clinical populations differences in behavioural task performance and neural activity are also evident.

BD patients and MDD patients display differing task performance and altered neural activity in response to positive stimuli (Matsubara et al., 2014).

1.4.4. Summary and future work

As demonstrated, fNIRS has allowed the investigation of hemodynamic changes during emotion-cognition interactions in a laboratory setting, removing the need for participants to be constrained in an fMRI scanner. Eliminating the need to enter an fMRI scanner increases the number of cognitive tasks that can be employed to investigate emotion-cognition interactions and allows a more ecologically valid methodology to be adopted. The use of fNIRS in studying patient groups and clinical populations is a welcome addition to the neuroscientists' toolkit as it allows neuroimaging equipment to be taken to the population as opposed to individuals visiting the fMRI scanner making it an ideal tool for studying hard to reach populations.

Emotion-cognition research presents differing experimental findings. Some studies provide evidence for influencing effects of emotion on behavioural performance whilst others do not. Similar disparities in PFC oxy-Hb activity are also evident during emotion-cognition interactions. Future research into the interrelations between emotion and cognition could focus on individual differences (e.g., personality traits) that may mitigate the relationship between emotion and cognition and top-down and bottom-up processing strategies. Findings from research investigating the mitigating effects of individual differences in cognition-emotion interactions will help inform the exact role of the PFC in emotion-cognition interactions as well as shed light on altered activity in clinical and affective populations. fNIRS is a valuable neuroimaging technique which offers a cost effective and minimally obtrusive approach to the study of emotion-cognition interactions.

The above paper demonstrates that fNIRS can be used effectively to investigate the neural mechanisms underpinning emotion-cognition interactions. Given the application of fNIRS within the current thesis, it is important to discuss the considerations that need to be made in such experiments. The following paper reviews fNIRS research that has investigated the role of the PFC during emotional processing and provides suggestions relating to experimental design.

1.5. A brief review of research using near-infrared spectroscopy to measure activation of the prefrontal cortex during emotional processing: The importance of experimental design[3]

1.5.1. Abstract

During the past two decades there has been a pronounced increase in the number of published research studies that have employed near-infrared spectroscopy (NIRS) to measure neural activation. The technique is now an accepted neuroimaging tool adopted by cognitive neuroscientists to investigate a number of fields, one of which is the study of emotional processing. Crucially, one brain region that is important to the processing of emotional information is the prefrontal cortex (PFC) and NIRS is ideally suited to measuring activity in this region. Compared to other methods used to record neural activation, NIRS reduces the discomfort to participants, makes data collection from larger sample sizes more achievable, and allows measurement of activation during tasks involving physical movement. However, the use of NIRS to investigate the links between emotion and cognition has revealed mixed findings. For instance, whilst some studies report increased PFC activity associated with the processing of negative information, others show increased activity in relation to positive information. Research shows differences in PFC activity between different cognitive tasks, yet findings also vary within similar tasks. This work reviews a selection of recent studies that have adopted NIRS to study PFC activity during emotional processing in both healthy individuals and patient populations. It highlights the key differences between research findings and argues that variations in experimental design could be a contributing factor to the mixed results. Guidance is provided for future work in this area in order to improve consistency within this growing field.

1.5.2. Introduction

Near-infrared spectroscopy (NIRS) is a non-invasive neuroimaging technique that measures changes in concentrations of specific chromophores (oxygenated hemoglobin [oxy-Hb] and deoxygenated hemoglobin [deoxy-Hb]) in biological tissue. Like functional magnetic resonance imaging (fMRI), NIRS relies on the principle of neurovascular coupling (the

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[3] Bendall, R.C.A., Eachus, P., & Thompson, C. (2016). A brief review of research using near-infrared spectroscopy to measure activation of the prefrontal cortex during emotional processing: The importance of experimental design. *Frontiers in Human Neuroscience,* 10(529), 1-7.

relationship between cerebral blood flow and neural activity) to infer brain activity from changes in oxygenation. The first NIRS studies were published in 1993 (e.g. Chance et al., 1993) and during the past two decades there has been a dramatic rise in the use of NIRS as a neuroimaging technique in cognitive neuroscience research. Whilst NIRS does have limitations in comparison to other neuroimaging techniques, including its poor temporal resolution compared to electroencephalography (EEG) and poor spatial resolution compared to fMRI, it also offers numerous advantages. NIRS is easily combined with other neuroimaging techniques including EEG (Herrmann et al., 2008) and has a higher temporal resolution than fMRI. Additionally, NIRS can reduce the discomfort to participants, make data collection from larger sample sizes more feasible, and individuals with non-removable metal objects in their body or who have tattoos are not excluded. Further, NIRS allows for the measurement of brain activation during a variety of tasks (e.g. during exercise; Lucas et al., 2012). Lastly, due to the fact that it is less invasive than other techniques, NIRS permits the monitoring of brain activation from certain populations that would otherwise be more difficult to access, such as infants (Franceschini et al., 2007), the elderly (Mehagnoul-Schipper et al., 2002), and patient populations (Matsubara et al., 2014; Matsuo et al., 2004; Ruocco et al., 2016; Yokoyama et al., 2015).

Crucial to the current work, NIRS is a useful technique for studying the influence of emotion. It is proposed that during an emotional situation, or when presented with emotional information, two competing processing strategies are present. Emotion influences cognition in a bottom-up manner regardless of the demands of a task, whilst simultaneously individuals adopt top-down cognitive control strategies to direct resources to task completion and emotion regulation. Emotional control therefore involves higher order emotion-related regions, including the prefrontal cortex (PFC), and it is hypothesized that the degree of success in the recruitment of prefrontal neural systems has a direct impact on task performance in emotional situations. As NIRS can only measure neural activation from cortical structures approximately 1-2cm deep it cannot record amygdala-generated neural activation from the limbic system, an area traditionally associated with emotional processing. However, NIRS is ideal for recording PFC neural activation and has been adopted by cognitive neuroscientists investigating the influence of emotion on cognition (Doi et al., 2013).

Having outlined the suitability of NIRS as a tool for measuring emotion-related neural activation, the next stage is to review evidence from NIRS research implicating the PFC in tasks incorporating emotional processing. Research will be reviewed from studies measuring PFC activation during the presentation of emotional stimuli (Table 1), studies recording activity during task completion where naturally occurring emotion is recorded or emotion is artificially induced (Table 1), and from studies of PFC neural activation in patient populations (Table 2). Differences in experimental findings will be discussed in relation to the chosen experimental design. There are studies using NIRS to investigate emotional processing in brain regions outside of the PFC (e.g. Köchel et al., 2011; Plichta et al., 2011) and whilst processing emotional faces (e.g. Rodrigo et al., 2016; Sun et al., 2016), however these are outside the scope of the current review. A number of recent articles have also covered methodological issues including filtering of NIRS data and artifact rejection (Guerrero-Mosquera et al., 2016; Kamran et al., 2016; Tachtsidis & Scholkmann, 2016) and these are also not covered in the present work. It should also be noted that in this review we focus on experimental findings that report concentration changes in oxy-Hb. NIRS measures changes in oxy-Hb, deoxy-Hb, and compound activity (oxy; oxy-Hb – deoxy-Hb) and it is been argued that changes in oxy-Hb concentrations are the most reliable measure of cerebral blood flow and, by extension, neural activity (Malonek et al., 1997; Strangman et al., 2002). Despite this, it has been suggested that deoxy-Hb has a closer relation to the blood oxygen level dependent response in fMRI, and simultaneously reporting both oxy-Hb and deoxy-Hb allows better physiological interpretations to be made (Tachtsidis & Scholkmann, 2016).

1.5.3. PFC activation during passive viewing of emotional stimuli

The neuroscientific study of emotional processing often involves individuals viewing and/or evaluating images of differing emotional valence. This allows the underlying neural networks involved in emotional processing to be investigated. Researchers can create their own emotional stimuli or make use of validated stimuli databases developed by other investigators (e.g., International Affective Picture System; IAPS; Lang et al., 2008; Nencki Affective Picture System; Marchewka et al., 2014). Glotzbach et al. (2011) adopted such an approach using images from the IAPS. The researchers found bilateral PFC oxy-Hb increased for negative compared to neutral images, suggesting that PFC regions are recruited during processing of negative stimuli. However, these findings are limited because a positive condition was not included. Hoshi et al. (2011) recorded PFC oxy-Hb changes during the presentation of both positive and negative stimuli. This study also found a significant increase in oxy-Hb for negative stimuli and showed a significant decrease in oxy-Hb for positive stimuli (compared to neutral). Yet, Herrmann et al. (2003) found no differences in oxy-Hb between baseline activity and the viewing of neutral, negative, and positive images. This small collection of studies shows the importance of the stimuli conditions included in experiments investigating emotional processing. Choosing to omit a neutral, negative, or positive stimuli condition means that researchers are not always making the same comparisons within their studies (i.e. whilst some compare negative [and positive] to neutral, others compare negative to positive). This affects the results and makes comparison between studies problematic.

An additional factor that makes it difficult to compare findings is that researchers make use of different analytic approaches. Critically, this seems to have an impact on the findings. Ozawa et al. (2014) analyzed their data by comparing neutral and negative conditions to baseline oxy-Hb and the results suggested increases in oxy-Hb for both types of stimuli. However, when they compared neutral stimuli directly to negative stimuli no differences in oxy-Hb were evident. It may therefore be argued that a comparison to baseline can also reflect task-related activation in addition to any activation due to emotion. Herrmann et al. (2003) compared oxy-Hb in positive, negative, and neutral stimuli to baseline and were able to conclude no influence of emotion in addition to no influence of task. Researchers should ensure baseline data is included in analysis, in combination with control and experimental conditions to allow separation of task-related and emotion-related activation.

A further problem is that whilst some researchers report only group level analysis of PFC activation, others analyze data at both a group and an individual level. When analyzing activation at a group level, Hoshi et al. (2011) found decreased activation in response to positive stimuli and increased activation for negative stimuli. Individual level analysis revealed mostly decreases in oxy-Hb for pleasant stimuli, but both increases and decreases in oxy-Hb for unpleasant stimuli (compared to baseline oxy-Hb). This implies individual variation in the effect of emotional stimuli, but this is not always acknowledged. The choice of analysis clearly has important implications for the interpretation of results.

1.5.4. PFC activation during task completion

Researchers have also used NIRS to measure activation within more demanding tasks. In this section two types of studies are discussed. First, those investigating the influence of induced or naturally occurring mood on cognitive task performance, and, secondly, studies where the content of the task itself is emotional. Aoki et al. (2011) demonstrated that naturalistic levels of negative mood were negatively correlated with PFC activity during a verbal working memory (WM) task. This is an important observation as it suggests that naturally occurring negative mood influences PFC activity. However, Ozawa et al. (2014) also used a WM task and found increased PFC oxy-Hb when participants were induced into negative mood (compared to neutral). Whilst there are differences in the exact nature of the WM tasks used in these two studies (Ozawa et al. (2014) used an n-back task whilst Aoki et al. (2011) adopted a verbal matching task), as well as differences in study design (i.e. using naturally occurring mood versus induced mood), these conflicting findings show that the relationship between negative mood and cognitive task-related PFC oxy-Hb needs clarifying and warrants further investigation.

Table 1 | Key findings from studies measuring PFC activation during passive viewing of emotional stimuli and cognitive tasks

Reference	**Participants**	**Method**	**Analysis**	**Main findings**
Glotzbach et al. (2011)	Healthy adults	Passive viewing of neutral and negative (fearful) images	Group analysis of oxy-Hb model-based contrasts between task conditions	↑ oxy-Hb for negative stimuli compared to neutral stimuli in 4 channels
Hoshi et al. (2011)	Healthy adults	Passive viewing of positive and negative images	Individual and group analysis of oxy-Hb during task conditions compared to baseline oxy-Hb	Individual analysis ↑ oxy-Hb for 1 participant and ↓ oxy-Hb in 9 participants for positive stimuli. ↑ oxy-Hb for 7 participants and ↓ oxy-Hb for 6 participants for negative stimuli. Group analysis ↑ oxy-Hb in 2 channels for negative stimuli. ↓ oxy-Hb activity in 1 channel for positive stimuli. All compared to baseline
Herrmann et al. (2003)	Healthy adults	Passive viewing of positive, neutral, and negative images	Group analysis of oxy-Hb during task conditions and baseline oxy-Hb	No differences in oxy-Hb when viewing positive, neutral, and negative images compared to baseline
Ozawa et al. (2014)	Healthy adults	Passive viewing of neutral and negative stimuli	Individual and group analysis of oxy-Hb during stimuli presentation compared to baseline oxy-Hb. Group analysis of oxy-Hb also compared between task conditions	Individual analysis ↑ oxy-Hb in 7 participants and ↓ oxy-Hb in 3 participants for neutral stimuli. ↑ oxy-Hb in 9 participants and ↓ in oxy-Hb in 6 participants for negative stimuli. All compared to baseline. Group analysis ↑ oxy-Hb for both neutral stimuli (12 channels) and negative stimuli (3 channels) compared to baseline. No differences between stimuli groups
Aoki et al. (2009)	Healthy adults	Verbal WM task	Correlated naturalistic negative mood with oxy-Hb during WM task	↑ levels of naturalistic negative mood correlated with ↓ oxy-Hb during WM task
Kreplin and Fairclough (2013)	Healthy adults	Image judgement task	Group analysis of oxy compared between task conditions	↑ oxy for positive stimuli compared to negative stimuli in 3 channels
Ozawa et al. (2014)	Healthy adults	n-back WM task	Individual analysis of oxy-Hb during n-back WM task compared to baseline. Group analysis of oxy-Hb compared directly against each other	Individual analysis ↑ oxy-Hb during negative 1-back task in 11 participants (one participant showed a ↓). ↑ oxy-Hb during negative 3-back task in 11 participants (2 participants showed a ↓). Group analysis ↑ oxy-Hb during n-back task after negative stimuli presentation compared to neutral stimuli
Tupak et al. (2014)	Healthy adults	Labelling and matching tasks	Group analysis of oxy-Hb contrasts between conditions (task and valence)	Labelling threat vs. control and labelling threat vs. matching threat contrasts revealed ↑ oxy-Hb in both vlPFC and dlPFC. Task x valence interaction ↑ oxy-Hb during labelling but not matching for threat compared to neutral valence. Labelling threatening stimuli ↑ oxy-Hb compared to matching threatening stimuli

Table 2 | Key findings from studies measuring PFC activation in patient populations

Reference	Participants	Method	Analysis	Main findings
Liu et al. (2014)	Major depression disorder (MDD) patients and healthy adults	Verbal fluency task	Group analysis of MDD patients and healthy adults. ± in oxy-Hb correlated with depression and anxiety scores	↑ oxy-Hb during verbal fluency task in 37 channels for healthy adults but only 6 channels in MDD patients. ↓ oxy-Hb during verbal fluency task for MDD patients compared to healthy adults in 15 channels. Oxy-Hb positively correlated with depression scores in 8 channels for MDD patients
Matsubara et al. (2014)	Bipolar disorder (BD) patients, MDD patients and healthy adults	Emotional Stroop task	Group analysis of BD, MDD and healthy adults between task conditions	↑ oxy-Hb during threat task for patients compared to healthy adults. BD patients ↑ oxy-Hb in left inferior frontal region, MDD patients ↑ oxy-Hb in left middle frontal region. For happy words BD patients ↓ oxy-Hb in middle and frontal regions, MDD patients no change.
Yokoyama et al. (2015)	Social anxiety disorder (SAD) patients and healthy adults	Verbal fluency task	Group analysis of SAD patients and healthy controls during verbal fluency task. ± in oxy-Hb correlated with social anxiety scores	↓oxy-Hb change in SAD patients vlPFC compared to healthy adults. Right vlPFC oxy-Hb negatively correlated with social anxiety in patients. Healthy adults oxy-Hb positively correlated with social anxiety in vlPFC

Consideration of the associated behavioural data does not necessarily help to explain the differences in these findings. This is particularly the case due to the different practices used by the researchers. For instance, Ozawa et al. (2014) did not analyze task performance in conjunction with oxy-Hb, yet Ogawa et al. (2014) did and found a correlation between increased PFC oxy-Hb and improved performance in a WM task. On the basis of the findings reported by Aoki et al. (2011) it may be predicted that negative mood would lead to poor performance and the researchers did find a relationship between lower negative mood scores and improved verbal WM performance. However, this relationship was no longer significant after controlling for age and gender suggesting that age and gender influence PFC activity during emotional WM tasks, and, that the relationship between mood scores and WM performance is weak. Nonetheless, again they did not correlate PFC oxy-Hb with WM performance. Consequently, it is impossible to conclude the association between PFC activation, mood, and task performance.

Adopting a different approach, Tupak et al. (2014) used emotional images embedded in a top-down labelling task and a perceptual matching task to investigate emotional processing. No differences were observed in ventrolateral prefrontal cortex (vlPFC) activity during the labelling task between negative (threatening) and neutral visual stimuli. However, increased vlPFC activity occurred during the matching of threatening images compared to neutral images, showing that the vlPFC is involved during the cognitive evaluation of threatening stimuli.

Kreplin and Fairclough (2013) also incorporated emotion into an experimental task. When participants were asked to make judgements about artistic images, they found increased activation for positive stimuli compared to negative stimuli. These findings contrast with studies investigating the passive viewing of emotional images and studies measuring activation during cognitive tasks. However, increases in dorsolateral prefrontal cortex (dlPFC) activity in response to positive stimuli (compared to negative) has also been found using fMRI (Herrington et al., 2005).

One aspect that contributes to the mixed findings is the choice of behavioural task used to measure the effects of emotion on performance. Many researchers make use of WM tasks and this does aid comparison between the different studies, however it also limits the applicability of the findings. An issue arises however when a different task is used. For instance, Bendall and Thompson (2016) induced participants into positive, negative, and neutral moods and measured PFC oxy-Hb in a change detection task and found no difference in activation across emotion conditions. One argument for the non-significant findings was that task difficulty limited the influence of emotion, a claim also supported by behavioural findings (Bendall & Thompson, 2015), as well as the findings of Tupak et al. (2014). Despite this, it can be concluded that it is important to justify the choice of task and to consider the difficulty of the task used in this area of research. Researchers must ensure that the experimental task is selected with some acknowledgement of how the work can compare to other findings in the field.

1.5.5. PFC activation in patient populations

In addition to measuring the effect of emotion on cognition in general, research has also explored the way in which emotion influences cognitive performance in tasks incorporating emotional information. Altered emotional processing is a key feature in the pathophysiology of mood disorders (Matsubara et al., 2014). For example, it has been shown that increased dlPFC activity when regulating negative affect is correlated with decreases in depression severity (Heller et al., 2013). Furthermore, it has been argued that difficulty initiating top-down control processes required to regulate emotion is a contributing factor in various patient groups or disorders, including major depressive disorder (MDD; Johnstone et al., 2007; Matsubara et al., 2014), bipolar disorder (BD; Matsubara et al., 2014), and borderline personality disorder (Krause-Utz et al., 2012; New et al., 2008).

Matsubara et al. (2014) used an emotional adaptation of the Stroop paradigm (Stroop, 1935) to investigate prefrontal activation in response to emotional words in patients with BD and MDD. They found different patterns of PFC activity for BD and MDD patients compared to healthy controls. In response to threat-related words, BD patients demonstrated increased oxy-Hb in the left inferior frontal region whilst MDD patients showed increased oxy-Hb in the left middle frontal region. Additionally, when responding to happy words, BD patients showed decreased oxy-Hb in the middle frontal regions in both hemispheres. Moreover, BD patients showed altered patterns of oxy-Hb activity compared to MDD patients when responding to happy words. These results suggest that altered PFC neural responses to emotional stimuli may be a trait marker in patient populations (Matsubara et al., 2014). Further, the differences in emotion-related oxy-Hb between patient groups suggests that different neural pathways play a role in emotional processing in these disorders.

BD and MDD have been shown to be comorbid with social anxiety disorder (SAD; Kessler et al., 2005) and all three disorders appear to show altered neural responses during emotional processing. Using a verbal fluency task that induced fear of evaluation by others, Yokoyama et al. (2015) measured oxy-Hb and found that SAD patients exhibited smaller increases in vlPFC oxy-Hb compared to healthy controls. In addition, right vlPFC activity was shown to be negatively correlated with social avoidance in SAD patients. In contrast, this correlation was reversed in healthy controls. Decreased vlPFC oxy-Hb suggests that SAD patients may have difficulty successfully recruiting emotion regulation-related brain regions. Liu et al. (2014) also adopted a verbal fluency task and found that MDD patients demonstrated smaller increases in oxy-Hb during task completion, and that bilateral PFC and antero-medial PFC oxy-Hb is correlated with depression severity. NIRS studies reporting observable differences in oxy-Hb between patient groups, as well as between patient groups and healthy individuals, demonstrate that NIRS is an effective imaging methodology in the study of the pathophysiology of patient disorders. Yet, given how research shows that state and trait emotion can have separate and combined effects on cognitive processing (Crocker et al., 2012), future studies need to consider the role of both state and trait emotion in their experimental design.

1.5.6. Recommendations for future research

There are a number of aspects related to experimental design that NIRS researchers should consider when investigating the influence of emotion on cognition.

Inclusion of sufficient experimental conditions

Altered neural processing has been observed in relation to both positive and negative stimuli (Hoshi et al., 2011; Glotzbach et al., 2011; Kreplin & Fairclough, 2013; Ozawa et al., 2014). Consequently, the inclusion of positive, negative, and neutral experimental conditions whenever possible will permit more accurate comparisons between studies and allow more precise conclusions about underlying neural substrates to be generated.

Experimental task considerations

Task difficulty can influence PFC neural activity and mitigate the influence of emotion on task performance. Thus, the choice of experimental task needs to be carefully considered. Additionally, some studies do not attempt to relate neural activation to task performance and where appropriate future work should include neural activation, emotion, and task performance in their analysis framework.

Inclusion of baseline data and experimental conditions within analysis framework

It is also important for future work to report analysis for activation changes compared between conditions (experimental conditions and control conditions) as well as comparison of oxy-Hb activity in relation to baseline oxy-Hb activity. Reporting both may help to disentangle task-related changes in activation from emotion-related differences in activation (during a task). It would also be advisable for researchers to report the way in which their baseline recordings are taken as this is an important consideration when reflecting on the changes taking place in response to emotional processing.

Inclusion of individual level and group level analysis

The content of emotional stimuli is subjective, and consequently PFC activation has been shown to vary across individuals in relation to emotional stimuli (Hoshi et al., 2011). We propose that researchers consider using individual level analysis to investigate these variations. This data would allow the investigation of any mitigating influence of emotion on task performance and underlying neural activity. Additionally, Tachtsidis and Scholkmann (2016) suggest that the strength of task-related systemic physiological change is dependent upon the emotional state of the individual, thus the inclusion of individual level analysis may be beneficial in avoiding false positives and false negatives in oxy-Hb analysis due to the influence of systemic physiological fluctuations.

1.5.7. Conclusion

The growing field of emotion science stands to benefit from studies adopting NIRS to measure neural activation during emotional and cognitive tasks. NIRS is well suited to measuring PFC neural activity, and the PFC has been shown to be involved in the processing of emotional information. Many of the benefits that NIRS affords, including its portability, reduction in participant discomfort, and ability to study a wider range of behavioural tasks, make it an excellent tool for the study of neural functioning in healthy and patient populations. Conflicting data has been reported concerning emotion-related neural activation and it is hoped that the recommendations included in this article may help researchers to unravel some of these inconsistences in future research. Specifically, researchers need to adopt more consistent experimental designs, critically consider their choice of experimental task, and provide more detail regarding analysis to allow for effective comparison between studies and better explore the influence of emotion on cognition.

The above paper provides further evidence to suggest that fNIRS is a suitable technique for the investigation of emotion-cognition interactions. Additionally, it discusses of some of the inconsistencies between research studies and provides suggestions in relation to experimental design and analytical frameworks that need to be considered by researchers within their own research, as well as when comparing findings between studies. The following section details the aims of the current thesis.

1.6. Aims of the current thesis

The focus of this thesis is the interaction between emotion and visuospatial attention. The first chapter has outlined some of the key findings in this area and has also introduced the broaden-and-build theory. Research investigating a possible broadening and/or narrowing of attention due to emotion has revealed mixed findings. Moreover, past research in this area suffers from a range of limitations including: 1) studies that claim to investigate a possible broadening or narrowing of attention due to emotion often actually use approaches that measure processing style, and related to this, very few studies have attempted to directly measure any broadening or narrowing of *visuospatial* attention due to emotion, 2) previous research does not always include both a positive emotion condition *and* a negative emotion condition which makes precise interpretations regarding the impact of emotion on attention problematic, 3) there is little consideration of top-down goals, 4) within the emotion-attention literature the role of emotional stimuli when they are not operationalised as task-relevant (e.g. target stimuli) or employed as distractors within a task is much less well understood, and 5) it remains largely unknown how emotion impacts selective visual attention within complex real-world scenes. The use of complex real-world stimuli permits the investigation of how emotion and emotional stimuli may influence selective visual attention and visual search in more ecologically valid conditions.

The initial aims of the thesis were to investigate the impact of an individual's emotion during selective visual attention, and secondly, to explore the role of emotional real-world scenes when searching for an embedded target of neutral valence. As the research progressed it became clear that affective traits may impact the relationship between emotional factors and top-down selective visual attention. Consequently, the aims of the thesis were extended to include the investigation of key affective traits and their impact on the relationship between emotional influences and top-down selective visual attention. Specifically, the research presented in this thesis was conducted to address six key research questions:

- Does positive emotion broaden and/or negative emotion narrow top-down selective visual attention?
- Does the emotional valence of complex real-world scenes influence selective visual attention?
- Do emotion and stimuli valence interact to influence selective visual attention?
- Can affective individual difference traits influence selective visual attention?
- Will key affective individual differences traits influence the relationship between emotion and/or stimuli valence and top-down selective visual attention?
- What are the roles of the PFC in emotional top-down visual search?

The research was conducted using different methodologies to comprehensively address the aims of the thesis. In total, five experiments were completed adopting two experimental paradigms to explore the interaction between emotion and attention. A change detection flicker task was used to assess the effect of emotion on attention in neutral real-world scenes. The first two experiments used the change detection task, one incorporating fNIRS (Chapter Two) and the second exploring affective personality traits (Chapter Three). The second paradigm was a visual search task, measuring attention to neutral targets embedded within emotional real-world scenes. The first experiment using this task is presented in Chapter Four. Following this, Chapter Five replicated this study with the inclusion of affective personality traits and trait levels of habitual use of two ER strategies, closely following the progression of research using the change detection flicker task. Chapter Six, incorporating fNIRS, presents the fifth experiment which encompassed the manipulation of both participant emotion and emotional stimuli as well as the inclusion of affective individual difference traits. Chapter Seven presents the Discussion. Supplementary detail regarding the stimuli used within the experiments is presented in Appendix One. Statistical analyses are presented in Appendix Two.

Chapter Two: The influence of emotion on change detection

2.1. Overview of Chapter Two

The broaden-and-build theory predicts that positive emotion broadens our attention, whilst negative emotion narrows attention. This Chapter presents Experiment One which investigates the impact of emotion on selective visual attention. Participants were induced into positive, neutral, and negative emotional states before completing a change detection flicker task encompassing neutral real-world scenes. To test the predictions of the broaden-and-build theory, changes were located either in the centre or periphery of scenes, permitting a broadening or narrowing impact of emotion on visuospatial attention to be measured. The main aims of the experiment are to investigate if positive emotion broadens visual attention and whether negative emotion narrows attentional scope. Additionally, a subset of participants completed the experiment whilst their PFC activity was recorded with fNIRS. This permitted investigation of whether emotion influences PFC activity during a change detection flicker task. The experiment is presented in two papers. The first paper presents the behavioural data, whilst the second paper reports the fNIRS findings. The Chapter begins with a discussion of change detection. Following this, the behavioural results from Experiment One are presented. Next, the neuroimaging findings are detailed. Finally, the Chapter concludes with a summary highlighting the main findings.

2.2. Introduction to change detection

The first two experiments in this thesis investigate the influence of emotion on top-down selective visual attention using a change detection task. During a change detection task an individual is required to conduct a visual search in order to identify a change made between two images (A – A`). Crucially, the presentation of the two images is separated by a brief inter-stimulus interval (ISI) usually consisting of a blank screen. This ISI produces a change in luminance and masks the motion transients which would otherwise allow the change to be rapidly detected, thus masking a bottom-up signal of the change (Rensink et al., 1997). Participants frequently find it difficult to identify the change taking an average of ~20 second to identify a change, whereas changes are identified quickly when the ISI is removed (Shapiro, 2000). The task was initially developed to investigate attentional mechanisms during saccade-contingent blindness, and the inability to identify a change is termed ‘change blindness’ (Rensink et al., 1997). Accuracy levels and the time taken to identify the change provide dependent measures of change blindness.

There are several ways in which change detection experiments can differ. For instance, the stimuli used in change detection studies can employ simple stimulus arrays (e.g. Luck & Vogel, 1997), real-world scenes (e.g. Rensink et al., 1997; Simons & Levin, 1998) or dynamic videos (e.g. Levin & Simons, 1997). Additionally, the type of change can vary. Items can be added or removed from a display, an item can be changed, or a change can be made to the layout. Moreover, the specific task requirements can also differ. For example, participants can be requested to detect a change, locate a change, or identify and locate a change (Hyun et al., 2009; Rensink, 2002). The precise methodology used by researchers investigating change blindness can also vary. For instance, as described above, a repeated change paradigm or flicker paradigm (Rensink et al., 1997) can be adopted whereby the two images are alternatively shown separated by an ISI until the change is identified. In contrast, the one-shot paradigm variation presents the images only once and individuals are required to make a forced choice regarding whether a change was present (Luck & Vogel, 1997; Pashler, 1988). Recently, it has been demonstrated that change detection performance is stable and findings are generalised across differing paradigms (Andermane et al., 2019). The change detection experiments in the current thesis adopted the change detection flicker paradigm.

Early work conducted on change detection was conducted by Rensink et al. (1997) using the flicker paradigm. Here, using real-world scenes, participants were shown an image (A) twice, each time for 240ms, followed by an ISI consisting of a blank screen that was displayed for 80ms. Subsequently, participants were presented with the changed image (A`), also presented twice for 240ms. This second image was almost identical to the first image differing only in that one change had been made to the image (e.g. colour of an item, addition of an item, deletion of an item). The ISI was again presented, and the images and ISI continued to be displayed in this manner until a change was detected following the pattern: A, A, A`, A`, A, A, A`, A`). Rensink et al. demonstrated that changes made to items of central interest were identified quicker than changes made to items of marginal interest. Moreover, when the ISI was removed, changes to items of central interest and marginal interest were identified substantially quicker demonstrating that the ISI was having a profound impact upon change detection. It was based on these findings that Rensink et al. proposed that the ISI masks the visual transient therefore removing the bottom-up signal of change. Consequently, it is suggested that this impairs visual encoding of the change into visual short-term memory and biases an individual towards using a top-down effortful visual search (Andermane et al., 2019). However, individual differences in change detection have been shown to be correlated with visual short-term memory capacity (Andermane et al., 2019). Additionally, it has also been shown that change blindness is influenced by salience. For instance, changes made to more salient objects within a scene are detected quicker than changes made to less salient regions (Wright, 2005), thus supporting theoretical arguments highlighting the importance of bottom-up processing in change detection and visual search (Itti & Koch, 2000).

A few studies have used the change detection flicker paradigm to investigate attentional biases. For example, it has been shown that snake-fearful participants (compared to snake-tolerant participants) took longer to identify changes in scenes without a snake present suggestive of a disengagement bias (McGlynn et al., 2008). Attentional biases are also evident in individuals with alcohol tolerance whereby problem drinkers detected changes made to alcohol-related scenes quicker than changes made to neutral scenes (Jones et al., 2006). Moreover, overweight individuals show an increased attentional avoidance bias towards food-related stimuli compared to individuals of normal weight in a change detection flicker task (Favieri et al., 2020).

Previously, using fMRI, change detection was shown to be associated with increased activity in the parietal cortex, right dlPFC and regions of the extrastriate visual cortex. Change blindness however, whilst also related to activity in extrastriate regions, appeared to be characterised by a lack of dorsal neural activation (Beck et al., 2001). Further studies have also suggested that the parietal cortex is actively involved in supporting change detection. Using transcranial magnetic stimulation (TMS) to disrupt activity within the parietal cortex, Beck et al. (2006) showed that disruption of the right parietal cortex, but not the left parietal cortex, caused an increase in RT to detect changes in a one-shot change detection paradigm as well as an increase in change blindness (compared to no TMS). Linking to previous behavioural findings suggesting a link between change detection and visual short-term memory (Andermane et al., 2019), disruption to regions of the parietal cortex associated with visual short-term memory via TMS suggest that disruption during the initial scene (as opposed to the subsequent changed scene) results in greater change blindness (Tseng et al., 2010). These studies adopting both correlational and causative experimental neuroimaging techniques have revealed some of the neural underpinning of change detection highlighting the role of the parietal cortex, extrastriate visual cortex and dlPFC during change detection.

Whilst research has used the change detection flicker task to investigate the contributions of top-down processing and bottom-up processing in selective visual attention, as well as provide evidence for attentional biases in different populations, the influence of emotion on change detection has not yet been studied. The change detection flicker task is ideally suited to measure central and peripheral visual attention in real-world scenes and therefore test the predictions of the broaden-and-build theory in relation to the effects of emotion on visual attention. The aim of the first experiment is to investigate the influence of emotion on visual attention using a change detention flicker task. Specifically, the experiment was designed to test the predictions made by the broaden-and-build theory: whether positive emotion broadens visual attention and whether negative emotion narrows visual attention. Additionally, the influence of emotion on PFC activity during change detection was also investigated.

2.3. Emotion has no impact on attention in a change detection flicker task[4]

2.3.1. Abstract

Past research provides conflicting findings regarding the influence of emotion on visual attention. Early studies suggested a broadening of attentional resources in relation to positive mood. However, more recent evidence indicates that positive emotions may not have a beneficial impact on attention, and that the relationship between emotion and attention may be mitigated by factors such as task demand or stimulus valence. The current study explored the effect of emotion on attention using the change detection flicker paradigm. Participants were induced into positive, neutral, and negative mood states and then completed a change detection task. A series of neutral scenes were presented, and participants had to identify the location of a disappearing item in each scene. The change was made to the centre or the periphery of each scene and it was predicted that peripheral changes would be detected quicker in the positive mood condition and slower in the negative mood condition, compared to the neutral condition. In contrast to previous findings emotion had no influence on attention and whilst central changes were detected

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[4] Bendall, R.C.A., & Thompson, C. (2015). Emotion has no impact on attention in a change blindness study. *Frontiers in Psychology*, 6 (1592), 1-9.

faster than peripheral changes, change blindness was not affected by mood. The findings suggest that the relationship between emotion and visual attention is influenced by the characteristics of a task, and any beneficial impact of positive emotion may be related to processing style rather than a "broadening" of attentional resources.

2.3.2. Introduction

The visual world is cluttered, and it is impossible to attend to all items and areas simultaneously. Priority is therefore given to the most relevant areas or objects within a scene. This 'biasing' of attentional resources, known as selective visual attention, is subject to a range of influences and is dependent upon top-down and bottom-up processing. Top-down processing is characterized by goal-directed behaviour, for example the allocation of attention to items matching target-defining features and the inhibition of distractors (Driver & Baylis, 1989; Schneider & Shiffrin, 1977). In contrast, bottom-up processing is the automatic capture of attention by salient information in the environment, regardless of task demand (e.g. Itti & Koch, 2000). It should however be noted that that the top-down and bottom-up viewpoint cannot adequately explain all attentional processing (Awh et al., 2012). Attention has also been shown to be biased by statistical irregularities learned over time that cannot be explained by top-down or bottom-up processing (Zhao et al., 2013).

Traditionally, research in the field of visual attention has focused on the influences common to all individuals, for instance task demand (e.g. Henderson et al., 1999), past experience (e.g. Brockmole & Henderson, 2006), stimuli properties (e.g. Treisman & Gelade, 1980), and visual biases (e.g. Tatler, 2007). However, more recent work has explored influences upon visual attention that vary between individuals, such as individual differences and expertise (e.g. Konstantopoulos et al., 2010; Sobel et al., 2007). One such influence is the effect of emotion, and the number of studies investigating the impact of emotion on visual attention (and cognition in general) is growing rapidly.

A predominant model in this field is the broaden-and-build theory (Fredrickson, 1998; 2001). The theory proposes that positive emotions, including joy, interest, contentment, pride, and love, have the ability to "broaden" an individual's "thought-action repertoires". It is also suggested that positive emotions "build" an individual's "enduring resources", including physical resources (e.g. life longevity; Danner et al., 2001), intellectual resources (e.g. theory of mind; Leslie, 1987), social resources (e.g. relationship quality; Aron et al., 2000), and psychological resources (e.g. resilience; Fredrickson et al., 2003). Specifically, the theory posits that, over time, experiencing positive emotions will have a cumulative effect; enabling an individual to become more creative, knowledgeable, resilient, socially integrated, and healthy, and providing them with resources that can be utilized as necessary in the future. Frederickson outlines that negative emotions have the opposite effect; preventing one from thinking broadly and from building lasting psychological reserves, however the theory is unique in that it focuses primarily on the positive influence of emotion. For instance, Fredrickson and Branigan (2005) propose that positive emotions have an evolutionary advantage over time as they build resources, whilst negative emotions have an evolutionary advantage ‘in the moment’ as they allow an individual to focus on a threat and the response to a threat.

Initial support for the broaden-and-build theory came from research suggesting that positive emotions result in an expansion of thoughts and actions (Fredrickson, 1998; Fredrickson & Branigan, 2005). Individuals experiencing positive mood states display increased levels of flexibility (Isen & Daubman, 1984), openness to information (Estrada et al., 1997), creativity and social openness (Baas et al., 2008; Garland et al., 2010; Isen et al., 1987) and enhanced semantic processing (Rowe et al., 2007). These studies demonstrate the ability of positive emotion to broaden cognition. However, they employ a range of tasks to measure the hypothesized expansion of thought-action repertoires and do not specifically measure the broadening of attention.

One task used to investigate the prediction that emotion affects the spread of attention is the global-local processing task (Navon, 1977, 2003). In this task participants are presented with large letters (global stimuli) composed of smaller letters (local stimuli) and are asked to respond to either the global or local feature. Findings consistently show a global precedence effect whereby responses are faster at the global level than the local level, and responses to local features are slowed when these are incompatible with the global feature (e.g. a global “H” comprised of local “S” compared to a global “H” comprised of local “H”). Research using this task has shown that negative moods promote a local processing style (with participants focusing more attention on the small letters) and positive moods induce a global processing style (with more attention directed to the large letter). It is argued that this reveals the narrowing of attention in negative moods and the broadening of attention in positive moods (e.g. Basso et al., 1996; Derryberry & Tucker, 1994). A study by Fredrickson and Branigan (2005) also utilized a global-local visual processing task and found that positive mood resulted in larger global biases compared to neutral mood. Participants were asked to make a comparison judgement on two sets of stimuli comprising both local and global features. The stimuli could be compared at a global or a local level and findings revealed that participants in a positive mood were more likely to compare on the basis of global features. The study additionally showed that negative mood did not have a narrowing effect on processing (in contrast to earlier findings).

Fredrickson and Branigan (2005) conclude that positive mood states broaden attentional resources, however, the global precedence effect would indicate that global processing is the preferred processing style and will be triggered automatically when a stimulus is presented. In addition, more resources are required to process information at a local level (in order to inhibit the global feature). This does not fit with the notion that the scope of attention expands due to positive emotions (or narrows due to negative emotions). We would therefore argue that positive affect is simply enhancing the bias towards global processing and not expanding the scope of attention. It is also suggested that the global-local processing task is not ideal for studying the benefits of positive emotion predicted in the broaden-and-build theory.

Whilst there are limitations in using a global-local processing task to investigate the effects of emotion on attention, other researchers provide support for the broaden-and-build theory using alternative methods. In an eye-tracking study, Wadlinger and Isaacowitz (2006) presented participants with three images (one located in the centre of the screen and two situated in the periphery). Participants induced into a positive mood state made more fixations on the peripheral stimuli compared to those induced into a neutral mood state. They conclude that greater search in the periphery provides evidence for a broadening of visual attention due to positive emotion. However, the researchers compared eye movements in the periphery, and they did not take into account any eye movements to the central image. The suggestion that positive moods broaden attention is specific in that individuals do not simply allocate attention more widely (potentially at the expense of processing information at the centre), but that the resources available when one is in a positive mood are enhanced. This should allow for an expansion of attention whereby increased processing of peripheral information comes with no associated cost to processing central information. The study conducted by Wadlinger and Isaacowitz is thus unable to conclude that positive moods expand attentional resources and it is argued that the findings are more indicative of a bias towards viewing the displays at a more global level (participants pay attention to the peripheral images at the expense of focal information). In addition, their findings show that the increased eye movements to the peripheral images only occurred when these images were positive and therefore consistent with the mood state. Again, without monitoring eye movements to the central image it is impossible to conclude whether these findings support a broadening effect, or if they merely represent a bias of attentional resources towards mood-congruent information.

Rowe et al. (2007) also argue that they have evidence of positive emotions broadening attention. In their experiment, positive and negative affect was induced using music with differing mood-altering properties (they also included a neutral condition in which participants were instructed to read information about Canada). In a modified version of the Eriksen flanker task (Eriksen & Eriksen, 1974) they presented participants with a central target that was flanked by compatible or incompatible distractors. The distance between the target and distractors was manipulated and findings showed that participants induced with positive mood suffered more interference from far distance distractors compared to those induced with neutral and sad moods (in the positive condition participants showed significantly slower response times to targets when they were incompatible to the distractors).

This evidence (albeit showing a negative impact of positive emotions) would initially suggest that in positive moods attention will expand, therefore allowing an individual to process more information (regardless of whether this information is relevant or irrelevant to the task). Yet other studies have failed to replicate these findings and there is now a growing body of literature that casts doubt on the broaden-and-build theory (and in particular, those findings demonstrating a broadening of visual attention under positive mood conditions). For example, a study by Bruyneel et al. (2013) partially replicated the flanker experiment of Rowe et al. (2007) but found no evidence for a broadening of attention on the basis of positive mood. In a second study Bruyneel et al. adopted a more ecologically valid mood induction procedure, whereby positive mood was induced by providing participants with positive feedback following completion of a task designed to induce stress (negative mood was induced by omitting this positive feedback and there was no neutral condition). An identical flanker task was adopted and results showed no interaction between mood, flanker compatibility, and flanker location on reaction times. The researchers did find that overall response times were larger in the negative mood condition (regardless of flanker location or compatibility), although they acknowledged this effect may have been due to a lack of counterbalancing in the experiment (the negative condition was always completed first therefore performance in the positive mood condition may have benefitted from a practice effect).

We propose that previous research investigating the effects of emotion on attention has been flawed due to the nature of the tasks utilized. Rather than explicitly measuring the scope of visual attention, many experimental paradigms have inadvertently measured processing strategy (and do not necessarily reveal the benefits of positive emotions predicted by the broaden-and-build theory). There are also many conflicting findings and results appear to vary according to task demand and stimuli valence. Further, whilst some studies do include conditions for positive, negative, and neutral mood states, other research fails to include either a negative condition, or a neutral (control) condition. As such, the precise way in which emotion affects attention cannot be concluded.

The current study sought to investigate whether emotion has an impact upon visual attention using a change detection flicker task. The change detection flicker paradigm (Rensink et al., 1997) involves presenting individuals with two images separated by a brief inter-stimulus interval (ISI). The images are identical except for one change and the task is to detect (and identify or locate) the change as quickly as possible. In the standard flicker paradigm, the images continue to alternate separated by the ISI until the change has been detected. Findings show that changes can take a long time to find (up to an average of 20 seconds; Shapiro, 2000), despite the change being found easily when the ISI is removed. The inability to find the change is termed ‘change blindness’ (Rensink et al., 1997) and the effect is explained through top-down and bottom-up allocation of attention. Under normal circumstances, when a change is made to the visual scene it elicits a motion transient that captures attention automatically. The ISI (or alternative, such as an eye movement) masks the motion transient and the change must therefore be found using a more controlled, effortful search.

The change detection flicker paradigm has been used to measure many of the influences upon visual attention and visual search. For example, changes made to salient features are detected faster than changes to less salient features, revealing an impact of bottom-up processing (e.g. Wright, 2005), and change blindness is affected by expertise (e.g. Werner & Thies, 2000), demonstrating the importance of top-down influences.

Relevant to the current study, findings also show that under normal circumstances participants pay more attention to central and focal stimuli than to peripheral stimuli, resulting in improved change detection for central changes compared to peripheral changes (e.g. Rensink et al. 1997).

Change blindness is a robust effect and given the success of the change detection paradigm in measuring the allocation of attention, we propose that it is ideal for the current investigation. Participants will be presented with neutral images and asked to detect changes made to these images. Crucially the changes will be made to the centre or to the periphery of each image. Three blocks of trials will be completed and prior to each one participants will be induced into positive, negative, or neutral mood states using images from the International Affective Picture System (IAPS; Lang et al., 2008). The IAPS is a large collection of images that have each been rated for valence and arousal and they have been successfully used to induce mood in a wide range of studies (Jiamsanguanwong & Umemuro, 2014; Lee et al., 2014; Limonero et al., 2015). On the basis of the broaden-and-build theory it is predicted that in the positive mood condition attentional resources will increase and peripheral changes will be detected significantly faster compared to the neutral condition. In contrast, peripheral change detection will be significantly slower in the negative condition. Critically, any benefit to peripheral change detection under positive mood should come with no associated cost to detection of central changes. This prediction is made on the assumption that the broaden-and-build theory argues for an overall expansion of attentional resources, rather than a bias to allocating resources to the wider surroundings at the expense of central information.

2.3.3. Materials and Methods

Participants

An opportunity sample of fifty-one (32 female) staff and students from the University of Salford aged between 18 and 44 years (*M* = 24.78, *SD* = 6.43) participated in this study. Written informed consent was gained from each participant after they were given procedural information regarding the experiment. Ethical approval was obtained from the College of Health and Social Care Ethics Panel at the University of Salford. All participants received a £10 inconvenience allowance.

Design

A within-participants design was used with two independent variables; *mood* induced prior to the change detection task (positive, neutral, or negative), and *location* of the changing item in the change detection task (central or peripheral). The dependent variables consisted of accuracy (percentage correct) and response times (in seconds) to detect the changes. A measure of positive and negative affect was also recorded to validate the method for inducing emotion.

Materials

The experiment was designed and run using E-Prime (Psychological Software Tools, Inc.) and participants completed the study using a Viglen Intel Quad Core computer with a 60 Hz, 19-inch monitor. Emotion was manipulated by presenting participants with visual images of differing emotional valence from the IAPS (Lang et al., 2008). A total of 80 images were selected, 20 positive (mean valence 7.65, mean arousal 5.05), 20 neutral (mean valence 4.62, mean arousal 3.11), and 20 negative (mean valence 2.35, mean arousal 5.17) images were presented during mood induction. Twenty additional positive images were presented at the end of the experiment (mean valence 7.87, mean arousal 5.13). No additional considerations were taken into account when choosing the experimental stimuli (i.e. the type of positive or negative mood evoked by each image). Please see Appendix One for a list of IAPS images used in this experiment. All images were presented in color and measured a maximum of 1024 x 768 pixels.

A total of 180 neutral images were used for the change detection task. Thirty-six original images were taken by the authors (both indoor and outdoor scenes) and one central and one peripheral change was made to each image (making a further 72 images). All changes were deletions (one item in the scene disappeared) and care was taken to ensure that changes were all of a similar size. Central changes were made within the centre of each image (within an area measuring 512 x 384 pixels) and peripheral changes were made outside of this area (see Appendix One). There were an equal number of peripheral changes made on the right and left side of the images. For each changed image a response screen was also created. This consisted of the original image separated into 4 equal sections that each contained a red letter (A, B, C, and D) to allow participants to indicate the location of a change. All images in the change detection task measured 1024 x 768 pixels.

The Positive and Negative Affect Schedule (PANAS; Watson et al., 1988), a 20-item self-report measure was used to record participants' mood after presentation of affective stimuli. The measure consists of 20 words that describe positive and negative feelings and emotions. The words were presented in a random order and for each one participants were asked to "indicate to what extent you feel this way right now, that is, at the present moment" on a scale of 1 (very slightly or not at all) to 5 (extremely). The PANAS provides a measure of positive affect from the summed rating of all positive words and a measure of negative affect from the summed rating of the negative words. The minimum score for each measure is 10 (indicating low affect) and the maximum is 50.

Procedure

After providing written informed consent participants were seated approximately 22 inches from the screen and given full instructions about the task. If they were happy to proceed with the experiment they pressed the spacebar and were presented with 20 images from the IAPS. The images were shown for 5000ms each in a random order, with a 500ms ISI separating each one, and participants were asked to view these pictures naturally. Once all images had been presented on-screen instructions were given for participants to complete the PANAS. Following this, participants pressed the spacebar again to begin the change detection task (Figure 2.1). A total of 24 change detection trials were completed, consisting of 12 central changes and 12 peripheral changes (6 to the left and 6 to the right). In each trial an image was presented for 1000ms followed by a blue blank screen for 500ms. The changed image was then presented for 1000ms, again followed by the blue screen for 500ms. Participants were instructed to search for the change between the two images and they continued to alternate until participants pressed the spacebar to indicate they had located the change. A response screen was then presented and participants reported the location of the change by pressing the relevant key on the keyboard (A, B, C, or D). Participants were told that the changes may be difficult to spot and if they were unable to locate the change they had the option of pressing '9' to end a trial, however they were asked to only use that as a "last resort". All trials were presented in a random order.

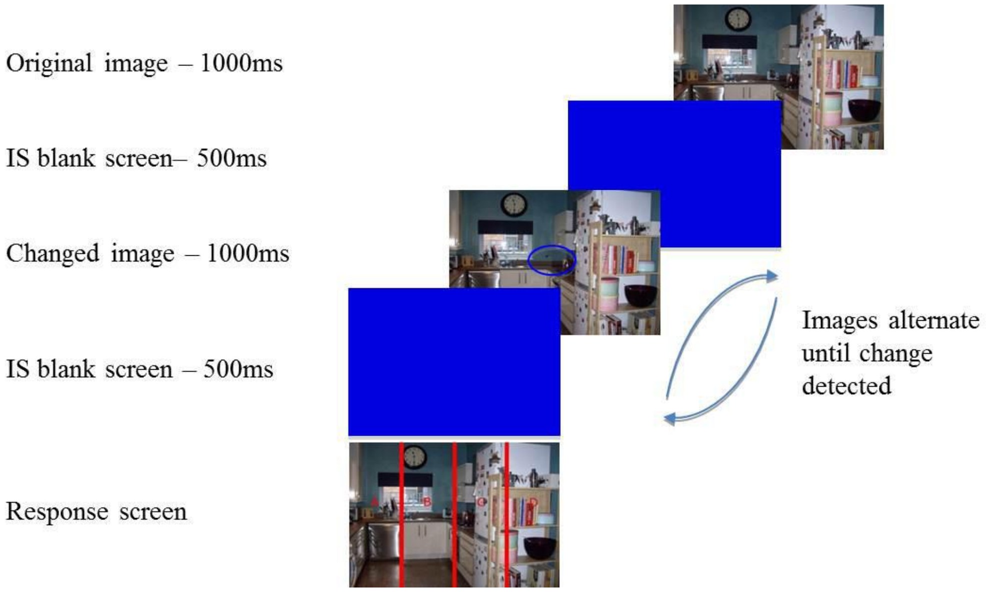

Figure 2.1. Illustration of the change detection flicker task. Participants were presented with an image for 1000ms followed by an inter-stimulus interval (ISI; blank screen) for 500ms. A changed image was then presented for 1000ms followed by another ISI for 500ms. This procedure continued until the participant identified the change in the scene and pressed the spacebar. They were then required to state where the change occurred by pressing the corresponding letter on the response screen. In this example the change was located in the centre of the image and the correct response was ‘B’.

Participants completed three blocks that each followed the above procedure (viewing of the IAPS images, completion of the PANAS, the change detection task). In the first block the IAPS images were either positive or negative (counterbalanced across participants). In the second block the images were always neutral, and in the final block they were again positive or negative depending on the valence of the first set of images. In the change detection task all 36 pairs of stimuli were shown twice (once with a central change and once with a peripheral change). The same image could not be presented twice in a single block. Following completion of the final change detection task participants were presented with 20 further positive images from the IAPS (presented for 5000ms each with an ISI of 500ms). This was to make certain that participants were induced into a positive mood when leaving the lab. At this point they were also thanked for their time and given an inconvenience allowance.

2.3.4. Results

Data collected included accuracy and response times to the change detection task and a positive and negative affect score from the PANAS. The analysis for each measure is presented below.

Affect Scores

The affect scores were taken to validate the mood induction technique (presenting participants with images from the IAPS). Positive and negative scores were analyzed separately using a one-way repeated measures analysis of variance (ANOVA) followed by planned comparisons to compare the positive and negative conditions to the neutral condition. Analysis of the positive affect scores showed a significant effect of mood, F (2, 100) = 36.12, MSE = 32.85, $p < .001$, partial η^2 = .42. Planned comparisons show that viewing positive stimuli significantly increased positive mood scores compared to viewing neutral stimuli (M = 30.80, SD = 8.16 vs. M = 22.35, SD = 8.66; F (1, 50) = 63.98, MSE = 56.93, $p < .001$, partial η^2 = .56; Figure 2.2a). There were no differences in positive affect after viewing negative stimuli (M = 22.55) compared to neutral stimuli (F (1, 50) = 0.031, MSE = 63.76, p = .862, partial η^2 = .00; Figure 2.2a). Analysis of negative affect also showed a significant effect of mood, F (2, 100) = 45.97, MSE = 19.78, $p < .001$, partial η^2 = .48. Planned comparisons reveal that viewing negative stimuli significantly increased negative mood scores compared to viewing neutral stimuli (M = 20.75, SD = 7.60 vs. M = 13.90, SD = 4.98; F (1, 50) = 57.01, MSE = 41.90, $p < .001$, partial η^2 = .53; Figure 2.2b). There was no difference in negative affect between the positive (M = 13.04) and neutral conditions (F (1, 50) = 1.381, MSE = 27.48, p = .245, partial η^2 = .03; Figure 2.2b).

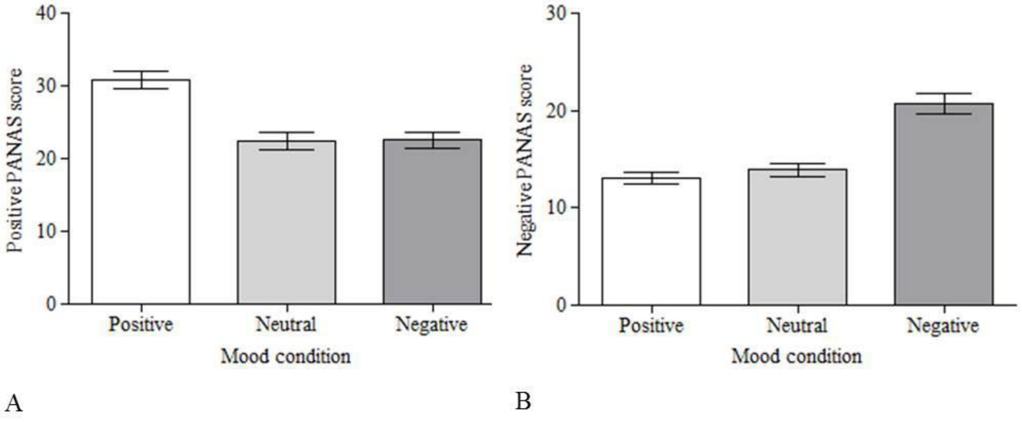

Figure 2.2. Mean PANAS scores for each induced mood condition. Self-reported mood varied across the conditions for both positive affect (A) and negative affect (B). Error bars = standard error of the mean.

Change detection task

Two 2 (*location*) x 3 (*mood*) repeated measures ANOVAs were completed to investigate the influence of emotion on the allocation of attention in the change detection task. Analysis of accuracy revealed a significant effect of location, *F* (1, 50) = 4.756, *MSE* = 0.01, *p* < .05, partial η^2 = .09. Central changes were detected more accurately (*M* = 90.56%, *SD* = 11.91) than peripheral changes (*M* = 88.42%, *SD* = 12.59; see Figure 2.3). However there was a non-significant effect of emotion, *F* (2, 100) = 0.241, *MSE* = 0.02, *p* = .786, partial η^2 = .01, and no significant interaction between location and emotion, *F* (2, 100) = 2.127, *MSE* = 0.01, *p* = .125, partial η^2 = .04.

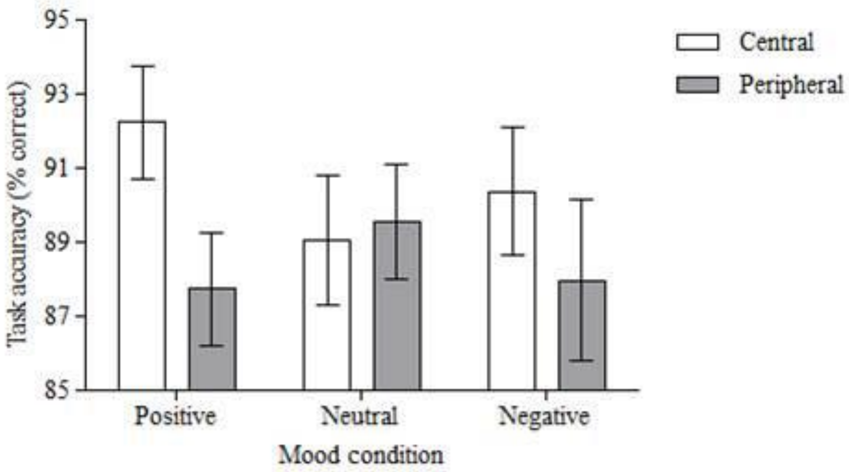

Figure 2.3. Mean percentage accuracy in the change detection task. Central changes were detected more accurately than peripheral changes, but this did not vary according to the mood induced prior to the task. Error bars = standard error of the mean.

For reaction time there was again a significant effect of location, *F* (1, 50) = 6.888, *MSE* = 9.005, *p* < .01, partial η^2 = .12. Central changes were identified quicker than peripheral changes (*M* = 10.77 seconds, *SD* = 3.69 vs. *M* = 11.67 seconds, *SD* = 3.93; see Figure 2.4). There was no main effect of emotion, *F* (2, 100) = 1.275, *MSE* = 12.395, *p* = .284, partial η^2 = .03, and there was no interaction between location and emotion, *F* (2, 100) = 0.075, *MSE* = 11.191, *p* = .928, partial η^2 = .00.

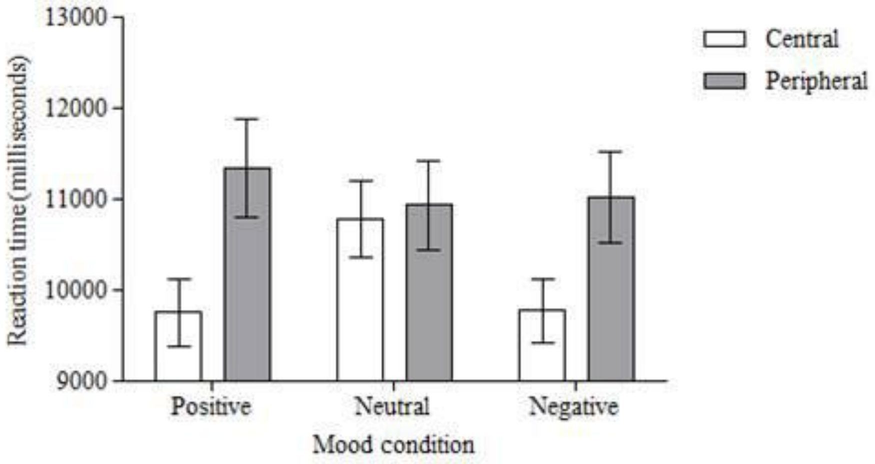

Figure 2.4. Mean response time (in seconds) to correctly detect changes. Central changes were detected faster than peripheral changes across all mood conditions. Error bars = standard error of the mean.

2.3.5. Discussion

The aim of the current study was to investigate the impact of emotion on visual attention. In particular the experiment was designed to measure whether positive emotions broaden visual attention, and whether negative emotions lead to attentional narrowing. This was explored using a change detection flicker task which allowed for the manipulation of ‘location’ whereby changes (centrally located or in the periphery) were made to images and participants had to detect these changes as quickly as possible. In accordance with the broaden-and-build-theory (Fredrickson, 1998; 2001), it was predicted that change blindness would reduce for changes in the periphery when participants were induced into positive mood but would increase when negative mood was induced (compared to a neutral condition).

The change detection flicker paradigm is a well-utilized method for studying attention, and differences between detection of central and peripheral changes have been evidenced in a number of studies. For instance, Rensink et al. (1997) found that changes to areas of central interest were detected faster than changes to peripheral areas. The current findings support this past research. Participants were significantly more accurate and significantly quicker to locate central changes than peripheral changes. This main effect is very important in endorsing the design of the flicker experiment. To establish any impact of emotion on the allocation of visual attention to central and peripheral locations it was vital to first show that visual attention and search followed the expected pattern, with resources located to the centre of a scene before the periphery. We can therefore have confidence in the experimental paradigm.

Despite showing that attention is allocated to information at the centre of a scene before being allocated to the periphery, there was no evidence that this varied according to mood. In contrast to past research (e.g. Fredrickson & Branigan, 2005; Rowe et al., 2007; Wadlinger & Isaacowitz, 2006) and contradicting the-broaden-and-build theory (Fredrickson, 1998; 2001), participants did not show a wider spread of attention when induced with positive mood. The current study therefore gives no support to the suggestion that positive emotions broaden attention (and that negative emotions lead to attentional narrowing). This finding was unexpected given that previous evidence has demonstrated an effect of emotion on attention (Fredrickson & Branigan, 2005; Wadlinger & Issacowitz, 2006; Rowe et al., 2007). It should be noted that despite the non-significant interaction between mood and location in the change detection task, there was increased accuracy in detecting central changes compared to peripheral changes in the positive condition. However, even this non-significant trend is inconsistent with the predictions of the broaden-and-build theory as it provides no evidence for a broadening of spatial attention under positive mood conditions. At most we would argue that this effect may be partially responsible for the significant difference between detection accuracy of central and peripheral changes. In addition, in many change blindness studies (including the current experiment) the most important measure of performance is reaction time (rather than accuracy) and analysis of this dependent variable shows no comparable trend.

One possible explanation for the non-significant effect of emotion in the current study could be that participants were not successfully induced into the experimental mood conditions. For instance, the PANAS self-report data were collected immediately after mood induction, and whilst analysis showed that emotion was successfully induced, it is not known whether this induced affect persisted throughout the change detection task. Given that the IAPS has been successfully used previously to induce emotion in research studies (Jiamsanguanwong & Umemuro, 2014; Lee et al., 2014; Limonero et al., 2015), we would argue that emotion was successfully induced but that this had no influence upon attention, however in future it would be prudent to collect self-report data after each change detection block.

An alternative explanation for the current findings is that the experimental paradigm measures visual processing in a different way to some of the former studies. By manipulating the location of the changes, the present study was able to investigate how visual attention is allocated across a real-world scene. Under standard viewing conditions an observer will allocate resources to the centre of a display before attending to the periphery (e.g. Brockmole & Henderson, 2006; Tatler, 2007) therefore central changes will be detected faster than peripheral changes (as was found in the current experiment). If positive emotions expand the available attentional resources then the scope of attention should broaden (Fredrickson, 1998; 2001), allowing for faster (and more accurate) detection of peripheral changes compared to neutral or negative emotions (a prediction not supported by the current findings). In earlier studies this central/peripheral distinction was not possible. For instance, in some studies supporting the broaden-and-build theory participants are asked to make a judgement about one feature of a single stimulus or a small set of highly similar stimuli (the global-local task, e.g., Derryberry and Tucker, 1994; Basso et al., 1996, and the flanker task; e.g. Rowe et al., 2007). We argue that these tasks measure visual processing style (i.e. global or local) rather than the spatial allocation of attention and are therefore unable to test the claim that positive emotions expand attentional resources. Taking the past findings into consideration, the current results would indicate that positive moods do not enhance attentional resources, they merely bias the observer towards a particular method of processing information. This bias cannot be tested using the current methodology yet incorporating global and local changes into a change detection paradigm may be one way to explore this further.

One study that comes close to measuring how visual attention is allocated through space and how emotion influences this was conducted by Wadlinger and Isaacowitz (2006). Similar to the current experiment they used natural scenes and measured search (via eye-tracking) to peripheral information. Their findings are however limited given that they did not analyze eye-movements to the centre of the display, and they also utilized a display containing three separate images. This again does not allow for a true measure of how attention moves within a scene and lacks ecological validity. The study did support the broaden-and-build theory by showing that participants made more fixations on peripheral information under positive mood conditions, yet this only occurred when the information was mood-congruent. Supporting the findings of Wadlinger and Isaacowitz (2006), other studies have shown that the influence of emotion on cognition can be dependent upon the characteristics of the specific task stimuli used. For example, Grol et al. (2014) argue that positive emotion broadens attention but only when the stimuli are self-related. These findings suggest caution when interpreting the present results. It is possible that participants were induced into mood states as a result of viewing emotionally valenced stimuli (validated by the PANAS scores), only for the change detection task stimuli (which consisted of neutral images) to return mood to neutral.

The variation in findings in this field thus outline the importance of the experimental task used to investigate any impact of emotion on attention. The paradigms used range from very simple tasks with a relatively low level of difficulty (e.g. the flanker task) to more demanding tasks incorporating real-world stimuli. It is also possible that emotion has differing influences on overt attention (e.g. measured by Wadlinger and Isaacowitz (2006) and the current study) and covert attention (e.g., measured by Bradley et al., 2000; Rowe et al., 2007). This makes comparison across different experiments very difficult. It also suggests that any impact of emotion may be influenced by the characteristics of a task, for example the stimuli used and the demand of the task. This argument could be made about the paradigm used in the current study and it may be possible that the change detection flicker task was too difficult to elicit any influence of emotion. Whilst participants in the current experiment took significantly less time to detect changes (a mean of 11.3 seconds) compared to some change detection tasks (up to 20 seconds; Shapiro, 2000), the difficulty of the task may have masked any potential influence of emotion on change blindness. Completion of a change detection task requires cognitive control to allow for focused attention towards relevant information and inhibition of irrelevant information. Regulating emotion also involves cognitive control processes whereby an individual may try to inhibit an inappropriate or unwanted response. It is therefore highly likely that task difficulty interacts with any impact of emotion, a suggestion supported by the study of Jasinska et al. (2012). In their study using the multi-source interference task (Bush & Shin, 2006) participants were presented with three numbers and had to identify an oddball number with a corresponding button press. The spatial position of the oddball could be congruent or incongruent to the correct response and on some trials threatening or rewarding distractors were also presented. Responses were slower with both threatening and rewarding distractors (compared to no distractor) for incongruent trials, but not for congruent trials. These data demonstrate that task difficulty can mitigate the influence of emotion on attention.

A further influence that may have contributed to the impact of task difficulty was if participants were trying to regulate their emotions during the change detection task. Emotional distraction occurring within a cognitive task depends on interactions between cognitive systems that allow an individual to stay focused on the task, and those systems that are responsible for the processing of emotional information (Dolcos et al., 2011). Here it is proposed that the two systems compete for processing resources where emotional distractors result in bottom-up processing of task irrelevant information and adversely influence task performance. This deficit in task performance can be mitigated by utilizing top-down cognitive control processes. Detrimental influences of emotional distraction on task performance have been seen in studies using clinical and healthy populations (Jasinska et al., 2012; Krause-Utz et al., 2012). This is a possible avenue for further study as the current experiment did not take into account any influence of emotional regulation. However, if participants were using cognitive resources to manage their emotions and inhibit the emotional distraction following viewing of the IAPS stimuli we would expect better performance in the neutral condition compared to the both the positive and negative condition and this was not found. As a consequence, it is unlikely that emotional regulation can explain the lack of any influence of emotion on attention in this study and instead other factors may play a role.

Cognitive theories attempt to explain behaviour in terms of average group level performance however these models often fit less accurately when they are applied to individuals (Parasuraman & Giambra, 1991). It is therefore possible that individual differences can mitigate any effect of emotion on cognition. For example, state and trait negative affect have been shown to have separate and combined influences on attentional processing (Crocker et al., 2012). The complexity of the relationship between emotion and visual attention due to individual differences is demonstrated in a study conducted by Grol and De Raedt (2014). Facial stimuli of varying emotions (happy, sad, and neutral) were used to investigate the influence of stimuli valence (under positive and neutral mood) on attentional breadth and participants were given the task of locating a small target appearing at varying distances from the face. The researchers also took a measure of depressive symptoms using the Beck Depression Inventory (BDI-II; Beck et al., 1996). Mood and stimuli valence had no influence on attentional breadth and only an effect of distance was observed whereby accuracy was higher when the target was presented closer to the facial stimuli. However, participants with high BDI-II scores showed greater attentional narrowing in the task under positive emotion. Further, among individuals with high BDI-II scores, increases in positive mood were related to more pronounced attentional narrowing for positive stimuli. For participants with low BDI-II scores, increases in positive mood were related to attentional broadening for positive stimuli. It therefore appears that individual differences can mitigate the influence of emotion on visual attention. The current study did not take account of individual mood or depressive symptoms and this needs to be investigated further. Research investigating the role of individual differences on emotion and cognition is important as it will help to understand functioning in healthy populations as well as those factors that may increase susceptibility to a range of affective disorders.

In conclusion, using a change detection flicker task there was no evidence that mood effects visual attention. The findings are consistent with the view that research showing a broadening effect of positive emotion and a narrowing effect of negative emotion may instead demonstrate a bias towards a particular processing strategy rather than a broadening of the available attentional resources. Consequently, the broadening role of positive emotion on visual attention may not be as simple as the broaden-and-build theory (Fredrickson, 1998; 2001) outlines. We propose that studies using simplistic tasks in which participants attend to a very limited set of features cannot adequately test the effects of emotion on spatial attention. The change detection flicker task offers a more effective measure of attention under differing emotional conditions as 1) the spatial location of stimuli can be controlled to allow for a comparison of central and peripheral attention, 2) the experiment paradigm allows for the use of real-world stimuli, and 3) the task is more complex and this provides a method for exploring how individual differences in attentional control and mood moderate the influence of emotion on cognition. There is a growing body of research showing that any influence of emotion on visual attention is affected by task constraints (e.g. the type of stimuli and the valence of this stimuli) and task difficulty and these can all be manipulated using the change detection paradigm. Research also shows that individual differences mitigate the effects of emotion on attention and there is scope to expand on this work to investigate whether such influences have contributed to the current findings.

The above paper demonstrates that a participants' emotion does not influence selective visual attention in a change detection flicker task. Additionally, the findings provide no evidence to support a broadening of attention under positive emotion conditions or a narrowing of attention because of negative emotion, failing to provide support for the predictions made by the broaden-and-build theory. However, it is still unclear whether emotion influences PFC neural activity during change detection. Due to the involvement of the dlPFC in both change detection (and visual attention more generally), as well as emotional processing and top-down cognitive control networks, changes in neural activation were recorded from the PFC in a subset of participants and this is presented in the following paper.

2.4. Emotion does not influence prefrontal cortex activity during a visual attention task. A functional near-infrared spectroscopy study[5,6]

2.4.1. Abstract

Research shows that positive and negative emotion can influence a range of cognitive processes as well as hemodynamic prefrontal cortex (PFC) activity. This study sought to investigate if PFC activity was influenced by positive and negative stimuli during mood induction as well as during a subsequent visual attention task. The International Affective Picture System was employed to induce affective states in participants before they completed a visual attention task. PFC hemodynamic activity was recorded using non-invasive functional near-infrared spectroscopy. Increased PFC activity was evident during the visual attention task compared to affective stimuli viewing. However, emotion did not influence PFC activity during affective stimuli viewing or completion of the visual attention task. Future research should take into account the role individual differences may play in mitigating any influence of emotion on PFC activity.

2.4.2. Introduction

Recently there has been increased focus regarding the influence of emotion on cognition at both the behavioural and neural level. At the behavioural level emotion has been shown to influence multiple aspects of cognition including working memory (Aoki et al., 2011), task shielding (Zwosta et al., 2013), attentional control (Ozawa et al., 2014), and visual

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[5] Bendall, R.C.A., & Thompson, C. (2016). *Emotion does not influence prefrontal cortex activity during a visual attention task: A functional near-infrared spectroscopy study*, in 5th Annual International Conference Proceedings on Cognitive and Behavioural Psychology, Global Science & Technology Forum, Singapore, 36-43.

[6] In the publication of this article the in-text citations were presented with numbers using the Vancouver referencing style. For consistency, the in-text citations are presented here using the author-date system adopted by the American Psychological Association referencing style.

attention (Fredrickson & Branigan, 2005; Rowe et al., 2007; Wadlinger & Isaacowitz, 2006). At the neural level research has shown that the prefrontal cortex (PFC) is involved in emotional processing during cognitive task completion; see Dolcos et al. (2011); Dolcos et al. (2014) for recent compressive reviews of this research area.

Information processing models highlight the importance of both top-down and bottom-up processing during cognitive task completion. For example, within the field of visual attention researchers propose that top-down processing is characterized by goal-directed behaviour whereas bottom-up processing refers to the automatic capture of attention by salient information in the environment regardless of task demand (Itti & Koch, 2000). It has been argued that during tasks investigating the effects of emotion on cognition it is likely that both processing strategies are evident (Dolcos et al., 2011). For instance during cognitive tasks involving emotional distractors, it is suggested that the influence of the emotional distraction depends on interactions between neural systems that allow an individual to stay focused on the task as well as systems responsible for the processing of emotional information (Dolcos et al., 2011). It is proposed that these two neural systems compete for processing resources and emotional distractors result in bottom-up processing of task-irrelevant information. This increase in bottom-up processing is likely to have a detrimental influence on task performance. Indeed evidence shows that negative mood is correlated with poorer performance during a working memory task incorporating emotional distractors (Aoki et al., 2011). It has been argued that impairments in task performance can be mitigated by employing top-down cognitive control processes. These processes allow systems involved in the regulation of emotional responses to be activated and therefore deal with any emotional distraction present (Dolcos et al., 2011).

To assume that effective top-down cognitive control processes are required for effective functioning in cognitive tasks leads to an important observation in clinical and affective populations. It has been reported that healthy individuals perform better than clinical populations in tasks involving executive control (Matsubara et al., 2014). Further, it has been suggested that difficulty in utilizing top-down control processes to regulate emotion is a contributing factor in various clinical and affective disorders including major depressive disorder (MDD) (Johnstone et al., 2007; Matsubara et al., 2014), bipolar disorder (BD) (Matsubara et al., 2014) and borderline personality disorder (Krause-Utz et al., 2012; New et al., 2008). Research investigating the influence of emotion on cognition in both healthy and clinical populations will advance our understanding of the impact of emotion on cognition.

Research that explores the effects of emotion on cognition at the neural level often concentrates on the role of the amygdala. The amygdala is a brain structure located deep in the brain involved with the processing of emotional information. It has been suggested that emotion regulation encompasses neural activation resulting from interactions between the *hot* emotional system found in limbic regions (e.g. the amygdala) and the *cold*, higher order emotional systems found in prefrontal regions (Dolcos et al., 2011; Gray et al., 2002). According to the limbic model the amygdala forms part of the evolutionary *old* brain found in sub-cortical regions and is involved in the generation of primitive emotions (e.g. fear). Emotions are then elaborated in the advanced PFC neural circuits.

Anatomically there are both direct and indirect pathways connecting the *hot* and *cold* emotional systems. For instance it has been shown that the ventral medial prefrontal cortex (vmPFC) is heavily innervated by the amygdala (Fossati, 2012). The medial prefrontal cortex (mPFC), which includes both the vmPFC and the dorsomedial prefrontal cortex (dmPFC), is heavily involved in the processing of emotional and social stimuli (Fossati, 2012). Further, the vmPFC has connections with the anterior cingulate, dorsolateral prefrontal cortex (dlPFC) and ventro lateral prefrontal cortex (vlPFC). These anatomical connections link medial brain areas involved in the processing of emotional information with lateral/dorsal brain regions implicated in higher order executive function (Fossati, 2012). Additionally the dlPFC has been cited as receiving influencing effects from the amygdala via indirect pathways through the cingulate and posterior orbitofrontal cortex (Ray & Zald, 2012).

Given the emerging role of the PFC during emotional processing it is important to study the influence of emotion on PFC activation. Functional near-infrared spectroscopy (fNIRS) is a novel, non-invasive neuroimaging technique that allows the study of PFC activation. fNIRS measures hemodynamic concentration changes in the brain similar to functional magnetic resonance imaging (fMRI). Whereas fMRI measures the paramagnetic properties of deoxygenated-hemoglobin (deoxy-Hb) to infer neural activity, fNIRS uses the differing light absorption properties of oxygenated-hemoglobin (oxy-Hb) and deoxy-Hb in the near-infrared range (650-1000nm) to infer neural activation changes. The relationship between vascular response and neural activity is termed *neurovascular* *coupling* and is described in detail in Villringer and Dirnagl (1995). Research has shown that the fMRI blood oxygen level dependent (BOLD) signal and fNIRS signals are correlated suggesting that studies using fMRI and fNIRS can be compared (Cui et al., 2011). One of the limitations of fNIRS is that it can only measure hemoglobin concentration changes in the cortex at a depth of 1-2cm. However, fNIRS also has many benefits including its quick application time, non-invasiveness, portability, and ability to be used in more ecologically valid testing environments. Moreover, it has been suggested that fNIRS is a suitable neuroimaging methodology for investigating emotion-cognition interactions in the PFC (Bendall & Thompson, 2015b; Doi et al., 2013).

Recent fNIRS research has helped in understanding the important role that the PFC has regarding the impact of emotion on cognition. It has been demonstrated that emotional stimuli influences oxy-Hb activity in the mPFC during an n-back task measuring attentional control (Ozawa et al., 2014). With a compound measure of oxygenation (oxy-Hb – deoxy-Hb), Kreplin and Fairclough (2013) provided evidence for the involvement of the medial rostral prefrontal cortex (mrPFC) during emotional introspection and identification of positively valenced stimuli (visual art) compared to neutral stimuli. In addition, Aoki et al. (2011) have shown that naturalistic mood (mood occurring naturally in individuals as opposed to experimentally induced mood or that observed in clinical and affective populations) is correlated with PFC activity during a working memory task. Here individuals with high levels of negative mood displayed lower levels of PFC activity during the task. This observation is important as it demonstrates that emotion has an influence on cognition at the neural level in everyday situations. Differences in PFC oxy-Hb activity have also been observed in MDD and BD patients (Matsubara et al., 2014). In an emotional Stroop task differing patterns of PFC oxy-Hb activity were observed in BP patients and MDD patients (in remission) compared to healthy individuals. Additionally, varying patterns of neural activity in response to positive stimuli was also evident in BP and MDD patients suggesting that different neural circuitry is involved during emotional processing in these two disorders (Matsubara et al., 2014). The aforementioned fNIRS research conducted on healthy individuals and clinical populations, combined with the observation that fNIRS signals are correlated with the fMRI BOLD response, suggest that fNIRS is a suitable neuroimaging tool for investigating the neural correlates of the relationship between emotion and cognition within the PFC.

Despite this past research, the exact role of the PFC within this relationship is not clear and differences in behavioural and neuroimaging data have been observed within the published literature. For example, behavioural data has reported that emotion does influence cognition (Wadlinger & Isaacowitz, 2006), whilst other data suggest this is not the case (Bruyneel et al., 2013). Similarly, neuroimaging data have reported increased activity in the mrPFC for positive but not neutral stimuli (Kreplin & Fairclough, 2013) whereas Ozawa et al. (2014) observed increased activity during viewing of both negative and neutral images. An increase in oxy-Hb activity for negative stimuli (compared to neutral) has also been observed by Glotzbach et al. (2011). In addition to findings revealing different patterns of PFC activity in response to viewing emotional stimuli, studies also show differences in activity within the same cognitive task. For example, it has been shown that lower levels of PFC activity during a working memory task are evident for individuals with higher levels of negative mood (Aoki et al., 2011), whereas Ozawa et al. (2014) have demonstrated higher levels of activation during a working memory task after exposure to negative but not neutral stimuli. Moreover, recent evidence has shown that task difficulty can moderate the influence of emotion on PFC activity. Here it was shown that in the multi-source interference task threat distractors decreased activity in the dlPFC during difficult trials, whereas they increase activity during easy trials. This finding suggest interactions are evident in brain regions involved in cognitive control as dlPFC activity in response to threat distractors differ according to task difficulty (Jasinska et al., 2012). The study of the influence of emotion on cognition at the neural level warrants further investigation.

The investigation of the way in which emotion influences cognition has progressed recently with researchers exploring additional aspects of neural processing during cognitive tasks. The current study will identify the effect of emotion on cognition at the neural level with the aim of explaining some of the conflicting findings within this field. Given the importance of the PFC in emotion and cognition the study will utilize fNIRS to measure changes in activation in this brain region. The change detection flicker paradigm (Rensink et al., 1997), which measures visual attention, will be employed. Change blindness is the failure to detect changes in a visual scene due to a brief interruption that prevents bottom-up capture of attention by the motion transient that usually accompanies a change. The detection of a change in the visual environment is therefore highly dependent upon top-down processing. Currently there is no published research examining whether mood influences PFC activity during a change detection flicker task.

The study aimed to investigate 1) how PFC activity varies according to emotional state, and 2) if emotion effects PFC activation in a cognitive task requiring significant top-down processing. It was predicted that positive mood would increase PFC activity whereas negative mood would decrease PFC activity during both the mood induction stage and the visual attention task. It was also predicted that PFC activity would be greater during the visual attention task compared to during the mood induction task. Therefore, we predict a main effect of emotion, a main effect of task, and no interaction effects.

2.4.3. Method

Participants

Thirty-two healthy individuals (20 female) aged between 18 and 38 (*M* = 24.8 years; *SD* = 5.4 years) participated in this study. Written informed consent was obtained from each participant after receiving procedural information regarding the study. Ethical approval was obtained from the College of Health and Social Care Ethics Panel at the University of Salford. All participants received a £10 inconvenience allowance.

Design

A within-participants design was used with two independent variables: *mood* (positive, neutral, or negative) and *task* (emotional stimuli viewing task and visual attention task). The dependent variable was changes in oxy-Hb. A measure of positive and negative affect was also recorded to validate the method of inducing emotion.

Materials and apparatus

Emotion induction / affective stimuli

Emotion was manipulated by presenting participants with visual images of differing emotional valence from the International Affective Picture System (IAPS; Lang et al., 2008). 60 images were selected; 20 positive (mean valence 7.65, mean arousal 5.05), 20 neutral (mean valence 4.62, mean arousal 3.11), and 20 negative (mean valence 2.35, mean arousal 5.17) images. A further 20 positive images were shown at the end of the experiment (mean valence 7.87, mean arousal 5.13). All images were presented in color and measured a maximum of 1024 x 768 pixels. The Positive and Negative Affect

Schedule (PANAS; Watson et al., 1988), a 20-item self-report measure of positive and negative affect, was used to record participants' affect after presentation of affective stimuli. The PANAS consists of 20 words that describe positive and negative feelings and emotions. For each word participants were asked to ''indicate to what extent you feel this way right now, that is, at the present moment'' on a scale of 1 (very slightly or not at all) to 5 (extremely). The PANAS provides a measure of positive affect from the summed rating of all positive words and a measure of negative affect from the summed rating of the negative words. The minimum score for each measure is 10 (indicating low affect) and the maximum is 50.

fNIRS data collection

In order to record cortical PFC oxy-Hb an fNIR Imager 1000 (fNIR Devices, LLC.) multichannel fNIRS system was used. This system has a temporal resolution of 500ms (2Hz) and consists of 4 light sources and 10 light detectors resulting in 16 measurement optodes. The probe was placed on the forehead aligned to frontal polar (Fp) 1 and Fp2 of the International 10-20 system (Jasper, 1958) where Fpz corresponded to the midpoint of the probe (Figure 2.5) (Ayaz et al., 2010). Changes in oxy-Hb were recorded with Cognitive Optical Brain Imaging Studio (fNIR Devices, LLC.) and analyzed offline using fnirSoft (Ayaz, 2010). Raw data was processed using a finite impulse response linear phase low-pass filter, with order 20 and cut-off frequency of 0.1Hz, to attenuate high frequency noise, respiration, and cardiac effects. Additionally, a sliding-window motion artifact rejection algorithm was employed to remove motion artifacts and saturated channels. These methods are described in detail in Ayaz et al. (2010). Optodes were also visually inspected for signs of light saturation or light obstruction caused by hair beneath the sensor. Oxy-Hb was then calculated using the modified Beer-Lambert Law (Sassaroli & Fantini, 2004). Three scene viewing and three visual attention task data segments were extracted using synchronization markers received from E-Prime (Psychological Software Tools, Inc) and averaged for statistical analysis.

Procedure

After providing written informed consent participants were seated approximately 22 inches from the screen. The fNIRS sensor was placed on a participant's forehead and secured using elastic strapping. The emotion induction images and visual attention task were presented on a computer using E-Prime (Psychological Software Tools, Inc) with a 19-inch monitor. Participants completed 3 blocks of trials and block order was counterbalanced. In each block, 20 color photographs taken from the IAPS were shown for 5000ms each in random order and were followed by a 500ms inter-stimulus interval (ISI). Images were neutral, positive, or negative, depending on block order. After presentation of the images, participants completed the PANAS followed by the change detection task. During a trial an image of neutral valence was presented for 1000ms followed by a blank image for 500ms. A changed image, which comprised the original image with a subtle change, was then presented for 1000ms followed by another blank image for 500ms. This cycle repeated until the participant identified the change at which point they pressed the space bar on the keyboard (Figure 2.6). After completion of the final change detection block participants were presented with 20 additional positive images from the IAPS. This was intended to make certain that participants were induced into a positive mood when leaving the lab. Participants were then thanked for their time and given £10 as an inconvenience allowance.

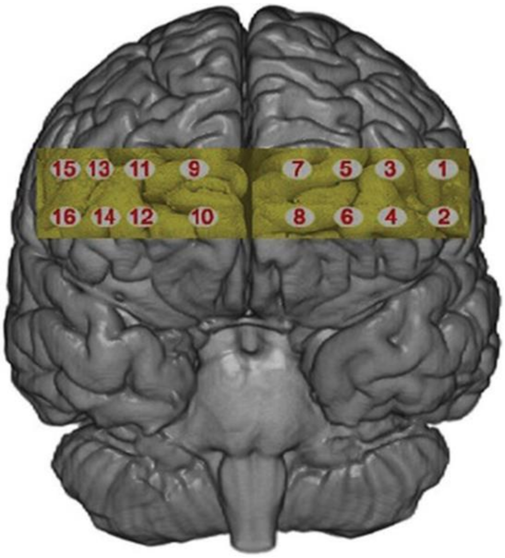

Figure 2.5. fNIRS probe location showing 16 optode sites on the prefrontal cortex.

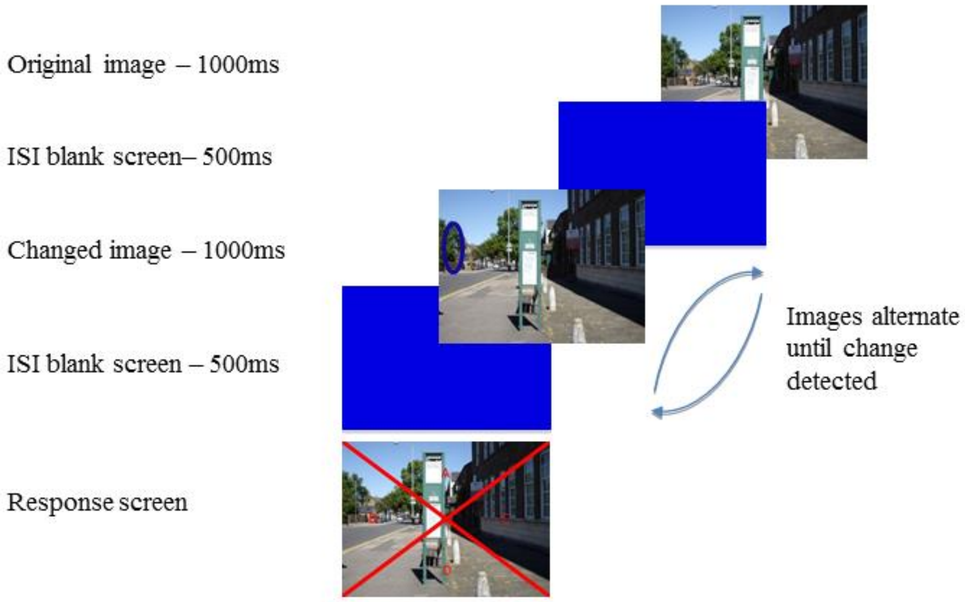

Figure 2.6. Illustration of the change detection flicker task.

2.4.4. Results

Affect scores

Two one-way repeated measures analysis of variance (ANOVA) followed by planned comparisons were conducted to check that the affective stimuli were successful at inducing positive and negative mood states in participants.

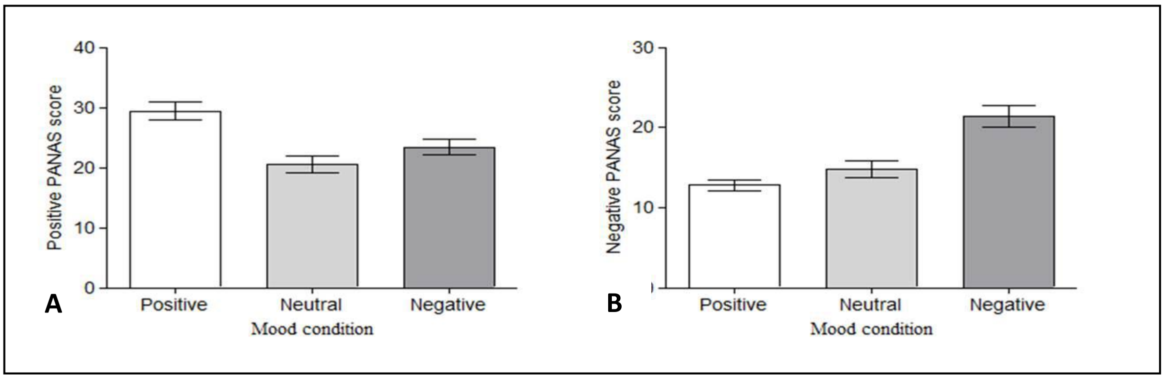

Figure 2.7. Mean PANAS scores for each induced mood condition. Self-reported mood varied across the conditions for both positive affect (A) and negative affect (B). Error bars = standard error of the mean.

Analysis of the positive affect scores showed a significant effect of mood, *F* (2, 60) = 21.782, *MSE* = 29.161, *p* < .001. Planned comparisons revealed that viewing positive stimuli significantly increased positive mood scores compared to neutral stimuli (29.4 vs. 20.5; *F* (1, 30) = 33.610, *MSE* = 72.583, *p* < .001; Figure 2.7). Higher positive mood scores were also evident after viewing negative (23.4) compared to neutral stimuli, *F* (1, 30) = 7.290, *MSE* = 35.049, *p* < .05; Figure 2.7).

Analysis of negative affect revealed that viewing emotional stimuli influenced negative mood, F (2, 60) = 40.441, *MSE* = 15.488, *p* < .001. Planned comparisons showed that viewing negative stimuli significantly increased negative mood scores compared to neutral stimuli (21.4 vs. 14.8; *F* (1, 30) = 41.024, *MSE* = 33.045, *p* < .001; Figure 2.7). Higher negative mood scores were also evident after viewing neutral compared to positive stimuli (14.8 vs. 12.8; *F* (1, 30) = 4.647, *MSE* = 25.832, *p* < .05; Figure 2.7).

fNIRS results

Analysis for each optode was conducted separately resulting in sixteen 2 (task) x 3 (emotion) repeated measures ANOVAs that investigated the effects of task and emotion on oxy-Hb in the PFC. Significant main effects of task were evident in optodes 1-3, 5, 7-9, 11, and 12 demonstrating higher levels of oxy-Hb during change detection trials compared to stimuli viewing (Figure 2.8; Table 2.1). No significant effect of task was evident in optodes 6, 13-16.

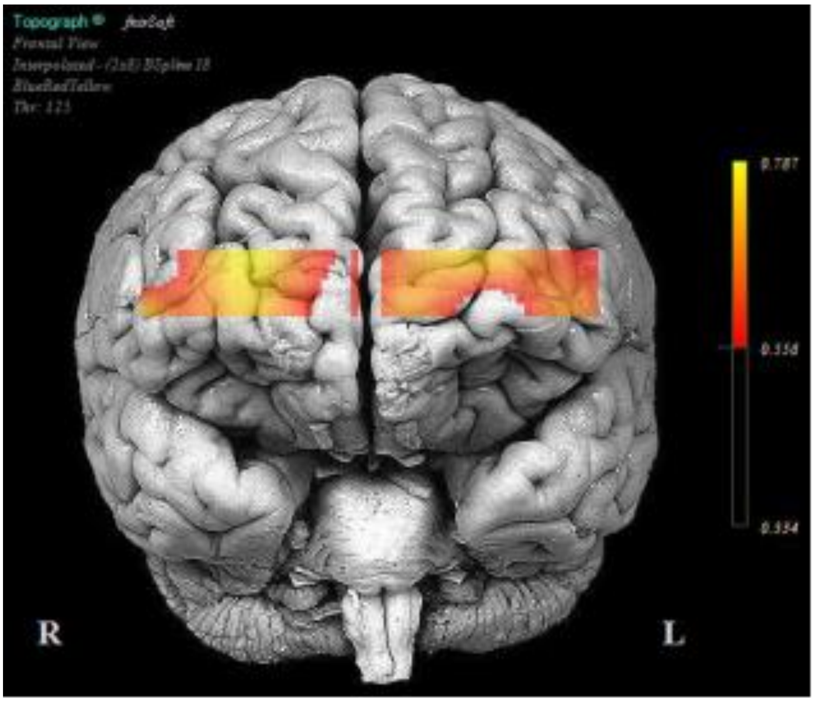

Figure 2.8. Increased oxy-Hb activation during the change detection task compared to scene viewing across the PFC. The increase in PFC activation during the change detection task compared to stimuli viewing task is visualized by subtracting stimuli viewing oxy-Hb activation from change detection task oxy-Hb activation.

Optodes 4 and 10 displayed a trend towards increased oxy-Hb activity during change detection trials compared to the stimuli viewing task (Table 2.1). There were no significant effects of emotion on oxy-Hb activity in any of the optodes and no significant interaction between emotion and task (Table 2.1).

Table 2.1. Results of 3 (emotional valence) x 2 (cognitive task) repeated measures ANOVAs of oxy-hb concentration changes.

Channel	**Emotional valence**			**Task**			**Interaction**		
	F	***MSE***	***p***	***F***	***MSE***	***p***	***F***	***MSE***	***p***
1	1.052	3.525	.362	8.977	1.290	.009**	1.773	1.057	.198
2	.798	4.299	.455	7.244	2.174	.012*	.331	1.837	.720
3	.596	5.495	.555	9.170	2.236	.006**	.806	1.422	.453
4	.773	3.147	.468	3.561	2.320	.073	1.008	1.504	.373
5	.089	3.551	.915	12.130	1.339	.002**	.191	1.033	.827
6	.244	4.552	.784	2.096	2.528	.159	.141	2.061	.869
7	.406	3.863	.669	8.032	2.622	.009**	.104	1.132	.901
8	.342	3.468	.712	6.466	3.058	.017*	.092	1.939	.912
9	.206	3.405	.815	4.290	2.535	.049*	.168	.939	.846
10	.327	4.839	.723	3.307	3.151	.082	.513	2.283	.602
11	.230	3.016	.795	13.815	1.299	.001**	.543	1.584	.585
12	.096	7.455	.909	9.457	2.477	.005**	.490	1.808	.615
13	1.255	5.132	.302	1.246	3.621	.285	.305	3.840	.739
14	.740	6.248	.491	.719	4.017	.418	.286	2.612	.755
15	.270	5.976	.767	1.953	1.953	.479	.575	1.637	.574
16	.238	5.296	.789	1.858	2.503	.192	.139	1.569	.870

* $p < .05$; ** $p < .01$.

2.4.5. Discussion

The aim of the current study was to investigate the underlying PFC activity during the viewing of emotional stimuli and during a subsequent cognitive task. It is the first study to use the change detection flicker task to investigate the influence of emotion on hemodynamic activity in the PFC (during a visual attention task). The exact role of the PFC in the relationship between emotion and cognition is still unknown despite recent advances in this area. Current research reports conflicting results in terms of PFC neural activity during the viewing of emotional stimuli (Kreplin & Fairclough, 2013; Ozawa et al., 2014), as well as during cognitive task performance after emotion induction (Aoki et al., 2011; Ozawa et al., 2014). Further investigation in this area will help to identify the role of the PFC in healthy populations, as well as inform research exploring emotional processing in clinical and affective populations.

Higher PFC oxy-Hb activity in 9 out of 16 optodes during the change detection task compared to the stimuli viewing task (irrespective of emotion condition) most likely demonstrates the increased cognitive resources needed to complete the change detection task. However, the neuroimaging data suggest that PFC activity did not differ between emotion conditions indicating that emotion does not influence PFC oxy-Hb activity during the viewing of emotion inducing stimuli or during a subsequent cognitive task. Additionally, no interaction effect between emotion group and task group was observed.

The observation of increased PFC oxy-Hb during the visual attention task compared to the emotional stimuli viewing task is indicative of increased cognitive demand during the visual attention task. The stimuli viewing task was passive, possibly involving bottom-up processing, whereas the visual attention task was more demanding and required additional top-down processing. Previous research utilizing fNIRS has shown increases in PFC oxy-Hb activity as a cognitive task gets progressively more difficult (Fishburn et al., 2014; Herff et al., 2014). Despite these differences in oxy-Hb between our two tasks no influence of emotion on PFC oxy-Hb activity was observed.

The finding that viewing different types of emotional stimuli has no impact on PFC oxy-Hb activity was surprising as previous research has demonstrated emotion-related changes in PFC oxy-Hb activity (Matsubara et al., 2014; Ozawa et al., 2014). One possible explanation could be that participants in the current study were not successfully induced into the experimental mood conditions. However, the results from the self-report PANAS suggest that emotional stimuli did induce positive and negative emotion in participants. In relation to mood induction during the cognitive task, due to the fact that our PANAS measures were completed immediately after the viewing of affective stimuli, rather than after (or in addition to) the change detection task had been completed, we cannot rule out the possibility that participants were induced into mood groups after viewing affective stimuli only for their mood to return to normal as they completed the change detection task. One possible reason could be the fact that the stimuli used in the change detection task were controlled so that all images were of neutral affect. Research has previously shown that the influence of emotion on cognition can be dependent upon the valence of the specific task stimuli used (Ozawa et al., 2014). It is worth noting here that we did observe an unexpected finding when analyzing the PANAS data. Participants reported higher positive mood scores after viewing negative compared to neutral stimuli. One possibility is that participants were responding to increased arousal in the negative images compared to neutral images. The important finding regarding the negative mood PANAS data is consistent with expectations that after viewing negative stimuli higher levels of negative mood were reported validating our mood induction method.

The non-significant effect of emotion on PFC oxy-Hb activity was also unexpected and this may be due to the way in which data is analyzed. For example, in the current study emotion-related oxy-Hb changes were compared against each other (positive, neutral, and negative mood) and no differences in activity were observed. In contrast, in Ozawa et al. (2014) changes in oxy-Hb for neutral and negative stimuli were compared against baseline oxy-Hb activation and it was shown that both neutral and negative stimuli increased PFC activation. When oxy-Hb activity was directly compared across neutral and negative stimuli conditions no differences in activation were evident. This finding is similar to the observation in the current study and suggests that comparing oxy-Hb changes to baseline data may inflate differences in activation.

The lack of any emotion-dependent changes in PFC oxy-Hb activity during the change detection task could be due to the methodological issue concerning the stimuli valence described above. However, previous research has shown that naturally occurring negative mood can influence PFC oxy-Hb activity during a cognitive task (Aoki et al., 2011). Additionally, it has also been demonstrated that oxy-Hb activity during a cognitive task is increased after participants viewed negative emotional stimuli compared to neutral stimuli (Ozawa et al., 2014). It would be interesting to see if there are interactions between the difficulty level of the visual attention task employed and emotion on behavioural performance and underlying neural PFC activity. Recent evidence has shown that threat distractors can decrease activity in the dlPFC during demanding trials in a multi-source interference task, whereas they increase activity during less demanding trials (compared to no distractor trials) (Jasinska et al., 2012). This finding suggests such interactions may be evident in brain regions involved in cognitive control as changes in dlPFC activity in response to threat distractors differ according to task difficulty. It has also been shown that PFC oxy-Hb activity increases as a cognitive task becomes more demanding (Fishburn et al., 2014; Herff et al., 2014). It is possible that as the current study only adopted one level of task difficulty the task may have been too demanding and therefore masked any possible influence of emotion on PFC oxy-Hb activation. However, if this was the case we would still expect to observe emotion-related changes in PFC oxy-Hb activity during the passive stimuli viewing task which we did not observe.

Cognitive theories attempt to explain behaviour in terms of accurate fits with average group-level performance. However, these models often fit less accurately when they are applied to individuals (Parasuraman & Giambra, 1991). Individual differences are likely to mitigate the effect of emotion on cognition and evidence from healthy populations supports this view. For example, it has been shown that neuroticism modulates amygdala-PFC connectivity in response to negative emotional facial expressions (Cremers et al., 2010). Interestingly, neuroticism and extraversion have been shown to predict attentional performance during change detection (Hahn et al., 2015). Additionally, Crocker et al. (2012) have shown that state negative affect and trait negative affect have both combined and separate influences on attentional processing. Further, it has been shown that in individuals with experience of early-life stress, personality traits linked to emotional control are related to sustained vmPFC activity during a mildly stressful task. The vmPFC is involved in emotional processing and regulation of amygdala activity (Wang et al., 2013). Finally, in a study investigating the influence of negative images and the positive affect trait on amygdala activation, it was found that amygdala response was influenced by both task demand and the positive affect trait (Sanchez et al., 2015). These findings demonstrate that individual differences play a role in mitigating the effect of emotion on cognition.

The current study did not take into account any individual differences in mood/depressive symptoms or personality traits and these need to be investigated further.

Initial research has demonstrated that rumination and mindfulness are linked to vmPFC activity involved in regulating amygdala activity (Wang et al., 2013) and are likely to moderate the effect of emotion on cognition. In addition, attentional impulsiveness (an index of impaired executive function) has been shown to be correlated with amygdala and dlPFC activity, both of which are brain regions involved in emotional and executive functioning during emotional distraction (Dolcos et al., 2013). It is likely that attentional impulsiveness will also impact upon the manner in which emotion influences cognition at both the behavioural and neural level. Research investigating individual differences in mood and cognition is important as it will help to advance our understanding of the brain regions and neural correlates in healthy individuals as well as those individual factors that may increase susceptibility to affective disorders.

In conclusion, using fNIRS there was no evidence that mood influences PFC oxy-Hb activity during affective stimuli viewing or during a subsequent visual attention task. This was unexpected and conflicted with the hypothesis as changes in oxy-Hb in response to emotional stimuli have been documented previously. It is possible that participants were not successfully induced into emotion groups, or that differences in the current experimental design and analysis and those used in past research influenced any potential observable differences. The finding of increased PFC oxy-Hb activity during the visual attention task compared to the emotional stimuli viewing task suggests the former is more cognitively demanding. This task requires additional top-down processing compared to the more passive (and bottom-up) stimuli viewing task. Recent research also suggests that individual differences mitigate the effects of emotion on cognition at the neural level. There is scope to expand on this work to investigate whether such influences have contributed to the current findings.

2.5. Chapter discussion

The first experiment was completed to measure the broadening and/or narrowing of visual attention due to emotion. A change detection flicker task was utilised as it is ideally suited to measure central and peripheral visual attention. Participants were induced into positive, neutral, and negative emotional states before searching for changes made to neutral scenes. Crucially, changes were located either in the centre or periphery of the scene. PFC neural activity was also recorded using fNIRS for a subset of the participants.

The findings show that participants were quicker and more accurate at detecting central changes compared to peripheral changes. This initial observation is important as it replicates similar findings shown using the same paradigm. In Rensink et al's early studies using real-world scenes, changes were made to areas of central interest or to areas of marginal interest, demonstrating that participants were quicker to identify changes made to items of central interest. Although the physical location of the changes in these early studies were not controlled to be presented either centrally or peripherally, the findings of the current experiment support these early findings and endorse the use of the change detection flicker task in the current work. However, whilst central changes were identified quicker and more accurately than peripheral changes, emotion had no impact on change detection. Therefore, the experiment shows that positive emotion did not broaden attention, nor that negative emotion narrowed attention in a change detection flicker task. Consequently, the findings provide no support for the predictions made by the broaden-and-build theory.

It is possible that the method of inducing emotion was unsuccessful, therefore providing an explanation for the lack of any effect of emotion on change detection. Whilst this suggestion cannot be categorically discounted it remains unlikely. Firstly, the emotion induction procedure produced a strong effect on self-report affect scores. Participants self-reported higher levels of positive affect after the positive emotion induction and higher levels of negative affect after undergoing the negative emotion induction. However, it must be noted that socially desirable responding is a general issue with self-report data collection methods. Further, there is evidence to suggest that in instances where participants guess the hypotheses of a study, they can provide responses that confirm a researcher's predictions or try to 'help' the researcher (Heppner et al., 1992)[7]. Previous evidence suggests that using valenced stimuli including images to induce changes in emotion or mood have been shown to be successful (e.g. Anderson et al., 2011; Jiamsanguanwong & Umemuro, 2014; Lee et al., 2014; Limonero et al., 2015) and is an established method for inducing emotion or mood in the laboratory. Therefore, this emotion manipulation technique has been shown to be successful in prior work and the analysis of the affect scores in the current experiment suggest that emotion had been successfully induced. Instead of emotion causing a broadening or narrowing of

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[7] Whilst this is a possibility it is the opinion of the author that participants were naïve to the crucial experimental hypotheses.

visuospatial attention, it is proposed here that emotion may instead bias individuals towards a particular processing style.

The neural activation data supports the behavioural findings. Here, changes in PFC oxy-Hb did not differ according to emotion. However, measurable effects of the task on oxy-Hb were evident with increased activity during the change detection task (irrespective of emotion condition) compared to when participants viewed images during emotion induction (irrespective of emotion condition). Increased oxy-Hb was seen in several PFC regions hypothesised to be involved in emotional processing and cognitive control including the dlPFC, vlPFC and mPFC. This finding suggests that fNIRS is sufficiently sensitive to detect increases in oxy-Hb during tasks that vary in their difficulty, but that the emotion conditions had no impact on these task-related increases in neural activity.

One explanation for the conflicting findings within the literature regarding the influence of emotion on either a broadening or narrowing of visual attention relates to possible differences between individuals. For instance, the effectiveness of emotion induction procedures has been shown to vary between individuals (Gomez et al., 2000; Kohn et al., 2013), whilst reactivity to positive information has been shown to be predicted by genetic variations (Haase et al., 2015). Differences in global-local processing are also observed when levels of depressive symptoms are considered (de Fockert & Cooper, 2014). The influence of emotion on visual attention has also been shown to be influenced by factors such as depression severity and trait negative affect (Crocker et al., 2012; Grol & Raedt, 2014; Hur et al., 2015). Moreover, some individual difference traits, including the personality traits extraversion and neuroticism, are linked to affective reactivity and models of psychopathology (Clark, 2005; Watson et al., 1994). These studies suggest that emotion may interact with individual difference traits linked to affective reactivity to influence selective visual attention. Interestingly, extraversion has also been shown to impact change detection performance (Hahn et al., 2015). However, currently it is unknown whether extraversion and emotion interact to influence selective visual attention during change detection. The current results were unexpected as they contrast with previous findings. One explanation for this may be variations in individual differences and this was explored in a second experiment.

Chapter Three: The influence of emotion, extraversion, and neuroticism on change detection

3.1. Overview of Chapter Three

In this Chapter an experiment is presented that offers a replication of Experiment One, and importantly, builds upon this first experiment with the inclusion of two personality traits: extraversion and neuroticism. Consequently, Experiment Two has three main aims. Firstly, it was important to provide a replication of Experiment One, especially given the non-significant effects of emotion on selective visual attention since previous studies show an impact of emotion on attention. Secondly, the inclusion of extraversion and neuroticism allow the investigation of whether individual difference traits linked to affective reactivity may impact selective visual attention during a change detection flicker task. Crucially, the inclusion of extraversion and neuroticism also permit the investigation of whether affective traits can mitigate any effect of emotion on selective visual attention. Initially, extraversion and neuroticism are introduced, and research is discussed linking both traits to emotional processing, affective disorders and visual attention. Following this, Experiment Two is presented. Finally, the Chapter will finish with a summary highlighting the main findings and their implications.

3.2. Evidence for links between extraversion and neuroticism and emotional processing

Personality describes individual differences in patterns of thinking, feeling and behaviour. The Five-Factor Model of personality (‘Big Five’) encompasses five broad trait dimensions or factors: openness, conscientiousness, extraversion, neuroticism and agreeableness (Costa & McCrae, 1992; McCrae & John, 1992)[8]. Of these five broad dimensions, extraversion and neuroticism are most often linked to psychopathology. The NEO Personality Inventory, which is frequently used to research personality and psychopathology, includes six facets for both extraversion: activity, assertiveness, excitement-seeking, gregariousness, positive emotions and warmth, as well as neuroticism: anxiety, depression, hostility, impulsiveness, self-consciousness and vulnerability to stress (Costa & McCrae, 1992). Extraversion is associated with optimism, energetic engagement

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[8] A detailed review of empirical research on personality and the corresponding theoretical debates are beyond the scope of this thesis.

with the world, enjoyment of social contact and reward sensitivity (DeNeve & Cooper, 1998; DeYoung, 2013; Diener et al., 1992; Eysenck, 1990; John et al., 2008; Smillie, 2013; Smillie et al., 2012; Watson et al., 1994). Moreover, extraversion is related to positive emotion and happiness, with extraverts reporting higher levels of wellbeing and additional positive experiences compared to introverts (Costa & McCrae, 1980; John et al., 2008), as well as lower levels dissatisfaction with life (Hettema et al., 2020; Lee et al., 2017). In comparison, neuroticism has been conceptualised in terms of emotional instability and increased reactivity to stress and aversive environmental stimuli, whilst reflecting the tendency to experience negative emotions and greater levels of dissatisfaction with life (Hettema et al., 2020; John et al., 2008; Lee et al., 2017; Watson et al., 1994).

Extraversion and neuroticism are associated with affective reactivity and feature in models of psychopathology (Clark, 2005; Watson et al., 1994). For example, extraversion has been linked to increased positive affect following mood induction (Smillie et al., 2012, 2013), whilst both extraversion and neuroticism have been linked to the development of affective disorders. For instance, major depressive disorder (MDD) has been shown to be predicted by greater levels of neuroticism (Kendler et al., 2006; Wilks et al., 2020). Moreover, neuroticism is able to predict hypomania symptoms (Wilks et al., 2020). Hirschfeld et al. (1989) and Krueger et al. (1996) found that low levels of extraversion can predict the onset of MDD. However, other researchers have failed to replicate this relationship in additional studies (Kendler et al., 1993, 2006). Extraversion has also been shown to be able to predict hypomania symptoms (Wilks et al., 2020). Interestingly, patients undergoing antidepressant treatment for MDD have experienced reductions in levels of neuroticism and increases in levels of extraversion. Moreover, decreases in levels of neuroticism following antidepressant treatment were predictive of reduced relapse rates for MDD patients (Tang et al., 2009). The above findings show that extraversion and neuroticism are related to affective reactivity and emotional wellbeing, in addition to being linked to the development of affective disorders. Whilst research investigating the relationships between personality (notably extraversion and neuroticism) and emotional processing and psychopathology has received much focus, substantially less is currently known regarding the impact of personality traits on visual attention.

3.3. Effects of extraversion and neuroticism on attention

Initial research suggesting a link between extraversion and attention demonstrated that extraverts are slower to shift their attention away from positive stimuli, whilst introverts took longer to move their attention away from negative stimuli, indicative of differences in disengagement (Derryberry & Reed, 1994). Both extraversion and neuroticism have also been linked to performance during tasks measuring the attentional blink (AB) suggestive of differences in the capacity of visual attention (Bredemeier et al., 2011; MacLean & Arnell, 2010). MacLean and Arnell (2010) asked participants to complete a rapid serial visual presentation task before completing self-report measures of extraversion and neuroticism. The results demonstrated that higher levels of neuroticism and lower levels of extraversion were associated with a larger AB. It is theorised that the AB effect occurs due to limited processing capacity where individuals are not able to process stimuli or information presented in close temporal proximity (Chun & Potter, 1995; Raymond et al., 1992). Therefore, it is argued that individuals with lower levels of neuroticism and higher levels of extraversion can process more information and subsequently suffer from the AB to smaller degree. Further research, adopting a psychometric approach, has suggested that measures of attentional control are able to mediate the influences of both neuroticism and extraversion on attention to emotional information (Yu et al., 2016). Here it was shown that self-reported levels of attentional control increase the positive emotion bias of individuals higher in levels of extraversion, whilst attentional control reduced the negative emotion bias observed in neurotic individuals. Recent work showing that individuals higher in levels of neuroticism and individuals lower in levels of extraversion are more susceptible to mind wandering is also suggestive of links between these traits and attentional control (Pereira et al., 2020; Robison et al., 2017).

The findings discussed above provide initial evidence that extraversion and neuroticism are associated with visual attention. Specifically, they show that attention to emotional stimuli differs dependent on levels of extraversion and neuroticism and that differences in the AB related to these personality traits may be due to altering processing capacities. Additionally, evidence also suggests that the differing relationship between extraversion and neuroticism to positive and negative stimuli is influenced by measures of attentional control.

A series of studies have also revealed differences in neural activation based on extraversion and neuroticism during attentional processing. For instance, using fMRI, it has been shown that attentional focus can influence the relationship between extraversion and striatal neural activity when viewing positive stimuli (but not negative stimuli) (Hutcherson et al., 2008). Additional research using EEG has demonstrated higher P2 and P3 amplitudes during the viewing of highly positive stimuli compared to when viewing moderately positive or neutral stimuli for extraverts (Yuan et al., 2009, 2012). Moreover, measuring the N2 in response to emotional stimuli, neuroticism has been shown to modulate the impact of extraversion on attention (Yu et al., 2016). These studies provide evidence that extraversion and neuroticism are associated with neural activation during attention and may reveal some of the neural mechanisms supporting increased wellbeing often seen in extraverts and individuals lower in neuroticism.

Extraversion and neuroticism have also been shown to be predictive of change detection performance. Using a change detection flicker task, where participants were required to indicate whether a change was present or absent, higher levels of extraversion and lower levels of neuroticism were related to improved accuracy (Hahn et al., 2015). Hahn et al. (2015) suggest that one possible mechanism explaining the link between personality and attention is the affective state associated with personality, and provide evidence from studies showing that positive emotion promotes global processing whilst negative emotion promotes a local processing style (Basso et al., 1996; Fredrickson & Branigan, 2005). However, as previously discussed (see Chapter One), studies measuring global-local processing are inadequate in measuring changes in the breadth of visuospatial attention. Further, Hahn et al. (2015) provide additional evidence of a broadening of attentional breadth from research adopting a flanker task (Rowe et al., 2007). However, a number of studies adopting the flanker task have failed to show an effect of emotion on attentional breadth including a direct replication of Rowe et al's initial study (Bruyneel et al., 2013; Jiang et al., 2011; Martin & Kerns, 2011; Wegbreit et al., 2015). Additionally, Hahn et al. (2015) do not provide any detail regarding the location of the changes in their change detection trials. Therefore, it is not possible to know whether the change detection performance benefits associated with increased levels of extraversion and reduced levels of neuroticism are due to any attentional broadening.

Whilst research suggests that extraversion and neuroticism are associated with visual attention and emotional processing, it is not currently known whether extraversion and neuroticism can interact with emotion to influence visual attention. Given the findings of Experiment One, showing that emotion did not impact selective visual attention, it was important to investigate possible reasons for this observation. One possibility is that levels of extraversion and neuroticism may have influenced the findings. Consequently, Experiment Two tested whether levels of extraversion and neuroticism can interact with emotion to influence selective visual attention in a change detection flicker task.

3.4. Interactive influences of emotion and extraversion on visual attention[9]

3.4.1. Abstract

Emotion has been shown to influence selective visual attention. However, studies in this field have revealed contradictory findings regarding the nature of this influence. One possible explanation for the variation in findings is that individual differences affect both attention and emotion and may therefore be moderating any influence of emotion on attention. The current work investigated the effects of induced emotional states and the traits of extraversion and neuroticism on visual attention. This allowed a direct investigation of any impact of extraversion and neuroticism on the way in which emotion influences attention. Participants were induced into positive, neutral, and negative emotional states before completing a change detection flicker task in which they were required to locate a change to a real-world scene as quickly and accurately as possible. Neuroticism had no impact on attention. Participants scoring high on extraversion were more accurate but slower at detecting changes. Importantly, this was particularly evident when induced into a negative emotional state. These findings support research linking extraversion to affective reactivity and models of psychopathology. Moreover, the current study provides evidence that extraversion can moderate the influence of negative emotion upon visual attention and may help to explain some of the contradictory findings in this research area.

3.4.2. Introduction

The visual world is cluttered, and it is impossible to attend to all items and areas simultaneously. Priority is therefore given to the most relevant areas or objects. This ‘biasing’ of attentional resources, known as selective visual attention, is subject to a range

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[9] Bendall, R.C.A., Begley, S., & Thompson, T. (2020). *Interactive influences of emotion and extraversion on visual attention.* Manuscript submitted for publication.

of influences and is dependent upon top-down and bottom-up processing (Schneider & Shiffrin, 1977). Top-down processing is characterised by goal-directed behaviour (e.g. directed attention to a target during visual search) whereas bottom-up processing refers to the automatic capture of attention by salient information in the environment regardless of task demand (Itti & Koch, 2000).

Selective attention (together with other aspects of executive function) is underpinned by the recruitment of the prefrontal cortex (PFC), in particular the dorsolateral prefrontal cortex (dlPFC) (Curtis & D'Esposito, 2003; Miller & Cohen, 2001). The dlPFC shares parallel anatomical connections with the posterior parietal cortex (Katsuki & Constantinidis, 2012), a region of the parietal lobe associated with a number of cognitive processes including selective attention (Behrmann et al., 2004). For instance, it has been revealed that dorsal attention networks, including the intraparietal cortex and superior frontal cortex, are involved in preparing and conducting goal-directed selection of stimuli and responses (Corbetta & Shulman, 2002). Further, the PFC has been shown to play a crucial role in the switching of top-down attention allocation (Rossi et al., 2009).

In addition to being crucial to selective attention, research has demonstrated that the PFC is involved in emotional processing during cognitive tasks (for reviews see Dolcos et al., 2011; Dolcos et al., 2014). It is suggested that emotional processing comprises neural activation resulting from interactions between the *hot* emotional system found in limbic regions (e.g. the amygdala) and *cold*, higher order emotional systems located in the PFC (Dolcos et al., 2011; Fossati, 2012). Additionally, direct and indirect anatomical connections exist connecting the *hot* and *cold* emotional neural systems (Fossati, 2012; Ray & Zald, 2012). Given that the same top-down resources are used in emotional processing and in the allocation of selective visual attention, it follows that emotion may have an impact on attention.

This suggestion is supported by a wide range of research findings and theoretical models, one of which is the broaden-and-build theory (Fredrickson, 2001). The theory proposes that positive emotions, including joy, interest, contentment, pride, and love, have the ability to "broaden" an individual's "thought-action repertoires". It is also suggested that positive emotions "build" an individual's "enduring resources", including physical resources (e.g. life longevity; Danner et al., 2001), intellectual resources (e.g. theory of mind; Leslie, 1987), social resources (e.g. relationship quality; Aron et al., 2000) and psychological resources (e.g. resilience; Fredrickson et al., 2003). Specifically, the theory posits that, over time, experiencing positive emotions will have a cumulative effect; enabling an individual to become more creative, knowledgeable, resilient, socially integrated, and healthy, and providing them with resources that can be utilized as necessary in the future. The theory predicts that positive emotions will therefore have a beneficial impact on visual attention by expanding available resources. Frederickson outlines that negative emotions have the opposite effect, preventing one from thinking broadly and from building lasting psychological reserves.

Empirical research has provided support for the predicted broadening impact of positive emotion on visual attention. In an eye-tracking study, participants were presented with three images (one located in the center of the screen and two situated in the periphery). Participants induced into a positive mood state made more fixations on the peripheral stimuli compared to those induced into a neutral mood state and the researchers concluded that this reveals a broadening of attention under positive moods (Wadlinger & Isaacowitz, 2006). Using a modified version of the Eriksen flanker task (Eriksen & Eriksen, 1974) Rowe et al. (2007) also provided evidence for a broadening of attention in positive moods. They presented participants with a central target that was flanked by distractors and manipulated the distance between the targets and distractors. Findings showed that participants induced into a positive mood suffered more interference from far distance distractors compared to those induced with neutral and sad moods. This suggests that in positive moods attention will expand, allowing an individual to process more information (regardless of whether this is relevant or irrelevant to the task).

Despite the evidence for a broadening effect of positive emotion there is now a growing body of literature that casts doubt on the broaden-and-build theory (Bendall & Thompson, 2015a; Bruyneel et al., 2013; Grol & Raedt, 2014; Taylor et al., 2017). Bruyneel et al. (2013) conducted a partial replication of the flanker experiment of Rowe et al. and found no evidence for a broadening of attention on the basis of positive mood. The researchers did find that overall response times were longer in the negative mood condition (regardless of flanker location or compatibility), although they acknowledged this effect may have been due to a lack of counterbalancing in the experiment. In a study investigating the allocation of spatial attention Bendall and Thompson (2015) induced participants into positive, neutral, and negative emotional states and asked them to locate central and peripheral changes in a change detection flicker task (Rensink et al., 1997).

Whilst central changes were detected faster than peripheral changes, emotion had no impact on this, providing no evidence for a broadening effect.

Given the contrasting findings regarding the effects of emotion on selective attention it is important to consider the factors that may be contributing to these mixed results. Cognitive theories attempt to explain behaviour in terms of average group-level performance, however, these models often fit less accurately when they are applied to individuals (Parasuraman & Giambra, 1991). On the basis of this, a possible explanation for the differing findings regarding the effects of emotion on attention is differences between individuals. One possible method to explore the influence of individual differences on the relationship between emotion and visual attention is to investigate personality traits. Extraversion and neuroticism are two personality traits that feature in models of psychopathology and are linked to affective reactivity (Clark, 2005; Watson et al., 1994). Extraversion is characterized by optimism, energetic engagement with the world, and enjoyment of social contact (DeNeve & Cooper, 1998; Diener et al., 1992; Eysenck, 1990; John et al., 2008; Watson et al., 1994). Extraversion is also associated with positive emotion and happiness and extraverts report higher wellbeing and more positive experiences than introverts (Costa & McCrae, 1980; DeNeve & Cooper, 1998). Neuroticism has been conceptualized in terms of emotional instability and heightened reactivity to stress and aversive environmental stimuli, and it reflects the tendency to experience negative emotions (John et al., 2008; Watson et al., 1994).

Using a rapid serial visual presentation task MacLean and Arnell (2010) found that higher levels of neuroticism were associated with a larger attentional blink (AB) whilst greater extraversion predicted smaller ABs. Early theories to account for the AB effect suggest that it occurs due to limited processing capacity whereby individuals are unable to process information presented in close temporal proximity (Chun & Potter, 1995; Raymond et al., 1992). These results would therefore indicate that extraverts and individuals low in neuroticism can process more information and consequently suffer from the AB to a lesser extent. Neuroticism and extraversion have also been found to predict attentional performance during change detection. It has been demonstrated that higher accuracy was associated with higher levels of extraversion but lower levels of neuroticism, suggesting that these individuals demonstrate improved performance in demanding tasks that measure the allocation of attention (Hahn et al., 2015). Research therefore shows that personality traits associated with emotionality can influence attention and cognitive resources.

On the basis of this the current work proposes that neuroticism and extraversion may moderate the effects of emotion on attention and this may be one reason for the differing findings in the literature. High levels of extraversion and low levels of neuroticism appear to be associated with increased cognitive resources, allowing for improved performance in tasks measuring attention. If emotion influences attention by influencing attentional capacity, it may be proposed that such personality traits will interact with the effects of emotion. For instance, due to their increased availability of cognitive resources, individuals high in extraversion and low in neuroticism may not show the predicted impact of positive emotion in comparison to neutral emotion. Similarly, individuals who are low in extraversion and high in neuroticism, and who may have limited attentional resources, will suffer from a negative mood state to a greater extent than those high in extraversion and low in neuroticism. This is because negative emotion will reduce the capacity of an already limited set of resources, whereas because those with higher levels of extraversion (for example) have more resources available to them they will be protected from the impact of negative emotional states. The aim of the current study is to investigate whether the influence of emotion on attention is affected by extraversion or neuroticism.

Participants were induced into positive, negative, and neutral emotion states and asked to detect central and peripheral changes to neutral scenes in a change blindness flicker paradigm (following the method of Bendall & Thompson, 2015). Three conditions of emotional state were used because it has been argued that positive and negative (as well as neutral) conditions need to be included in studies investigating affective processing to allow more precise conclusions to be reached (Bendall et al., 2016; Carretié, 2014). Self-reported levels of extraversion and neuroticism were recorded based on previous research demonstrating a beneficial influence of extraversion and a negative impact of neuroticism on change detection. It was predicted that high levels of neuroticism would result in poorer performance, whereas high levels of extraversion would be associated with improved change detection. Following the findings from Bendall and Thompson (2015) that emotion does not impact visual attention during a change detection flicker task, it was predicted that, when analysed in isolation, emotion would have no influence on performance. Crucially it was hypothesised that emotion would have an influence when considered together with the individual difference traits of extraversion and neuroticism. Specifically, it was predicted that a negative emotional state would impair performance for those reporting low levels of extraversion compared to those high in extraversion. It was also predicted that performance a under a negative emotional state would be reduced for participants high in neuroticism but not for those low in neuroticism.

3.4.3. Methods

Participants

A sample size calculation aiming to achieve statistical power of .80 with an alpha criterion of .05 and effect size of .25 suggested that a sample of 28 participants were required[10]. An opportunity sample of 30 students (26 female) from the University of Salford aged between 19 and 30 years (*M* = 23.47, *SD* = 3.45) participated in this experiment. Written informed consent was gained from each participant. Ethical approval was obtained from the School of Health Sciences Ethical Approval Committee at the University of Salford. All methods were carried out in accordance with the relevant guidelines and regulations. Where appropriate participants received course credit for participating.

Design

A mixed design was used with three independent variables. A within-participants variable included *emotion* induced prior to the change detection task (positive, neutral, or negative). Two between-participant variables consisted of levels of *neuroticism* (high or low), and levels of *extraversion* (high or low)[11]. Because the study did not make predictions regarding possible interaction effects between extraversion and neuroticism, and to maximise the power of the statistical analyses, neuroticism and extraversion were analysed separately resulting in a 3 x 2 analytical framework. The dependent variables consisted of accuracy (percentage correct) and response time (in seconds) to detect the changes. A measure of positive and negative affect was also recorded to validate the method for inducing emotion.

Materials

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[10] Further details regarding the sample size/power analysis is provided in Appendix Four.

[11] Descriptive statistics for individual difference traits are provided in Appendix Five.

The experiment was designed and run using E-Prime (Psychological Software Tools, Inc.) and participants completed the experiment using a Viglen Intel Quad Core computer with a 60 Hz, 19-inch monitor. Emotion was manipulated by presenting participants with visual images of differing emotional valence from the International Affective Picture Systems (IAPS; Lang et al., 2008). A total of 60 images were selected to induce mood, 20 positive (mean valence 7.65), 20 neutral (mean valence 4.62), and 20 negative (mean valence 2.35; see Appendix One). Twenty additional positive images (mean valence 7.87) were presented at the end of the experiment (see Appendix One). All images were presented in color and measured a maximum of 1024 x 768 pixels.

A total of 180 neutral images were used for the change detection task. One central and one peripheral change was made to thirty-six original images (both indoor and outdoor scenes) making a further 72 images. All changes were deletions (one item in the scene disappeared) and care was taken to ensure that changes were all a similar size. Central changes were made within the center of each image (within an area measuring 512 x 384 pixels) and peripheral changes were made outside of this area. There were an equal number of peripheral changes made on the right and left side of the images. For each changed image a response screen was also created. This consisted of the original image separated into 4 equal sections that each contained a red letter (A, B, C, and D) to allow participants to indicate the location of a change. All images in the change detection task measured 1024 x 768 pixels and were identical to those used by (Bendall & Thompson, 2015a).

The Positive and Negative Affect Schedule (PANAS), a 20-item self-report measure, was used to record participant mood after presentation of affective stimuli (Watson et al., 1988). The measure consists of 20 words that describe positive and negative feelings and emotions. The words were presented in a random order and for each one participants were asked to “indicate to what extent you feel this way right now, that is, at the present moment” on a scale of 1 (very slightly or not at all) to 5 (extremely). The PANAS provides a measure of positive affect from the summed rating of all positive words and a measure of negative affect from the summed rating of the negative words. The minimum score for each measure is 10 (indicating low affect) and the maximum is 50.

The Revised NEO Personality Inventory (NEO-PI-R; Costa & McCrae, 2008) was administered to measure levels of neuroticism and extraversion. The 240-item self-report scale includes questions relating to personality characteristics and traits that are measured on a 5-point Likert scale from 0 (strongly disagree) to 4 (strongly agree). Each trait is measured by 48 questions, the minimum score for each trait is 0 (indicating low levels) and the maximum is 192.

Procedure

After providing written informed consent participants completed the NEO-PI-R. They were then seated approximately 22 inches from the screen and given full instructions about the task. The experimental procedure followed that used by Bendall and Thompson (2015). If participants were happy to proceed with the experiment they pressed the spacebar and were presented with 20 images from the IAPS. The images were shown for 5000ms each in a random order, with a 500ms inter-stimulus interval (ISI; blank white screen) separating each one, and participants were asked to view these pictures naturally. Once all images had been presented participants were instructed to complete the PANAS. Following this, participants pressed the spacebar to begin the change detection task. Twenty-four change detection trials were completed, consisting of 12 central changes and 12 peripheral changes (6 to the left and 6 to the right). In each trial an image was presented for 1000ms followed by a blue blank screen for 500ms. The changed image was then presented for 1000ms, again followed by the blue screen for 500ms. Participants were asked to search for the change between the two images and the images continued to alternate until participants pressed the spacebar to indicate they had located the change (Figure 3.1). A response screen was then presented, and participants reported the location of the change by pressing the relevant key on the keyboard (A, B, C, or D). Participants were told that the changes may be difficult to spot and if they were unable to locate the change they had the option of pressing ‘9’ to end a trial; however, they were asked to only use this as a “last resort”. See Appendix One, Supplementary Figure 1 for an example of trial stimuli. All trials were presented in a random order.

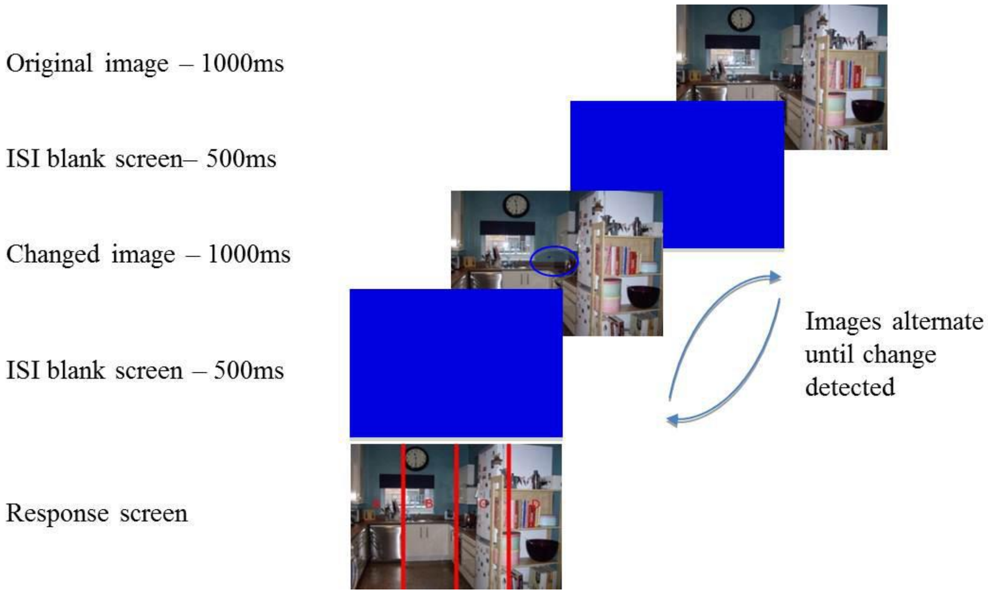

Figure 3.1. Illustration of the change detection flicker task. Participants were presented with an image for 1000ms followed by an inter-stimulus interval (ISI; blank screen) for 500ms. A changed image was then presented for 1000ms followed by another ISI for 500ms. This procedure continued until the participant identified the change in the scene and pressed the spacebar. They were then required to state where the change occurred by pressing the corresponding letter on the response screen. In this example the change was located in the centre of the image and the correct response was 'B'. Replicated with permission from Bendall and Thompson (2015).

Participants completed three blocks that each followed the above procedure (viewing of the IAPS images, completion of the PANAS, the change detection task). In the first block the IAPS images were either positive or negative (counterbalanced across participants). In the second block the images were always neutral, and in the final block they were again positive or negative depending on the valence of the first set of images. Across the task all 36 pairs of stimuli were shown twice (once with a central change and once with a peripheral change). The same image could not be presented twice in a single block.

Following completion of the final change detection task participants were presented with 20 further positive images from the IAPS (presented for 5000ms each with an ISI of 500ms). This was to make certain they were induced into a positive mood when leaving the lab.

3.4.4. Results

Data collected included accuracy (percentage correct) and response times (seconds) for the change detection task. Overall accuracy was 84.84% and participants took an average of 9.02s to correctly identify the change. Outliers were removed at ±2 standard deviations from the mean resulting in one participant being excluded from the analysis. In order to ensure that emotion was successfully induced the positive and negative affect scores from the PANAS were analysed.

Two one-way repeated measures analysis of variance (ANOVA) were conducted followed by planned contrasts to compare scores in the positive and negative conditions to scores in the neutral condition. Analysis of the positive affect scores showed a significant effect of emotion, $F(2, 56) = 23.55$, $MSE = 42.28$, $p < .001$, $\eta_p^2 = .46$. Planned comparisons show that viewing positive stimuli significantly increased positive mood scores compared to viewing neutral stimuli ($M = 29.90$, $SD = 9.48$ vs $M = 20.03$, $SD = 8.47$), $F(1, 28) = 29.45$, $MSE = 95.77$, $p < .001$, $\eta_p^2 = .51$; Figure 3.2. There were no differences in positive affect after viewing negative stimuli ($M = 19.48$, $SD = 5.26$) compared to neutral stimuli, $F(1, 28) = .16$, $MSE = 55.33$, $p = .693$, $\eta_p^2 = .01$; Figure 3.2.

For negative affect Mauchly’s test indicated that the assumption of sphericity had been violated therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\sum = .60$). Analysis of negative affect also showed a significant effect of emotion, $F(1.206, 37.781) = 37.95$, $MSE = 65.80$, $p < .001$, $\eta_p^2 = .58$. Planned comparisons revealed that viewing negative stimuli significantly increased negative mood scores compared to viewing neural stimuli ($M = 24.76$, $SD = 9.69$ vs $M = 12.28$, $SD = 3.13$), $F(1, 28) = 59.09$, $MSE = 76.47$, $p < .001$, $\eta_p^2 = .68$; Figure 3.2. There was no difference in negative affect between the positive ($M = 12.28$, $SD = 4.52$) and neutral conditions, $F(1, 28) = .00$, $p = 1.000$, $MSE = 25.14$, $\eta_p^2 = .00$; Figure 3.2.

Negative affect scores were also compared between individuals high and low in extraversion and neuroticism under negative emotion conditions to provide a measure of affective reactivity. Individuals high in extraversion ($M = 21.20$, $SD = 8.92$) showed reduced negative affect scores in the negative emotion condition compared to individuals low in extraversion ($M = 27.53$, $SD = 9.82$), $t(28) = 1.850$, $p = .038$, $d = .68$. There was no difference in negative affect scores in the negative emotion condition for individuals high in neuroticism (*M* = 23.73, *SD* = 10.17) and individuals low in neuroticism (*M* = 25.00, *SD* = 9.66), *t*(28) = .350, *p* = .365, *d* = .13.

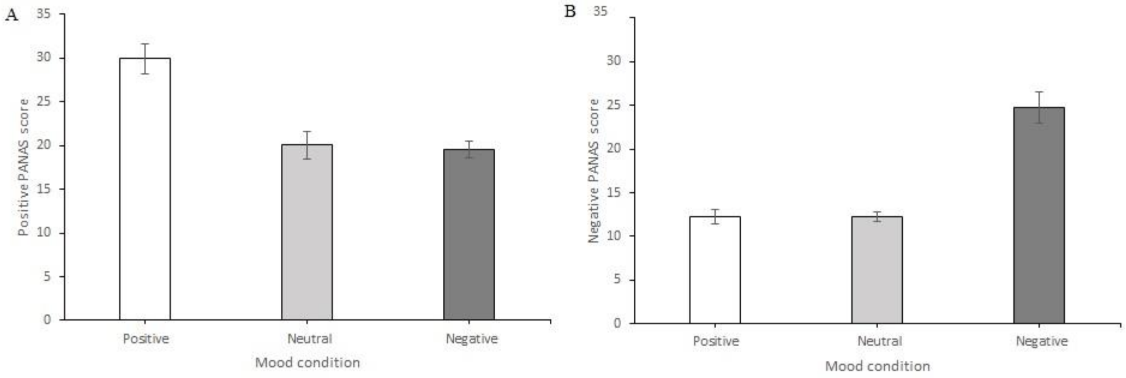

Figure 3.2. Mean Positive and Negative Affect Schedule (PANAS) scores for each induced mood condition. Self-reported mood varied across the conditions for both positive affect (A) and negative affect (B). Error bars = standard error of the mean.

Given that the mood induction procedure was found to be successful, the effects of emotion, extraversion, and neuroticism on attention were then analysed. To maximise power the influence of extraversion and neuroticism were assessed separately using a series of 3 (emotion) x 2 (extraversion or neuroticism) mixed measures ANOVAs. The effect of emotion was non-significant for both accuracy, *F*(2, 54) = .66, *MSE* = 151.77, *p* = .521, η_p^2= .24, and reaction time, *F*(2, 54) = 2.00, *MSE* = 8.52, *p* = .145, η_p^2= .07. Neuroticism also had no significant effect on accuracy, *F*(1, 27) = .18, *MSE* = 264.49, *p* = .671, η_p^2= .01, or reaction time, *F*(1, 27) = .75, *MSE* = 11.12, *p* = .393, η_p^2= .03. For accuracy, the interaction between neuroticism and emotion was non-significant, *F*(2, 54) = .882.76, *MSE* = 162.03, *p* = .421, η_p^2= .03. The interaction between neuroticism and emotion for reaction time was also non-significant, *F*(2, 54) = .08, *MSE* = 10.44, *p* = .926, η_p^2= .00.

There was a significant effect of extraversion on accuracy, *F*(1, 27) = 10.02, *p* = .004, *MSE* = 194.23, η_p^2= .27; Figure 3.3. Individuals in the high extraversion group detected changes more accurately than those in the low extraversion group (*M* = 91.70%, *SD* = 8.08 vs. *M* = 80.11%, *SD* = 11.25). There was also a significant effect of extraversion on reaction time, *F*(1, 27) = 15.44, *MSE* = 7.27, *p* = .001, η_p^2= .36; Figure 3.4. Individuals high in extraversion took longer to detect changes than those in the low extraversion group

(*M* = 10.48s, *SD* = 2.86 vs. *M* = 7.70s, *SD* = 3.32). This suggests a speed-accuracy trade-off for participants reporting high levels of extraversion.

For accuracy the interaction between extraversion and emotion approached significance, *F*(2, 54) = 2.76, *MSE* = 151.77, *p* = .072, η_p^2= .09; Figure 3.3. This was explored using planned contrasts that compared the positive and negative conditions to the neutral condition (planned contrasts do not require the omnibus *F* to reach significance). The contrasts showed no significant difference in the extraversion groups between the positive and neutral conditions, *F*(1, 27) = .35, *MSE* = 445.59, *p* = .560, η_p^2 = .01. However, when comparing the negative and neutral conditions there was an effect of extraversion, *F*(1, 27) = 8.62, *MSE* = 185.83, *p* = .007, η_p^2= .24; Figure 3.3. To explore this interaction further *t*-tests were conducted (an adjusted significance threshold was used due to multiple comparisons; *p* = .0125). When induced into a negative mood accuracy was higher for individuals high in extraversion compared to the low extraversion group, *t*(20.55) = -4.050, *p* = .001, *d* = 1.49. In contrast, when induced into a neutral mood there was no difference in accuracy for individuals high and low in extraversion, *t*(27) = -1.334, *p* = .193, *d* = .50.

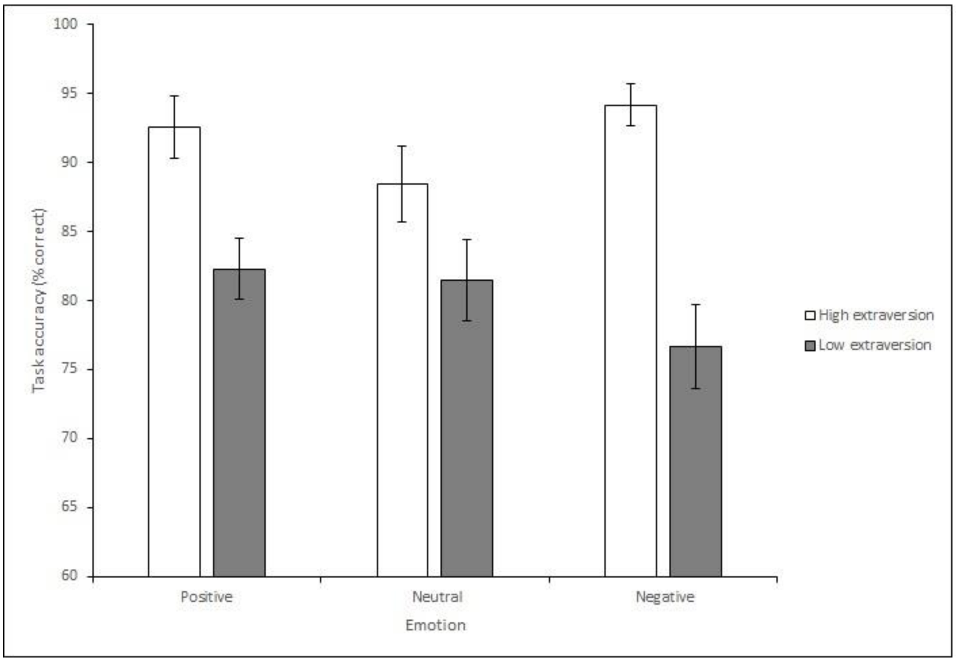

Figure 3.3. Mean percentage accuracy in the change detection task. Individuals high in extraversion detected changes more accurately than individuals low in extraversion. Accuracy to identify changes during the negative emotion condition were greater for those high in extraversion compared to those low in extraversion, whereas no differences in accuracy were evident during neutral and positive mood conditions on the basis of extraversion. Error bars = standard error of the mean.

There was also a significant interaction between extraversion and emotion for reaction time, $F(2, 54) = 6.18$, $MSE = 8.52$, $p = .004$, $\eta_p^2 = 0.19$. This was explored using planned contrasts that compared the positive and negative conditions to the neutral condition. The contrasts showed no interaction between emotion and extraversion in the positive and neutral conditions, $F(1, 27) = .24$, $MSE = 14.88$, $p = .626$, $\eta_p^2 = .01$. However, there was an interaction when comparing the negative condition to the neutral condition, $F(1, 27) = 12.58$, $MSE = 14.30$, $p = .001$, $\eta_p^2 = .32$; Figure 3.4. To explore this interaction further independent *t*-tests (alpha criterion of .0125) were conducted showing that when induced into a neutral mood reaction time was quicker for individuals low in extraversion compared to those in high extraversion, $t(27) = -5.705$, $p < .001$, $d = 2.13$. In contrast, when induced into a negative mood there was no difference in reaction time between individuals high and low in extraversion, $t(27) = -.628$, $p = .535$, $d = .23$.

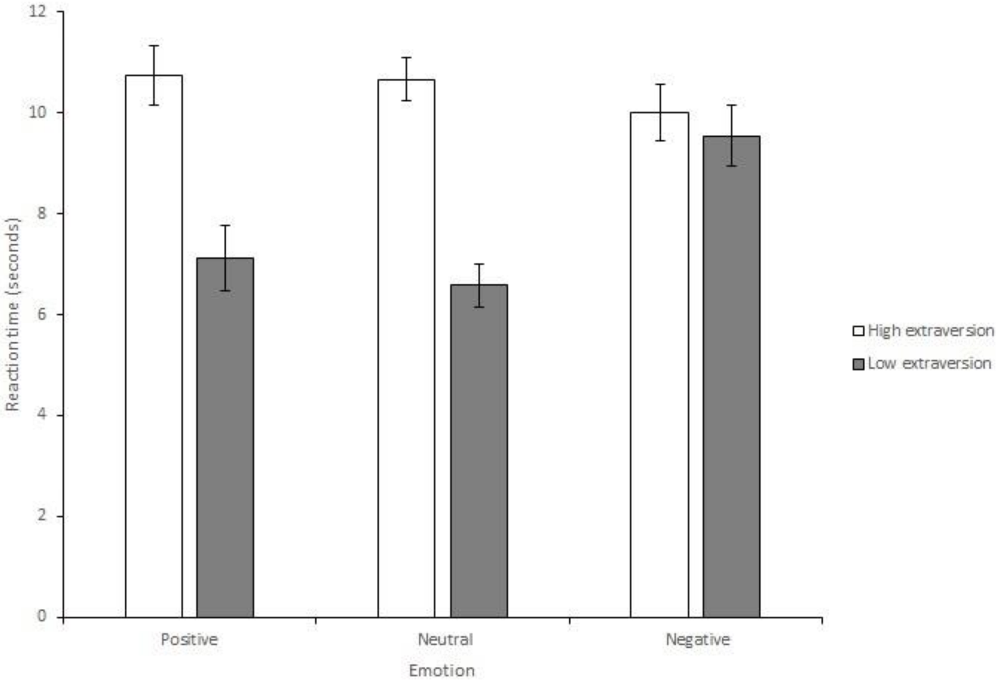

Figure 3.4. Mean reaction time in the change detection task. Individuals high in extraversion took longer to detect changes than those in the low extraversion group. Response times during the neutral emotion condition were quicker for the low extraversion group compared to the high extraversion group, whereas during the negative and positive emotion condition no differences in response time were evident between the two extraversion groups. Error bars = standard error of the mean.

3.4.5. Discussion

The aim of the current study was to investigate whether extraversion and neuroticism moderate the effect of emotion on visual attention. This was explored using a change detection flicker task whereby participants were induced into positive, negative, and neutral mood states and had to detect changes made to real-world images as quickly and as accurately as possible. It was predicted that higher levels of neuroticism would have a detrimental impact upon change detection, whereas higher levels of extraversion were predicted to improve change detection performance. It was expected that emotion would have no impact on change detection when considered in isolation (as found by Bendall and Thompson using the same experimental paradigm). However, due to the predicted benefit of extraversion during emotional processing, and the detrimental impact of neuroticism on emotional processing, when the effects of extraversion and neuroticism are considered it was predicted that individuals high in neuroticism and individuals low in extraversion would show reduced performance under negative conditions compared to neutral conditions.

Extraversion was shown to influence accuracy overall in the task whereby individuals high in extraversion detected changes more accurately than individuals low in extraversion. This finding supports previous work showing that extraversion is able to predict performance during a change detection task with higher levels of extraversion related to improved accuracy (Hahn et al., 2015). Extraversion was also shown to influence reaction time. Individuals high in extraversion were slower to detect changes than individuals low in extraversion. Taken together, these results suggest that in relation to extraversion, participants exhibited a speed-accuracy trade-off in performance.

An explanation for the current finding is that extraverts possess additional attentional resources compared to introverts. Indeed, Eysenck (1982) suggests that extraverts have greater resource availability than introverts and this hypothesis is supported by a number of studies adopting a range of experimental paradigms (e.g. the attentional blink, MacLean & Arnell, 2010; for a review see Matthews, 1997). The current study used the change blindness flicker paradigm to investigate visual attention and this is a demanding task. Participants are presented with an image, followed by a blank screen, then the image is presented again but with a change that participants are required to locate and identify. This process repeats until the change is identified (Rensink et al., 1997), and due to the removal of the usual motion artifacts with the blank screen, identification of the change is difficult. Individuals are required to hold information in their mind in order to compare it to the following representation. The finding that those high in extraversion show greater accuracy in a change detection task suggests that extraverts have more capacity (resources) for creating and storing a representation and so are better able to complete the task. However, extraverts were also slower to detect changes in the current study. One possible explanation is that as introverts find the task more difficult they put in less effort and this makes them faster but less accurate. This is an avenue for future work whereby experiments can be specifically designed to investigate if extraversion is linked to visual working memory capacity and effortful task completion. Overall, the current result suggests that extraversion is linked to enhanced attentional performance during a change detection flicker task due to increased ability to allocate attention. The observed increase in reaction time for individuals high in extraversion may be due to these individuals conducting a more exhaustive (but accurate) visual search, and so it can be suggested that individuals low in extraversion did not have the required resources to search the whole scene demonstrated by quicker (but less accurate) responses. Recent findings have suggested that eye movements are related to personality traits including neuroticism, extraversion and curiosity (Hahn et al., 2015; Hoppe et al., 2018; Risko et al., 2012). This can be investigated further using eye movements in future work adopting paradigms that specifically measure visuospatial attention.

As predicted, extraversion was shown to interact with emotion to impact change detection performance. In the negative condition accuracy to identify changes was higher for individuals high in extraversion than individuals low in extraversion, whereas no differences in accuracy between individuals high and low in extraversion were evident during the neutral (and positive) emotion conditions. This suggests that when individuals are in negative moods, those who are low in extraversion have reduced ability to allocate attention. Further, extraversion was also shown to interact with emotion for change detection response time. Response times during the neutral (and positive) emotion condition were quicker for the low extraversion group compared to the high extraversion group, whereas no differences in response time were evident between the high and low extraversion groups during the negative emotion condition. This interaction effect is the result of a slowing of reaction time under negative emotion conditions for individuals low in extraversion compared to the same individuals when in positive and neutral emotion conditions. This suggests that negative emotion is impacting reaction time within the task only for individuals low in extraversion. Overall, the findings for accuracy and reaction time suggest that negative emotion does impact visual attention, but that this affect is masked for individuals high in extraversion, as indexed by poorer performance of introverts in the negative emotion condition compared to the positive and neutral emotion conditions.

One possible mechanism for this result comes from the proposition that emotion regulation requires the recruitment of resources and brain regions also involved during completion of the change detection task, thus reducing the availability of top-down attentional resources. Emotion regulation is broadly defined as the initiation of a conscious or non-conscious effort to start, stop, or modulate an emotion (Gross, 2015). Areas of the PFC are implicated in emotion regulation (Buhle et al., 2014; Ochsner et al., 2012) and these same structures are also involved in selective attention (Curtis & D'Esposito, 2003; Miller & Cohen, 2001; Rossi et al., 2009) therefore it may be expected that they would complete for resources. Importantly however, it may be that individuals high in extraversion are able to successfully regulate their emotion more effectively than individuals low in extraversion. Successful regulation means fewer resources are devoted to this process, allowing more resources to be directed to the change detection task. In turn this means that performance will be impaired under negative conditions that require effortful emotion regulation, but only for those low in extraversion. The analysis of negative affect during the negative emotion condition supports this argument as individuals low in extraversion demonstrated heightened affective reactivity to the negative emotion induction. This finding complements our behavioural findings and interpretation suggesting that the negative emotion condition impacted individuals low in extraversion to a greater extent than individuals high in extraversion. Additional evidence to support the proposed link between negative emotion, extraversion, and emotion regulation comes from studies showing 1) that high levels of extraversion are linked to improved emotion regulation as well as negatively correlated with emotion dysregulation (Kokkonen & Pulkkinen, 2001), 2) that poor emotion regulation is related to affective disorders such as depression (Aldao et al., 2010), and 3) that affective disorders are linked to low levels of extraversion (American Psychiatric Association, 2013; Shankman & Klein, 2003). We argue that extraverts are better able to regulate negative emotion thus affording increased levels of cognitive resources compared to individuals low in extraversion. This is supported by the observed findings showing that task performance was impaired for individuals low in extraversion compared to those high in extraversion under negative emotion conditions. These findings raise the possibility that individuals high in extraversion may have protection against the detrimental influences of negative emotion.

In contrast to the hypotheses made, neuroticism did not impact change detection performance. Previous research has found that neuroticism is negatively correlated with attentional control (Bredemeier et al., 2011) and change detection accuracy (Hahn et al., 2015). The neuroticism groups were significantly different ($p < .001$) with very large effect sizes ($d = 2.42$), and so it is unlikely that the lack of any effects are due to a restricted range of neuroticism scores. However, in the current study, when the negative affect scores for individuals high in neuroticism and low in neuroticism were compared (for the negative emotion condition), no differences were evident between groups. This suggests that in the current study individuals high in neuroticism and individuals low in neuroticism were impacted to a similar degree by the negative emotion condition. This result complements the behavioural data showing that neuroticism had no impact on task performance. It may be that the influence of neuroticism on change detection is weaker than the influence of extraversion. For example, Hahn et al. (2015) showed that once eye movement measures were included in their regression model, a previously significant correlation between neuroticism and change detection was no longer significant. This finding supports the use of eye-tracking as a measurement in future studies investigating the impact of emotion on visual attention.

The current study explored the effects of extraversion and neuroticism on the links between emotion and visual attention to try and account for some of the conflicting findings within the literature. Whilst some studies show that positive emotions expand visual attention, other work shows no impact of emotion on attention. It was proposed that because extraversion and neuroticism are associated with affective reactivity and emotional processing that they may moderate the effects of emotion on attention. This was tested using a change blindness flicker task in which participants searched for changes made to real-world scenes under positive, negative, and neutral emotion states. The work replicated the basic findings of Bendall and Thompson (2015) showing no effect of emotion on attention in this task, however high extraversion was associated with increased processing effort overall (as reflected through longer reaction times and higher accuracy). Negative emotion did impair performance, but this was only for individuals low in extraversion, therefore there is some evidence that extraversion can moderate the influence of emotion on attention. The results suggest that the way in which emotion can influence attention may be partly determined by the ability of an individual to regulate their emotional state. This links to clinical findings reporting that those suffering from affective disorders show deficits in the allocation and control of attention.

3.5. Chapter discussion

The second experiment was completed to measure if emotion influences visual attention providing a replication of Experiment One. Additionally, the inclusion of self-report measures of extraversion and neuroticism permitted the investigation of whether these personality traits influence selective visual attention. Importantly, the design of this experiment provided a method for testing whether extraversion and/or neuroticism can interact with emotion to influence selective visual attention. Participants were successfully induced into positive, neutral, and negative emotional states before completing a change detection flicker task providing a method for measuring visuospatial attention. Changes were made to neutral scenes and participants were required to conduct a visual search to identify the change as quickly and accurately as possible. Participants also completed self-report measures of extraversion and neuroticism.

The findings demonstrate that emotion had no impact on accuracy in identifying changes in the change detection task, nor the time it took to correctly locate the change. Participants were successfully induced into the experimental emotion conditions as evidenced by the analysis of the self-report affect scores after each emotion induction. Therefore, these results replicate those reported in Experiment One and suggest that emotion does not influence selective visual attention in a change detection flicker task. Previous research using different experimental tasks show that emotion can influence selective visual attention. Therefore, one possibility is that the change detection flicker task may prevent the influence of emotion on attention and this suggestion is supported by recent theoretical work. Vanlessen et al. (2016) argue that the influence of emotion on visual attention is dependent upon task difficulty and the levels of cognitive control that are required to complete a task. Specifically, when task load and cognitive control are low, emotion influences selective visual attention via orientating an individual towards an internal attentional processing style when in a positive emotional state, whereas when in a negative emotional state attention is biased towards an external attentional processing style. However, when task load is high and increased cognitive control is required, it is predicted that positive emotion would have no impact on attention, whereas in a negative emotional state, individuals will be biased towards an external attentional processing style. The change detection flicker task is challenging to complete resulting in a high task load on participants who are required to deploy high levels of cognitive control. Therefore, the findings from the change detection experiments suggesting that positive emotion has no impact on visual attention (in a task requiring high levels of cognitive control) appear to support the predictions made by Vanlessen et al. (2016). However, their theoretical framework would predict that in tasks where high levels of cognitive control are required, negative emotion would influence visual attention by biasing an individual towards an external attentional processing style, and this prediction is not supported by the current work.

There is a lack of research that has sought to investigate the influence of personality traits on selective visual attention. The observation that individuals with higher levels of extraversion were more accurate but slower at correctly identifying changes is an important finding. A previous study has shown that extraversion is able to predict change detection performance and the results are consistent with this earlier observation (Hahn et al., 2015). However, the current work extends these initial findings and show that extraversion is also related to RT during a change detection flicker task. Individuals higher in extraversion were slower to correctly identify changes. These findings relating to RT, in combination with the improvements in accuracy, demonstrate a speed-accuracy trade-off in performance. One possibility is that as introverts find the change detection task difficult, they display an earlier quitting threshold which results in quicker RTs, but also a reduced accuracy to identify changes.

The current study demonstrated that neuroticism did not effect change detection. Previously, neuroticism has been shown to predict change detection accuracy whereby lower levels of neuroticism were associated with improved performance (Hahn et al., 2015). However, once Hahn et al. had included eye movement measures in their regression model, the association between neuroticism and change detection was no longer significant. This highlights the importance of considering eye movements in visual attention research. Taken together, the findings from the current study and that of Hahn et al. (2015), which are the first studies to investigate the influence of extraversion and neuroticism on attention using a visual search task, suggest that extroverts are more successful in allocating their attention during demanding top-down visual search tasks.

A central aspect of the current study was that it permitted the investigation of possible interactions between personality traits and emotion during a visual search task. In this regard the current study provides an important and novel finding. Specifically, whilst there was no main effect of emotion on change detection performance, the interaction between emotion and extraversion was significant. Here it was demonstrated that extraversion interacted with negative emotion to influence change detection accuracy and RT. When induced into a negative emotional state, change detection accuracy was greater for individuals higher in levels of extraversion compared to individual lower in levels of extraversion (such differences were not evident when in the positive or neutral emotion conditions). For RT, when induced into a neutral emotional state, individuals with lower levels of extraversion were significantly quicker at correctly locating the change. However, when induced into a negative emotional state, no changes between the two extraversion groups was evident. This provides evidence of a slowing (worsening of performance) in the negative emotion condition for individuals lower in levels of extraversion. These interactions between extraversion and emotion appear to suggest that individuals lower in levels of extraversion are impacted by the negative emotion state more than individuals with higher levels of extraversion. One possible mechanism for this result is the proposition that these individuals are better able to regulate their emotion and thus have additional resources available to direct toward successful completion of the visual search task in negative emotion conditions. This is supported by research showing improved emotion regulation (ER) ability is associated with higher levels of extraversion (Kokkonen & Pulkkinen, 2001), the observation that poor ER is associated with the development of affective disorders (Aldao et al., 2010), and evidence suggesting that lower levels of extraversion are linked to affective disorders (American Psychiatric Association, 2013; Shankman & Klein, 2003). Moreover, analysis of the negative affect scores after the negative emotion induction reported in Experiment Two, suggest that individuals with lower levels of extraversion were impacted to a greater degree (reporting higher levels of negative affect) than individuals with lower levels of extraversion. Presently it is unknown whether the emotional valence of real-world scenes influences selective visual attention when searching for neutral targets and this was investigated in the following experiment.

Chapter Four: The influence of emotional stimuli on visual search

4.1. Overview of Chapter Four

The previous experiments in this thesis have investigated the impact of emotion on selective visual attention. However, when investigating emotional influences on selective visual attention it is also important to consider the effect of the emotional valence of stimuli used within specific tasks. In this Chapter an experiment is presented where the focus is not the mood or emotion of the individual, but rather the emotional valence of stimuli and its effect on visual search. Using a new visual search task, the main aims of Experiment Three are to investigate if emotional stimuli can influence selective visual attention during the identification of neutral targets superimposed on real-world scenes, and to identify if emotional stimuli result in a broadening or narrowing of visuospatial attention. Below, the visual search task adopted in Experiments Three, Four and Five is outlined. Following this, Experiment Three is presented. Finally, the Chapter will finish with a summary highlighting the main findings.

4.2. Introduction to the visual search task

Research has shown that the emotional valence of stimuli can bias selective visual attention (Carretié, 2014; Pool et al., 2016; Pourtois et al., 2013). For example, emotional distractors are able to capture attention to a greater degree than neutral distractors demonstrating an influence of bottom-up processing (Carretié, 2014). Influences of emotional valence on selective visual attention have also been shown to impact top-down mechanisms evidenced by research showing that emotional targets are detected faster and more accurately than neutral targets (Eastwood et al., 2003; Williams et al., 2005). However, much less research has investigated the ability of emotional stimuli to influence visual search using real-world scenes that more closely resemble attention in our normal everyday lives. Moreover, it is currently not known whether emotional scenes influence visual search towards neutral targets. Instances where goal-directed behaviour necessitates searching for a neutral target within an emotional situation are common. For example, one can imagine searching for a fire escape whilst fleeing a burning building (signs detailing escape routes are themselves not affective in nature whilst the burning building and general environment are arousing). Additionally, research has detailed a narrowing of attentional focus in stressful situations within the eyewitness testimony literature

(Albright, 2017). The task detailed below was designed to permit the investigation of whether emotional-real world scenes impact top-down selective visual attention when searching for a neutral target.

The visual search task was based on a task originally developed by Brockmole and Henderson (2006) who were interested in whether context-target covariation impacts attention during visual search in real-world scenes. Previously, several studies conducted by Chun and colleagues using abstract arrays had provided support for a contextual cueing hypothesis. These studies demonstrated that repeated presentation of specific target-distractor arrangements results in a more efficient search for the target (Chun, 2000; Chun & Jiang, 1998, 1999, 2003). In these initial experiments the stimulus arrays consisted of a target ('T') presented amongst a set of distractor items ('L'). Targets and distractors were presented at varying degrees of rotation. Most trials in such experiments present novel trials where the targets and distractors are presented randomly – i.e. there is no specific relationship between the target and distractor items. However, a subset of trials are repeated – i.e. they are presented more than once. Crucially, in these repeated trials, the relationship between the target and distractors were fixed. Therefore, the design permitted the investigation of contextual cueing. Findings from these studies demonstrated that RT for repeated trials were quicker compared to novel trials and that this effect became stronger over repeated presentations, suggesting that the learned context can influence visual search. Additionally, when participants had completed the task and asked to identify novel and repeated trials, they performed at chance level suggesting that learning was implicit (Chun & Jiang, 1998). Brockmole and Henderson (2006) extended these findings using real-world scenes. In their experiment, visual search targets consisted of the letter 'T' or 'L' and these were embedded within real-world scenes. It was demonstrated that the contextual cueing effects previously shown by Chun et al. transferred to real-world scenes even when the meaning of the scene had no relationship to the location of the target. Further, Brockmole and Henderson provide evidence for semantic learning as a possible mechanism underpinning this finding from the observation that memory for scene-target covariation was improved in comparison to novel trials (an effect which was reduced when scenes were inverted).

The experiment presented in this Chapter was designed to permit the investigation of whether emotional-real world scenes impact top-down selective visual attention when searching for a neutral target. Additionally, targets were presented in the centre or the periphery of the scenes to test if stimuli valence impacts the spread of visuospatial attention. The task was based on the experiment utilised by Brockmole and Henderson (2006) but modified in several ways. Firstly, the stimuli consisted of real-world scenes taken from the Nencki Affective Picture System (NAPS; Marchewka et al., 2014). The NAPS is a database of real-world scenes each containing normative ratings of stimuli characteristics including levels of luminance, contrast, entropy, arousal, and valence. The scenes are high-quality and offer a number of improvements on previously published databases (e.g. the IAPS; Lang et al., 2008). The choice of stimuli used within affective science experiments is crucial and it is important for researchers to control aspects of their chosen stimuli as much as possible. For example, it has been suggested that the physical characteristics of stimuli such as luminance, complexity and image size may impact affective visual processing (Bradley et al., 2007; Codispoti & De Cesarei, 2007; De Cesarei et al., 2017). Stimuli in the experiment were chosen based on their emotional valence, whilst controlling for additional physical characteristics. As such, three stimuli sets were created consisting of positive, neutral, and negative real-world scenes. This allowed a direct investigation of whether differences in the emotional valence of real-world scenes impacts visual search when identifying a neutral target. Secondly, as the aim of the current work was not focussed on contextual cueing, all trials were presented only once and so all trials were novel to participants. Lastly, whilst the same target stimuli were used (‘T’ and ‘L’), their location within the visual scene was precisely controlled. Targets were presented pseudorandomly either in the centre of the scene (450 x 342 pixels) or the periphery of the scene (located outside of the central area). This allowed the investigation of any broadening or narrowing of visuospatial attention because of the emotional valence of the stimuli. Experiment Three made several predictions. Firstly, given research shows that task irrelevant emotional stimuli (often distractor stimuli or emotional faces) can capture attention in a bottom-up manner, it was predicted that targets would be identified less accurately and slower when embedded within positive and negative real-world scenes (compared to neutral scenes). Additionally, based on previous research suggesting that positive emotion can broaden attention or cue a particular attentional processing style (e.g. globally-focussed processing), it was predicted that peripheral targets will be identified quicker and more accurately when embedded within positive real-world scenes compared to neutral real-world scenes.

4.3. Emotional real-world scenes impact visual search[12]

4.3.1. Abstract

Research shows that emotional stimuli can capture attention and this can benefit or impair performance, depending on the characteristics of a task. Additionally, whilst some findings show that attention expands under positive conditions, others show that emotion has no influence on the broadening of attention. The current study investigated if emotional real-world scenes influence attention in a visual search task. Participants were asked to identify a target letter embedded in the centre or periphery of emotional images. Identification accuracy was lower in positive images compared to neutral images, and response times were slower in negative images. This suggests that real-world emotional stimuli have a distracting effect on visual attention and search. There was no evidence that emotional images influenced the spatial spread of attention. Instead it is suggested that findings may provide support for the argument that positive emotion encourages a global processing style and negative emotion promotes local processing.

4.3.2. Introduction

Selective visual attention refers to the biasing of attentional resources due to an inability to attend to all items and areas of the visual world simultaneously. This biasing of resources is dependent upon top-down processing (characterised by goal-directed behaviour, e.g. searching for a target item located in a visual display) and bottom-up processing (characterised by automatic capture of attention by salient information in the environment regardless of task demand, e.g. Itti & Koch, 2000). When presented with emotional information, or during an emotional situation, these two competing processing strategies are also evident. For instance, emotion influences cognition in a bottom-up manner, whilst simultaneously, individuals adopt top-down cognitive control strategies to direct resources to emotion regulation (Ochsner et al., 2012). Consequently, emotion has the potential to influence resources and impact selective attention.

It has recently been suggested that emotional stimuli may provide an additional type of influence on attentional processing and selective attention beyond the traditional top-down and bottom-up distinctions (Pourtois et al., 2013). This influence has been

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[12] Bendall, R.C.A., Mohamed, A., & Thompson, C. (2019). Emotional real-world scenes impact visual search. *Cognitive Processing*, 20(3), 309-316.

referred to as emotional attention (Vuilleumier, 2005), and research has suggested that top-down processing, bottom-up processing, and emotional processing can have a summative impact on selective attention (Brosch et al., 2011). It is proposed that these three systems can operate simultaneously and are able to exert separate influences upon visual attention (Pourtois et al., 2013).

A number of recent review articles have demonstrated the ability of both negative stimuli (e.g. Carretié, 2014; Pourtois et al., 2013) and positive stimuli (e.g. Carretié, 2014; Pool et al., 2016) to impact selective attention. This is evidenced by more accurate and faster detection of emotional targets in a variety of tasks (e.g. during visual search; Eastwood et al., 2003; Williams et al., 2005), as well as by the increased ability of emotional distractors to capture attention compared to neutral distractors (Carretié, 2014). Initial research in this area has focused on the investigation of the negative emotion fear; which is often operationalised using threat-related stimuli (Carretié, 2014; Eastwood et al., 2003; Pourtois et al., 2013; Williams et al., 2005).

The majority of the research in this field has adopted stimuli depicting emotional faces or employed tasks using stimuli arrays incorporating emotional targets and/or distractors, and little research has made use of more naturalistic stimuli or visual scenes. One study that did employ natural scenes demonstrated that search performance was reduced for negative stimuli compared to neutral stimuli (Simpson et al., 2000). Using natural real-world images from the International Affective Picture System (Lang et al., 2008), Simpson et al. found that when participants were asked to make a judgement regarding the number of humans located within a visual scene response times increased when the scene was negative compared to neutral. This finding demonstrates that the emotional content of natural scenes has an influence on visual attention.

A predominant theory to account for the influence of emotion on attention is the broaden-and-build theory (Fredrickson, 2001) which proposes that positive emotions (e.g. joy, interest, contentment, love) have the ability to “broaden” an individual’s “thought-action repertoires” and “build” an individual’s “enduring resources” (Fredrickson, 2001, p. 218). The theory also suggests that negative emotion (e.g. anxiety, sadness, anger, despair) has the opposite effect, preventing an individual from thinking broadly and building lasting psychological reserves. Initial support for the broadening influence of positive emotion on attention (and therefore the broaden-and-build theory) comes from studies that have utilised the global-local processing task (Navon, 1977). These early studies demonstrated that positive emotion promotes a global processing style, whereas negative emotion encourages local processing, and researchers argue that this shows that positive emotions ‘expand’ attentional resources, allowing individuals to process more information (Basso et al., 1996; Fredrickson & Branigan, 2005). However, these initial studies do not specifically measure the spread (and capacity) of attention, and rather suggest that emotion may influence processing style (a preference towards local or global processing) without affecting the attentional resources available (Bendall & Thompson, 2015a; Taylor et al., 2017).

This argument is consistent with the levels-of-focus hypothesis (Clore et al., 2001) which proposes that emotions guide processing whereby positive mood encourages a focus on the most accessible information within the mind, whereas negative mood will lead to more emphasis on external, incoming information. Given that global processing is proposed to be the default method of information processing (Fiske & Taylor, 1991) it is theorised that positive emotions will allow greater focus on internal, accessible information, and will therefore be more likely to activate a global strategy compared to negative emotions. Gasper and Clore (2002) provided evidence to support this theory, showing that when induced into a negative mood, participants were less likely to focus resources at a global level. They argue that the findings provide no support for differences in the amount of resources or the amount of processing taking place, and instead emotion influences the level at which resources are focused.

More recently different tasks have been used to investigate the influence of emotion on attention. Wadlinger and Isaacowitz (2006) presented individuals with three images simultaneously and used eye-tracking to measure the allocation of attention. One image was located in the centre of the screen and two were located in the periphery. Participants who were induced into a positive emotional state made a greater number of fixations on peripheral stimuli than those individuals induced into a neutral emotional state. Wadlinger and Isaacowitz (2006) suggest that this shows the expansion (or broadening) of visual attention under conditions of positive emotion. Rowe, Hirsh, and Anderson (2007) also provide findings to support a broadening effect under conditions of positive emotion. Using a modified version of the Eriksen flanker task (Eriksen & Eriksen, 1974) they compared the influence of near and far peripheral distractions under positive, neutral, and negative moods. Participants induced into positive emotion were more distracted by the far flankers, again suggesting that during positive emotion attention expands and allows an individual to process additional information. Despite the fact that in these studies the manipulation of emotion was the emotional state of the observer, rather than the emotional content of the scene, these findings are consistent with those from Simpson et al. (2000) showing that emotion affects attention and search.

Further studies have failed to show a broadening of visual attention as a result of emotion. For example, using a change detection task that specifically measured the allocation of attention to central and peripheral information (allowing comparison of attention to the centre and periphery of a natural visual scene), Bendall and Thompson (2015) found no influence of emotion on attention using real-world stimuli. However, the stimuli in the change detection task were controlled so that only those of neutral valence were used and this may have influenced the results. Prior to completing this task participants were induced into positive, negative, and neutral mood states, yet as the change detection trials then involved neutral stimuli the mood induced may have reverted to neutral.

The research discussed thus far demonstrates two different approaches to the investigation of emotional influences on visual attention. A number of studies have focused on the effect of emotional state on attention (e.g. Basso et al., 1996; Bendall & Thompson, 2015; Bruyneel et al., 2013; Fredrickson & Branigan, 2005; Gasper & Clore, 2002; Rowe et al., 2007; Wadlinger & Isaacowitz, 2006), whilst other research has investigated the impact of emotional stimuli on attention (Carretié, 2014; Eastwood et al., 2003; Pool et al., 2016; Pourtois et al., 2013; Simpson et al., 2000; Vuilleumier, 2005; Williams et al., 2005). This study focuses on the latter, but rather than measuring attentional capture of, or attentional orienting towards emotional stimuli, it investigates the effects of emotional scenes on the ability to identify neutral targets.

In general, research indicates that when the emotional content of stimuli is varied during visual search tasks positive and negative information can have similar influences on attention. However, the majority of these studies have used emotional distractors (see Carretié, 2014), artificial displays (Eastwood et al., 2003), or emotional targets (Eastwood et al., 2003; Williams et al., 2005). Consequently, it is not currently known how positive and negative real-world scenes impact visual search towards neutral targets, and this is one of the aims of the current study. One advantage of adopting real-world scenes is that they more closely resemble the everyday environment and therefore provide increased ecological validity. In the current study a modified version of the visual search task designed by Brockmole and Henderson (2006) was used to measure the effect of emotional real-world scenes on visual attention. Participants were asked to identify targets embedded in images of varying emotional valence (neutral, negative, and positive) from the Nencki Affective Picture System (NAPS; Marchewka et al., 2014). The NAPS is a large collection of real-world images that have each been rated for valence to allow for the precise control and manipulation of experimental stimuli. Previous literature has focussed on the ability of negative emotional stimuli to influence visual attention (see Carretié, 2014), and it has been argued that research investigating the impact of emotional stimuli on visual attention needs to include a positive emotion condition to allow more precise conclusions to be reached (Bendall et al., 2016; Carretié, 2014). As a result, three experimental conditions were included in the current experiment: neutral stimuli, negative stimuli, and positive stimuli. The study design allowed the investigation of whether emotional real-world stimuli impact visual search to neutral targets. Research investigating the emotional modulation of attention during visual search tasks incorporating neutral targets is limited and was an additional aim of the current investigation. It is important to adopt visual search paradigms that include neutral targets as this reflects instances in which individuals are required to attend to neutral targets within an emotional situation. It was predicted that identification of search targets embedded within positive and negative stimuli would be less accurate and slower compared to targets embedded within neutral stimuli. Additionally, as the targets were located in the centre or periphery of each image, this also provided a measurement of any “broadening” or “narrowing” of attention. If positive information does have a broadening effect on visual attention this will increase the breadth of attention and therefore the amount of information an individual can process. Consequently, it is predicted that peripheral targets will be identified significantly quicker and more accurately when embedded in positive images compared to neutral images.

4.3.3. Method

Participants

Based on previous studies this experiment aimed for a minimum sample size of 36, and in total 39 female participants completed the experiment. Participants were an opportunity sample of students from the University of Salford aged between 18 and 37 years (*M* =

22.69, *SD* = 4.12). Where appropriate volunteers received course credit for participating. Ethical approval was obtained from the School of Health Sciences & School of Nursing, Midwifery, Social Work and Social Science Ethics Approval Committee at the University of Salford.

Design

A within-participants design was used with two independent variables; *location* of the search target in the visual search task (central or peripheral), and *emotional stimuli* used during this task (positive, neutral, or negative). The dependent variables consisted of accuracy (percentage correct) and response time (in seconds) to identify the search target.

Materials

The experiment was designed and run using E-Prime (Psychological Software Tools, Inc.) and participants completed the study using a Viglen Intel i7 Core computer with a 60 Hz, 22-inch monitor. Images from the NAPS (Marchewka et al., 2014) consisting of objects, landscapes, people, and animals were selected on the basis of their affective valence ratings and a total of 192 images were used for the visual search task; 64 positive, 64 neutral, and 64 negative images (identification numbers are provided in Appendix One, Supplementary Table 3). The NAPS is a database of real-world scenes and each image has been rated by 204 individuals to provide a valence rating. All images in the visual search task were presented in colour and measured 1600 x 1200 pixels. In each trial a target (the letter T or the letter L) was presented over the image. The targets were shown in Arial font size 12 in blue and were presented at 0, 90, 180, or 270-degree orientations. Central targets were located within the centre of the image within an area measuring 450 x 342 pixels and peripheral targets were located outside of this area.

The NAPS database provides the physical properties of each image including a measure of image complexity indexed using image JPEG size, entropy, luminance, and contrast. It was important to check that the stimuli sets differed in valence but were similar in these physical characteristics. All statistical analyses were conducted using JASP adopting a Bayesian approach (JASP Team, 2017). JASP calculates Bayes factors (BF) on distributions of effect size to assess the relative probability of observed data between two competing statistical hypotheses; the null hypothesis (H0) and the alternative hypothesis (H1) (see Jarosz & Wiley, 2014 for an introduction to Bayesian statistics). BFs are reported expressing the probability of the data given H1 relative to H0 where values larger than 1 represent evidence for H1. To investigate the evidence for and against an effect of valence within our stimuli sets a Bayesian one-way repeated measures analysis of variance (ANOVA) with default priors selected was completed. This result supported the predicted difference in valence scores between the three stimuli sets (positive, neutral, and negative). Analysis revealed a BF_{10} of 4.398e + 138 in favour of the alternative hypothesis suggesting that the data are 4.398e + 138 times more likely to be observed under the alternative hypothesis (Table 4.1). A BF of greater than 100 is considered extreme evidence for the alternative hypothesis (Jeffreys, 1961). Post hoc analysis revealed a BF_{10} of 1.012e+52 for the comparison between positive stimuli (*M* = 7.70, *SD* = .34) and neutral stimuli (*M* = 5.01, *SD* = .20) demonstrating higher valence scores in the positive stimuli set compared to the neutral stimuli set. The comparison between positive stimuli and negative stimuli (*M* = 2.55, *SD* = .58) provided a BF_{10} of 5.150e+56 in favour of the alternative hypothesis suggesting that valence scores in the positive stimuli set are greater than the negative stimuli set. Finally, the comparison between neutral stimuli and negative stimuli revealed a BF_{10} of 9.090e+36 in favour of the alternative hypotheses suggesting that valence scores were greater in the neutral stimuli set compared to the negative stimuli set. A series of Bayesian one-way repeated measures ANOVAs with default priors selected were also completed to investigate if the experimental stimuli differed across valence conditions for image complexity, entropy, luminance, and contrast. BFs_{10} of .375, .086, .067 and .104 were produced for complexity, entropy, contrast, and luminance respectively, supporting the null hypotheses. These findings demonstrate that the stimuli sets did not differ in levels of these characteristics (Table 4.1). It should however be noted that the stimuli sets differed with regard to levels of arousal (Table 4.1; see Discussion for further details).

Table 4.1

Physical characteristics of experimental stimuli

	Valence		Complexity		Entropy		Contrast		Luminance		Arousal	
Stimuli set	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Positive	7.70	.34	331574	112027	7.46	.38	62.60	13.14	120.55	30.47	3.96	1.01
Neutral	5.01	.20	333836	120486	7.50	.36	65.10	13.92	118.64	33.11	5.19	.60
Negative	2.55	.58	369031	128968	7.52	.38	62.82	12.22	117.01	29.60	6.69	.66

M = mean, *SD* = standard deviation, *N* = 64

A Bayesian repeated measures ANOVA produced a BF_{10} of 1.920e+57 providing extreme support for the alternative hypothesis. Post hoc analyses for arousal revealed BF_{10}s of 1.609e+19, 7.207e+29 and 1.599e+19 for negative-neutral, negative-positive, and neutral-positive comparisons respectively.

Procedure

After providing written informed consent participants were seated approximately 22 inches from the screen and given full instructions about the task. If they were happy to proceed with the experiment, they pressed the spacebar and were presented with an example negative image for 5 seconds to allow consideration of whether to continue with the experiment. Following this, they were shown onscreen instructions as a reminder of what the task entailed and were asked to press the spacebar when ready to begin. In each trial a fixation cross was presented for 1000ms following which an image was presented with the letter T or L superimposed. The image remained on the screen until participants had identified the target as a T or L by pressing the corresponding key. If they were unable to locate or identify the target, they had the option of pressing the spacebar to terminate the trial but were asked to use this as a last resort. Once a response had been made feedback was provided onscreen for 500ms and following this the next trial began. Participants completed a total of 192 trials presented in a random order. There were 64 images for each condition of valence, half showing the letter T and half showing the letter L. In these 32 images the target was presented at a randomly selected central location for 16 trials and a randomly selected peripheral location for 16 trials. There were 4 trials for each angle of rotation for each condition. After completing the visual search task participants were asked to view 10 positive images from the NAPS (mean valence 8.20) for 2 seconds each. This was to ensure that they were not adversely affected by the negative images when leaving the laboratory.

4.3.4. Results

Data collected included accuracy (percentage correct; %) and response times (seconds; s) to the visual search task. Overall accuracy was 95.05% and participants took an average of 1.72s to correctly locate a target. A total of 74 trials were terminated (0.01% of trials) and the number of terminated trials did not differ according to stimuli valence. A further 116 trials (2.48% of total correct trials) were removed at ±2 standard deviations from the mean on the basis of reaction time. Two participants were excluded from the analysis due to mean accuracy that was ±2 standard deviations from the mean. A further two participants were removed because their mean response times were ±2 standard deviations from the mean.

Two 2 (*location; central or peripheral*) x 3 (*stimuli valence; positive, neutral, or negative*) Bayesian repeated measures ANOVAs with default priors selected were completed followed by post hoc comparisons. Analysis of accuracy revealed that the model including only valence outperformed all other models where a BF_{10} of 759.763 was observed in support of H1 suggesting that the data are 759.763 times more likely to be observed under the alternative hypothesis. This suggests that there is extreme evidence in favour of H1 where the valence of the stimuli had an effect on accuracy scores in the visual search task. Post hoc analyses for valence revealed BF_{10}s of 1.822, 3.604 and 260.585 for negative-neutral, negative-positive, and neutral-positive comparisons respectively. These observations suggest that there is anecdotal evidence for H1 in the negative-neutral comparison, moderate evidence in support of H1 for the negative-positive comparison and extreme evidence in support of H1 for the neutral-positive comparison. These findings suggest that accuracy in the visual search task was comparable for negative and neutral stimuli, but that accuracy was reduced for positive stimuli compared to neutral stimuli. Additionally, there was moderate evidence to suggest that accuracy was also reduced for positive stimuli compared to negative stimuli (Figure 4.1). For location a BF_{10} of .190 was observed indicating anecdotal evidence in support of H0 suggesting that location has no impact on accuracy in the visual search task. Finally, the interaction effect model produced a BF_{10} of .107 (15.869/148.189) indicating substantial evidence against an interaction between location and valence.

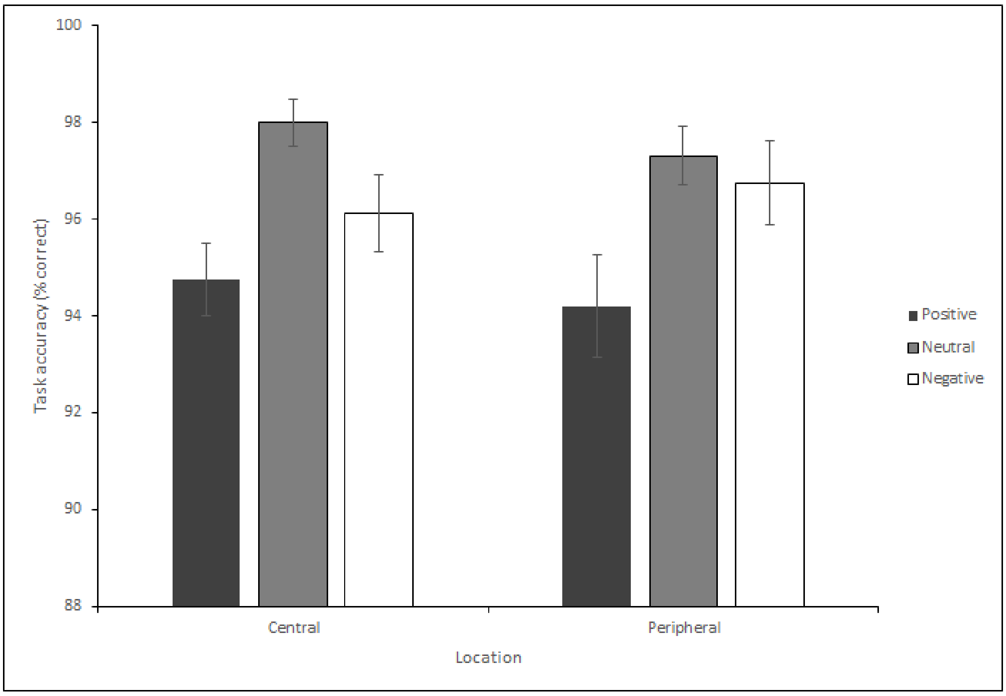

Figure 4.1 Mean percentage accuracy in the visual search task. Error bars = standard error mean.

Analysis of reaction time revealed that the model including valence and location outperformed all other models where a BF_{10} of 1.573e+11 was observed providing extreme support for H1. A BF_{10} of 19.949 was observed for valence indicating strong evidence for H1. Post hoc analyses for valence revealed BF_{10}s of 502.520, 2.004 and .501 for negative-neutral, negative-positive, and neutral-positive comparisons respectively. These observations suggest that there is extreme evidence for H1 in the negative-neutral comparison where reaction time in the visual search task was quicker for neutral trials compared to negative trials. Anecdotal evidence was observed in support of H1 for the negative-positive comparison, whilst there was anecdotal evidence in support of H0 for the neutral-positive comparison, suggesting that reaction time in the visual search task did not differ between negative and positive trials and between neutral and positive trials (Figure 4.2). For location a BF_{10} of 1.375e+9 was observed indicting extreme evidence for H1 suggesting that central targets were identified quicker than peripheral targets. Finally, the interaction model produced a BF_{10} of .118 (1.849e+10/1.573e+11) indicating substantial evidence against an interaction between location and valence.

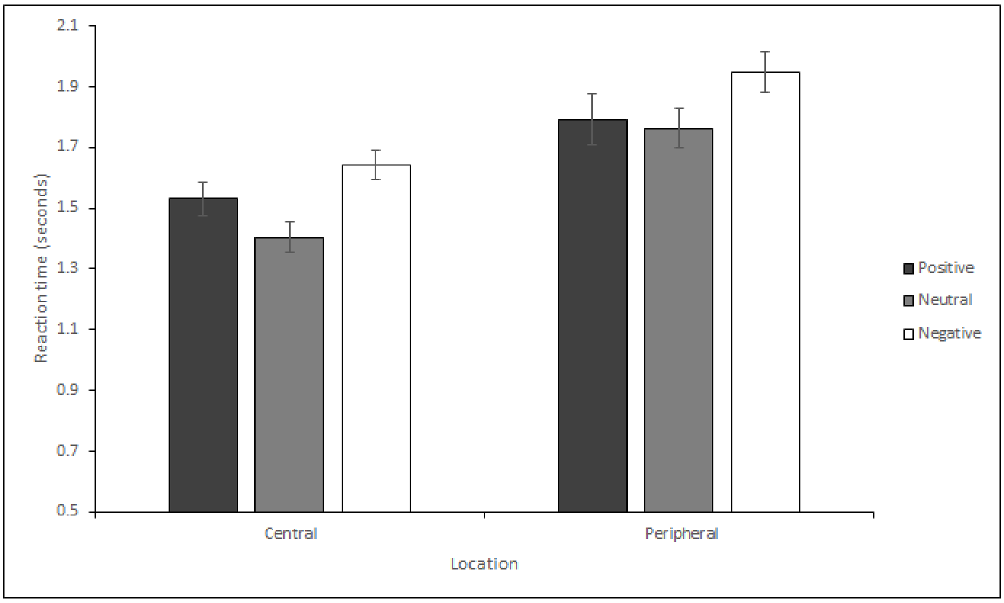

Figure 4.2. Mean response time to correctly detect search targets. Error bars = standard error mean.

4.3.5. Discussion

The aim of the current study was to investigate the allocation of attention to neutral targets within emotional real-world scenes. The experiment was designed to measure whether emotional stimuli affect visual search task performance. Additionally, the study investigated whether positive emotional stimuli has the potential to broaden visual attention, and whether negative emotional stimuli can narrow attention. This was investigated by adopting a simple visual search task in which neutral targets were situated in the centre or periphery of positive, negative, and neutral images and participants had to identify each target as quickly and as accurately as possible.

Participants were quicker to detect visual search targets when they were presented centrally compared to in the periphery. This main effect is important as it endorses the design of the visual search task. To establish any influence of emotional stimuli on the allocation of visual attention to central and peripheral locations it was important to initially demonstrate that visual attention and search followed the expected pattern, with resources located to the centre of a scene before the periphery during control conditions (neutral stimuli). Differences in response times to detect central and peripheral targets have been reported previously in studies investigating visual attention (Bendall & Thompson, 2015a; Tatler, 2007). For instance, during a change detection flicker task, where participants are presented with two images separated by a brief inter-stimulus-interval and are required to identify a change in one of the images, Bendall and Thompson (2015) found that changes made to the centre of a visual scene were located faster than changes made in the periphery of a visual scene. The current findings support this past research.

In addition to showing that attention is allocated to information at the centre of a scene before being allocated to the periphery, there was also evidence that attention varied according to the emotional valence of the stimuli. Participants were less accurate at identifying the target when it was presented in a positive image compared to a neutral image. It also took participants longer to correctly identify a target when it appeared on a negative image compared to a neutral image. These findings demonstrate that both positive real-world stimuli and negative real-world stimuli can influence visual attention but suggests that they may do so in different ways. In accordance with the levels-of-focus hypothesis proposed by Clore et al. (2001) we suggest that emotional information may influence processing style whereby positive stimuli promotes a global processing style, and negative stimuli encourages a local processing style. This theory proposes that positive moods encourage greater focus on internal, accessible information (with a global processing strategy being the most ‘usual’ and therefore accessible method of processing) and negative moods prevent this internal focus and instead lead to more local processing of external, incoming information. In the current study the reduced accuracy to identify targets in positive images (with no impact on response times) is indicative of impaired *identification* of the search target. This suggests that participants were allocating attention to the wider scene (global processing) so could locate the target, but could not accurately identify this due to a lack of attention at the local level. Conversely, longer response times to identify targets in negative images (with no impact on accuracy), suggests that *localisation* of the target may be impaired. It may be argued that it took participants longer to find the target in negative images due to a lack of attention at the global level, but when they did find the target they could identify it with a high level of accuracy.

Whilst it is proposed that the findings provide support for the levels-of-processing hypothesis this interpretation cannot be tested with the current experimental design. The dependent variables measured the ability to identify the target and future work should attempt to separate out detection (localisation) and identification. In addition, the experimental design is substantially different from other studies intending to test this hypothesis. For instance, Gasper and Clore (2002) induced participants into positive or negative mood states and asked them to try and interpret a drawing before reproducing it from memory. They found that participants in a positive mood were more likely to reproduce the global features within the drawing compared to those in a negative mood. The accuracy and extent of recall did not vary across the mood conditions, again offering no support for the proposal that mood affects the amount of resources available for processing. It should be noted that the levels-of-focus hypothesis posits that mood affects attention and processing when it is relevant to the task as the emotional cues are processed as information pertaining to the task and this biases the individual to a global or local focus. In the current study the valence of the scene has no relevance to the task itself and the targets are neutral, yet an effect of valence is still apparent. By using real-world scenes it is possible to show that even when individuals are not experiencing a particular mood and they are not required to attend to the emotional content of a situation, their attention may still be influenced by that content and the information within the situation may cue a particular processing style.

Simpson et al. (2000) also used real-world scenes to investigate the influence of emotional stimuli on visual search. In their experimental task participants had to count the number of individuals present in a scene and this could either be one person or two. Findings showed that response times in the visual search task were slower for negative stimuli compared to neutral stimuli. These findings are replicated in the current work, with slower response times to targets presented in negative scenes. Additionally, Simpson et al. (2000) found a significant interaction between stimuli valence and trial type for response accuracy. Increased accuracy was evident for negative trials compared to neutral trials when the correct target response was “two”, whereas accuracy was reduced for negative trials compared to neutral trials when the correct response was “one”. Whilst our findings showed no effect of negative stimuli on accuracy, it may be argued that the findings of Simpson et al. lend support to the proposal that negative information encourages a local style of processing. In that study participants knew there was a maximum of two possible targets, and when two targets have been located the search has been exhausted. At this point, the use of local processing (in the negative condition) means the target is identified more accurately. However, when there is only one search target it is possible that participants continue to search and accuracy suffers as a result because participants do not benefit from this bias towards local processing.

Whilst showing that attention is allocated to information in the centre of the scene before being allocated to the periphery, the lack of any interaction between target location and emotion shows no evidence of a broadening or narrowing of visual attention due to emotion. This provides no support for the broaden-and-build theory which suggests that emotion has the ability to affect processing resources and modulate the scope of attention. The research utilising tasks that measure the spatial allocation of attention (e.g. Bendall & Thompson, 2015) show limited evidence for any narrowing or broadening of attention due to emotion. The current findings suggest that whilst emotional stimuli can influence the manner in which an individual will process visual information, it does not necessarily influence the amount of resources available to process this information. We argue that because many previous studies adopt tasks such as the global-local processing task, they are unable to directly measure the spatial allocation of visual attention. Instead of measuring the breadth of visual attention a number of paradigms have instead measured processing strategy. Further research is needed to explicitly test this argument and this is an avenue for future work.

Two limitations of the current study are worthy of note and these could be rectified in future experiments. Firstly, our sample was entirely female, and so it is plausible that the current findings may not be generalizable to males. For instance, sex differences have been observed in self-report ratings of negative affect and fronto-limbic connectivity during emotional processing (Lungu et al., 2015), when attending to disgust facial expressions (Kraines et al., 2017), and during response inhibition in emotional contexts (Ramos-Loyo et al., 2016). Further research is needed to investigate if the observed effects of emotional stimuli reported here in females are also evident for males. Secondly, our experimental stimuli sets, whilst controlled for image complexity, entropy, contrast and luminance, differed in levels of arousal. Valence is often linked to arousal where negatively valenced stimuli are highly arousing whilst positively valenced images are rated as low in arousal. Therefore, we cannot reject the assertion that the observed effects were due to alterations in stimuli arousal rather than manipulations in valence. Whilst this is an avenue for future research, the current findings still demonstrate that emotional stimuli (whether in terms of valence or arousal) have an impact on visual search performance.

Studies show differing effects of emotion on attention and this is influenced by a range of factors such as the nature of the task and the characteristics of the emotions themselves. The current study used a visual search task incorporating real-world stimuli to investigate the effect of emotion and found that emotional stimuli distracted attention during visual search. This finding adds to the literature suggesting that emotional stimuli capture attention in visual search tasks using abstract arrays and/or emotional targets, and provides evidence that this finding extends to visual search tasks using emotional real-world images and neutral targets. Additionally, due to the different effects of positive emotional stimuli and negative emotional stimuli on reaction time and response accuracy, there is some evidence to support the concept that positive information encourages a more global processing style, and negative information promotes a more local processing style. However, there was no evidence for a broadening of attention for positive emotional images, or a narrowing of attention for negative emotional images. The current results provide further evidence for the complex relationship between emotion and visual attention. The research supports empirical findings in the literature and indicates that emotion does have an impact on the way in which attentional resources are allocated.

4.4. Chapter discussion

Experiment Three was designed to provide an investigation of whether positively and negatively valenced real-world scenes impact selective visual attention. Participants were required to locate and identify a neutral target embedded within scenes of differing emotional valence presented in random order. The scenes and their varying emotional valence were not relevant to the search task. Additionally, targets were located either in the centre of periphery of the scene, permitting the investigation of any broadening or narrowing of attentional scope because of emotional valence to be tested. The design of the current experiment was novel in several ways. Firstly, the author is unaware of any studies that have previously investigated the impact of positively and negatively valenced real-world scenes on visual search towards a neutral target. The investigation of whether emotional stimuli influences the allocation of attention during visual search towards neutral targets is important as this more closely mirrors our experience in the real world. For example, when an individual might need to search for an exit sign when evacuating a dangerous situation Moreover, the current study is the first to investigate any broadening or narrowing of attention because of emotionally valenced stimuli. Whilst research using abstract arrays and artificial images have helped to develop our understanding of the mechanisms underpinning selective visual attention, without research adopting more realistic stimuli researchers can only provide a partial description of the underlying attentional processes which occur in the real world and our every daily life.

Replicating the findings in Experiment One, participants were quicker at correctly identifying targets when they were presented in the centre of the scene compared to the periphery of the scene (although there was no influence on accuracy). This effect endorses the study design and suggests that visual search follows the expected pattern with attentional resources allocated to the centre of the scene before peripheral regions (e.g. Tatler, 2007). It was also demonstrated that the emotional valence of real-world scenes impacted visual search. Participants were less accurate at identifying the target when it was presented within a positive scene compared to a neutral scene. Additionally, there was moderate evidence to suggest that targets were identified more accurately in negative scenes compared to positive scenes, although this evidence was substantially less robust compared to the positive-neutral comparison (BF_{10} 3.604 vs BF_{10} 260.585). The emotional valence of the scenes also had an impact on RT. There is extreme evidence to suggest that RT to identify targets was slower when the scenes were negative competed to when the scenes were neutral. The comparisons for negative-positive trials and positive-neutral trials provided no meaningful support for the alternative hypotheses suggesting that RTs were similar when comparing positive scenes to neutral scenes and positive scenes to negative scenes. Additionally, there was no evidence for an interaction between target location and the emotional valence of the scene.

The observation that the emotional valence of real-world scenes appears to impact visual search in differing ways is an important and novel finding. Participants were less accurate at identifying the target when the scene was positive, yet they were slower when the target was presented within a negative scene. It is possible that in agreement with the levels-of-focus hypothesis (Clore et al., 2001), emotional information may influence (or cue) processing style (rather than result in any broadening or narrowing of visuospatial attention), whereby positive stimuli promote a global processing style and negative stimuli promote a local global processing style.

Previous work has also demonstrated that real-world scenes can cue visual search resulting in quicker identification of search targets in a contextual cueing task (Brockmole

& Henderson, 2006a). Additionally, emotional information has also been shown to influence contextual cueing. Kunar et al. (2014) presented participants with negative or neutral images before they completed a contextual cueing task comprising arrays of distractor items ‘L’ presented amongst a target item ‘T’. Participants in the negative condition demonstrated a reduced contextual curing effect compared to those in the neutral condition. Although when all trials were analysed (both novel trials and repeated trials) no differences in RT were evident based on the previously displayed emotional stimuli. A further contextual cueing study presented participants with search arrays containing images of threat and non-threat objects. The threat objects were task-irrelevant, and although they were shown to capture attention, the presence of threat-related objects within the search array did not impact contextual cueing (Yamaguchi & Harwood, 2017). Building on these initial findings, the effect of task-irrelevant emotional stimuli presented during a contextual cueing task has recently shown to be valence specific (Zinchenko et al., 2020). Again, participants were shown stimuli arrays consisting of distractor items ‘L’ presented amongst a search item ‘T’. However, these arrays were superimposed on positive, neutral, or negative real-world scenes. Whilst positive stimuli were shown to reduce contextual cueing, negative stimuli enhanced contextual cueing, demonstrating a valence specific effect. These studies suggest that emotional stimuli can influence the encoding of spatial target-distractor associations, and by extension, impact visual context memory for the visual search environment. The effects of stimuli valence on visual search performance seen in Experiment Three were also valence specific. Whilst accuracy to identify search targets was reduced for positive trials, RT was slower for negative trials. Corroborating the findings from Zinchenko et al. (2020) the current experiment suggest that emotional stimuli influence visual search and that this effect is valence specific. However, comparing the two studies also reveals that the influence of emotional stimuli used within search tasks can have beneficial and detrimental influences dependent upon the specific task requirements. In Experiment Three, it is suggested that positive stimuli may cue a global processing style, whilst negative stimuli cues a local global processing style.

Given the findings in Experiment Three showing that the emotional valence of real-world scenes can impact the ability to identify visual search targets, and the results of Experiment Two showing that affective personality traits can influence visual search during a change detection flicker task adopting neutral real-world scenes, it is possible that affective individual difference traits may also influence visual search performance within emotional scenes. For instance, the results from Experiment Two demonstrate that extraversion is associated with improved visual search performance in a change detection task. However, the stimuli used in Experiment Two were controlled so that only images of neutral emotional valence were used, and so currently it is unknown whether extraversion interacts with stimuli valence to influence visual search. The possible influences of affective individual difference traits including extraversion on visual search within emotional real-world scenes is an important avenue for further research and is investigated in the subsequent experiment.

Chapter Five: The influences of extraversion and emotion regulation on emotional visual search

5.1. Overview of Chapter Five

In this Chapter Experiment Four is presented. This experiment provides a replication of Experiment Three and builds upon this experiment with the inclusion of affective individual difference traits. Consequently, the experiment had the following main aims. Firstly, it was important to attempt a replication of the findings from Experiment Three. A second aim was to investigate the impact of extraversion and habitual use of two emotion regulation (ER) strategies, cognitive reappraisal, and expressive suppression on selective visual attention within emotional real-world scenes. As a result, the experiment is the first to test whether individuals with higher levels of these traits show improved visual search performance in real-world scenes. Moreover, the design of the study permits the investigation of whether extraversion and ER interact with the emotional valence of scenes to influence top-down processing mechanisms involved in selective visual attention. The current experimental design also allowed investigation of whether the beneficial impact of extraversion on change detection shown in Experiment Two extended to improvements in visual search performance in the current task. As this study was a replication (and extension) of Experiment Three, it was also able to test if positive real-world scenes reduce accuracy during visual search towards neutral targets, and whether negative real-world scenes slow RT during visual search towards neutral targets. First, ER is introduced and research and theory detailing ER and associations with visual attention are discussed. Following this, Experiment Four is presented. Finally, the Chapter will finish with a summary highlighting the main findings and their implications.

5.2. Emotion regulation

ER is an individual difference trait linked to psychopathology and affective reactivity, specifically the regulation of our emotions, and is currently an area of great interest within psychology. Due to the increase in research interest in ER there have been many terms used to describe emotion and emotion regulation-related processes. The main element of ER is the activation of a goal to influence the emotion trajectory (Gross et al., 2011), and ER can be broadly described as the initiation of a conscious or non-conscious effort to start, stop, or modulate an emotion (Gross, 2015). Mostly commonly thought of as efforts to either down-regulate negative emotion (e.g. trying to reinterpret an unsuccessful job application) or increase positive emotion (e.g. sharing a success with friends or family), ER also encompasses situations where either an increase of negative emotion or a decrease of positive emotion may be beneficial (e.g. enhancing feelings of unfair treatment before an argument or controlling facial expressions after being dealt a winning poker hand). Examples of ER are often thought of as internal, or intrinsic (as in the examples above). However, ER strategies can also be external, or extrinsic in nature (e.g. trying to comfort a child after the death of a pet). Frequently, instances of ER detail conscious efforts to influence ongoing emotional experience, as in the above examples. Nevertheless, ER can occur subconsciously, such as quickly moving attention away from distressing stimuli (Gyurak et al., 2011).

The predominant theoretical model of ER is the process model of emotion regulation (Gross, 1998; Figure 5.1). The model details five main emotion regulatory processes: situation selection, situation modification, attentional deployment, cognitive change and response modulation. These differing ER strategies can be further categorised as either antecedent-focussed, where the strategies are deployed before the generation of the emotional response, or response-focussed, when regulatory strategies are adopted after the emotional response. Briefly, situation selection refers to an ER strategy whereby an individual has the option to choose between differing situations that may confer differing emotional consequences (e.g. avoiding your grumpy neighbour or attending a music concert to see your favourite band). Situation selection modification refers to the ability to modify a specific situation with the goal of changing the emotional impact (e.g. placing an overdue bill in a drawer instead of on the noticeboard). Attentional deployment details the decision to direct attention towards one of many possible aspects of a given situation based on the individual’s motivations (e.g. thinking of an upcoming celebration whilst in a boring lecture or shifting one’s gaze from an unpleasant stimulus). Cognitive change refers to the evaluation of a situation and the choice of which meanings are given to a specific experience or situation (e.g. my sweaty palms are a sign that my body is ready for the interview). It is these cognitive evaluations, or appraisals, that provide the behavioural and physiological response tendencies that describe emotion. Finally, response modulation describes the changing of one of the response tendencies after they have occurred (e.g. using substances to change one’s mood).

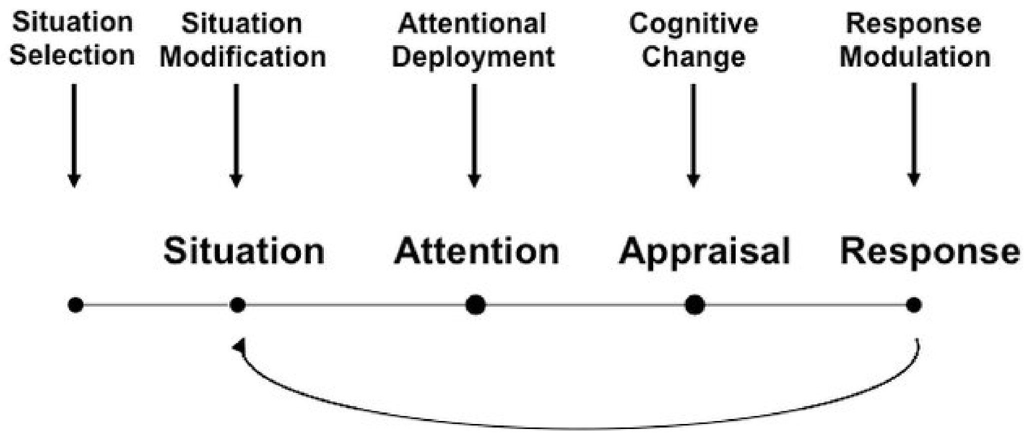

Figure 5.1. The process model of emotion regulation (Gross, 1998).

5.3. Emotion regulation and its association with affect and psychopathology

ER has strong associations with affect and psychopathology. Two ER strategies which have received ongoing focus in the literature are cognitive reappraisal and expressive suppression. Cognitive reappraisal, an antecedent-focussed strategy, involves individuals reappraising a potentially emotional situation in a way which changes its emotional impact. Expressive suppression, a response-focussed strategy, dictates individuals inhibiting ongoing emotion-expressive behaviour (Gross & John, 2003). It is likely that individual differences in ER may determine susceptibility or resilience when individuals are presented with emotional information or situations. For instance, individuals who are more likely to adopt cognitive reappraisal experience increased positive emotion and less negative emotion, whereas individuals more likely to adopt expressive suppression experience less positive emotion and increased negative emotion (Gross & John, 2003). Similar findings have been replicated across a number of studies (e.g. Brockman et al., 2017; Denny et al., 2015; Gross, 1998; Latif et al., 2019; Suri & Gross, 2015) suggesting that specific ER strategies may provide either a vulnerability or protective factor when presented with emotional situations.

Moreover, poor ER ability or maladaptive ER is related to the development of affective disorders including depression and anxiety (Aldao et al., 2010). Individuals who more frequently adopt reappraisal ER strategies and infrequently adopt suppression-related strategies, report low levels of depression, anxiety and posttraumatic stress disorder.

Conversely, individuals who report infrequent or ineffective use of reappraisal, show higher levels of depression, anxiety and posttraumatic stress disorder (Eftekhari et al., 2009). Moreover, novel therapies based on specifically targeting ER (emotion regulation therapy) have shown clinical improvement for individuals suffering from depression and anxiety (Fresco et al., 2017; Renna et al., 2018; Scult et al., 2019). These findings show that poor or dysregulated ER is associated with increased levels of negative affect and decreased levels of positive affect. Further, the findings also show links to the development of affective disorders, as well as clinical improvements for individuals undergoing emotion regulation therapy.

5.4. Associations between emotion regulation and attention

Research investigating the influences of emotional stimuli on attention has received much focus within the literature (for reviews see; Carretié, 2014; Pool et al., 2016; Pourtois et al., 2013). Additionally, findings show that affective disorders are characterised by emotion-congruent attentional biases demonstrating links between emotional and attentional processes in psychopathology and highlighting attention as a key mechanism in their development (Yiend, 2010). There are theoretical similarities between models of attention and models of ER. For instance, dual process models of ER (Barrett et al., 2004; Gross, 1998) are theorised to include the automatic encoding of emotional stimuli (bottom-up processing), as well as the integration of cognitive control mechanisms (top-down processing) (Hofmann et al., 2012; Ochsner et al., 2009; Posner & Rothbart, 1998). These dual processing models have direct similarity to models of attention describing goal-directed/top-down and automatic/bottom-up mechanisms (Itti & Koch, 2000; Schneider & Shiffrin, 1977). Considering the above theoretical and empirical research, in addition to the well documented influences of ER in the development of psychopathology (Aldao et al., 2010), there has been surprisingly little research conducted investigating the links between ER (as opposed to the emotion of an individual or the emotional content of stimuli) and attention.

Research investigating ER and attention has demonstrated that regulating negative affect results in reduced dwell time to emotional regions of negative images compared to when passively viewing negative images, suggestive of reduced engagement and encoding of the stimuli (Bebko et al., 2011; Manera et al., 2014; van Reekum et al., 2007). Moreover, it has also been shown that the use of differing ER strategies when regulating negative affect is associated with contrasting patterns of eye movements (Strauss et al., 2016). Specifically, when adopting suppression regulatory techniques, participants showed a global decrease in dwell time to arousing areas of an image during the duration of a trial. However, when adopting reappraisal, participants demonstrated an initial increase in dwell time to arousing scene elements followed by a subsequent orientating away from these scene regions. Therefore, when instructed to adopt specific ER strategies, differing patterns in eye movements are observed. One study which investigated the association between habitual use of ER strategies (as opposed to directing participants to adopt a specific ER strategy) revealed that individuals who more frequently adopt cognitive reappraisal are faster to disengage from sad faces compared to positive faces (Vanderhasselt et al., 2013). However, currently there are no studies that have investigated habitual use of ER strategies and their impact on attention to real-world scenes or during visual search. It is important to investigate attentional mechanisms and their relationships with ER in situations when participants are free to choose how they allocate their attention rather than being directed towards adopting a specific ER strategy. Experiment Four, presented below, permits such investigation by focussing on habitual use of two ER strategies: cognitive reappraisal and expressive suppression. The inclusion of these strategies permits the investigation of an ER strategy often referred to as a protective factor (cognitive reappraisal) and an ER strategy often referred to as maladaptive (expressive suppression). Moreover, standardised psychometric questionnaires are available to reliably record habitual self-report use of these specific ER strategies. Additionally, the neuroscientific study of ER and attention has focussed on these two strategies and their adoption within the current thesis provides a starting point for comparison with biobehavioural models of ER.

5.5. Emotional real-world scenes impact visual search: A replication and extension including the influences of extraversion and emotion regulation[13]

5.5.1. Abstract

Attention is a key mechanism in the development of psychopathology. Further, emotion and affective traits, including extraversion and emotion regulation, are important

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[13] Bendall, R.C.A., Eachus, P., & Thompson, C. (2020). *Emotional real-world scenes impact visual search: A replication and extension including the influences of extraversion and emotion regulation*. Manuscript submitted for publication.

considerations in clinical psychology due to their associations with the occurrence of affective disorders. Previously, emotional real-world scenes have been shown to influence visual search. However, it is currently unknown whether extraversion and emotion regulation can influence visual search towards neutral targets embedded within real-world scenes, or whether these traits can impact the effect of emotional stimuli on visual search. An opportunity sample of healthy individuals had trait levels of extraversion and emotion regulation recorded before completing a visual search task. Participants more accurately identified search targets in neutral images compared to positive images, whilst response times were slower in negative images. Importantly, individuals with higher trait levels of cognitive reappraisal and expressive suppression displayed faster identification of search targets regardless of the emotional valence of the stimuli. Extraversion did not influence visual search. These findings add to our understanding regarding the influence of extraversion, cognitive reappraisal, and expressive suppression on our ability to allocate attention during visual search when searching real-world scenes.

5.5.2. Introduction

Theories suggest that attentional resources are biased towards task-relevant stimuli (top-down processing; Schneider & Shiffrin, 1977) and to salient stimuli (bottom-up processing; Itti & Koch, 2000). However, it has been proposed that these distinctions are unable to explain all attentional processing (Awh et al., 2012). For instance, it has been argued that the emotional valence of stimuli may provide an additional type of influence on attentional processing and selective attention (Carretié, 2014; Pool et al., 2016; Pourtois et al., 2013). This influence has been termed emotional attention (Vuilleumier, 2005) and research exists demonstrating that emotional processing, top-down processing, and bottom-up processing can exert summative influences on selective attention (Brosch et al., 2011; Pourtois et al., 2013).

Studies have shown that emotional targets are detected more accurately and faster in a range of tasks, including during visual search (Eastwood et al., 2003; Williams et al., 2005). Additionally, emotional distractors capture attention more than neutral distractors (Carretié, 2014). Most research studying the influence of image valence on attention uses faces or non-naturalistic arrays containing targets and/or distractors. Fewer studies have used naturalistic visual scenes, although those that do show similar effects of valence. For instance, it was shown that when participants were required to decide how many humans were located within a visual scene response times were slower when the scene was negative compared to neutral (Simpson et al., 2000). Further, it has been shown that the emotional content of real-world scenes also influences fixation number and duration whereby individuals make more fixations on negative and positive stimuli compared to neutral (Bradley et al., 2011). Additionally, the duration of fixations has been shown to vary in emotional and neutral scenes (Bradley et al., 2011; Kaspar et al., 2013; Kuniecki et al., 2017).

Bendall et al. (2019) investigated visual search within emotional and neutral real-world scenes asking participants to search for neutral target letters embedded within positive, negative, and neutral scenes. Image valence had an impact on target search, with lower accuracy when the target was embedded in positive images and slower response times when the target was embedded in negative images. Together with the earlier findings this shows that emotional valence of stimuli therefore has an impact on visual attention, adding to the influence of bottom-up and top-down processing.

There is also an argument that personality and individual differences can influence visual attention. Related to this, some personality traits and individual differences are linked to affective reactivity – conceptualised here as individual responses to stressors and/or emotional stimuli. For instance, one trait linked to affective reactivity which features in models of psychopathology is extraversion (Clark, 2005; Watson et al., 1994), and it is associated with positive emotions, higher wellbeing, and more positive experiences (DeNeve & Cooper, 1998). Models of depression link low levels of extraversion to Major Depressive Disorder (MDD; Shankman & Klein, 2003) and depressed individuals show reduced reactivity to emotional stimuli (Rottenberg et al., 2005; Rottenberg & Gotlib, 2004). Additionally, research evidencing emotion-congruent attentional biases in affective disorders demonstrates the links between attentional and emotional processes in psychopathology, highlighting attention as a key mechanism in the development of such disorders (Yiend, 2010).

Extraversion has been found to affect processing of neutral stimuli. For example, using a rapid serial visual presentation task, MacLean and Arnell (2010) found that greater extraversion predicted a smaller attentional blink (AB). Early theories to account for the AB effect suggest that it occurs due to a limited processing capacity whereby individuals are unable to process information presented in close temporal proximity (Raymond et al., 1992). These results would therefore indicate that extraverts can process more information and consequently suffer from the AB to a lesser extent. Extraversion has also been found to predict attentional performance during change detection where improved accuracy is associated with higher levels of extraversion, suggesting that extraverts allocate attention more effectively in demanding tasks (Hahn et al., 2015).

It has also been theorised that extraversion influences attentional bias to emotionally valanced stimuli (Rusting, 1998, 1999; Rusting & Larsen, 1998). For example, extraversion increases attention towards positive information and reduces attention towards negative information (Yu et al., 2016). Additionally, extraversion is related to increased neural responses to positive stimuli compared to neutral stimuli and linked to sustained attention to positive stimuli (Canli et al., 2001; Lou et al., 2016; Speed et al., 2015). Therefore, there is evidence suggesting that extraversion is associated with emotional attention at both the behavioural and neural level.

A further individual difference trait linked to affective reactivity is emotion regulation (ER), broadly defined as the initiation of a conscious or non-conscious effort to start, stop, or modulate an emotion (Gross, 2015). Poor ER is related to affective disorders such as depression and anxiety (Aldao et al., 2010), and individual differences in habitual ER strategy use may determine susceptibility and resilience when presented with affective stressors. The most extensively studied strategies are cognitive reappraisal; an antecedent-focussed strategy where individuals reappraise a potentially emotional situation in a way that changes its emotional impact, and expressive suppression; a response-focussed strategy where individuals inhibit ongoing emotion-expressive behaviour (Gross & John, 2003). Cognitive reappraisal is related to reduced negative affect (Denny et al., 2015; Gross, 1998), whilst expressive suppression is associated with increased negative affect (Brockman et al., 2017; Latif et al., 2019; Suri & Gross, 2015).

Viviani (2013) has argued that the prevailing theoretical view of ER encompasses a dual-process model (Barrett et al., 2004) involving both the automatic encoding of emotional stimuli and the integration of prefrontal cognitive control mechanisms (Hofmann et al., 2012; Ochsner et al., 2009; Posner & Rothbart, 1998). This standpoint is in line with models of attention whereby bottom-up processing (similar to automatic encoding of emotional stimuli) and top-down processing (similar to cognitive control mechanisms) guide the allocation of attentional resources (Itti & Koch, 2000; Schneider &

Shiffrin, 1977). Additionally, there is overlap between brain structures that underpin ER, attention, and top-down cognitive control (Buhle et al., 2014; Miller & Cohen, 2001; Ochsner et al., 2012; Paneri & Gregoriou, 2017) suggesting that attentional control and emotion regulation share common mechanisms.

Studies have shown that ER can influence visual attention. For example, research has shown that regulating negative affect reduces dwell time to arousing areas of unpleasant images compared to when passively viewing unpleasant images (Bebko et al., 2011; Manera et al., 2014; van Reekum et al., 2007). Additionally, Strauss et al. (2016) have shown that successful down regulation of negative affect is associated with differing patterns of eye movements across ER strategies. For instance, when participants were required to adopt reappraisal, initial increases in dwell time to arousing scene regions were followed by a move away from the same scene regions later in the trial. In contrast, when adopting suppression, participants displayed reduced dwell time to arousing areas during the complete trial. Moreover, when regulating emotion, variations in fixations have been shown to account for 35-78% of the variance in brain activity, demonstrating that gaze fixations are predictive of changes in brain activity during an ER task (van Reekum et al., 2007).

Research therefore suggests that extraversion and instructed ER can influence the allocation of attention to both neutral and emotional information. However, it is currently unclear whether trait levels of extraversion and habitual use of ER strategies can influence visual search during tasks involving emotional stimuli and neutral targets. Previous research investigating the links between ER and attention have employed tasks where participants are explicitly instructed to adopt ER strategies, and consequently it is not presently understood whether habitual use of ER strategies impacts attention and visual search when there is no explicit instruction to adopt a specific regulation strategy.

The aim of the current study was to investigate whether the influence of stimulus valence on the allocation of attention varies due to extraversion and habitual ER strategy use. The visual search task used by Bendall et al. (2019) was adopted with the additional inclusion of measures of extraversion and habitual ER strategy use. Participants were required to identify neutral targets embedded within images varying in emotional valence (positive, neutral, or negative). Following the results of Bendall et al. (2019) it was predicted that accuracy would be reduced for positive trials and that reaction time would be longer for negative trials. Additionally, it was predicted that individuals reporting greater levels of extraversion, cognitive reappraisal, and expressive suppression would show improved behavioural task performance compared to individuals reporting low levels of these traits. Importantly, it was also predicted that these individual difference traits would show an interactive effect with stimuli valence; performance of individuals with greater levels of extraversion, cognitive reappraisal, and expressive suppression would show improved performance during the positive and negative trials compared to individuals low in these traits.

5.5.3. Method

Participants

For our focal analyses adopting a 3 x 2 mixed measures experimental design, an a priori sample size calculation aiming to achieve statistical power of .95 with an alpha criterion of .05 and a medium effect size of .25 suggested that 36 participants were required[14]. Participants were a convenience sample of 50 (40 female) staff and students from the University of Salford aged between 18 and 40 years (*M* = 25.30, *SD* = 6.50). Volunteers received a £10 inconvenience allowance. Ethical approval was obtained from the College of Health and Social Care Research Ethics Committee at the University of Salford.

Design

A mixed design was used with four independent variables. A within-participants variable was the emotional valence of the stimuli used during this task (positive, neutral, or negative). Between-participants variables were levels of extraversion, cognitive reappraisal, and expressive suppression (high or low)[15]. As the current study had no predictions regarding interaction effects between extraversion, cognitive reappraisal, and expressive suppression, and to maximise the power of our statistical analyses, each trait was analysed separately resulting in a 3 x 2 analytical framework. Behavioural performance during the visual search task provided two dependent variables consisting of accuracy (percentage correct) and response time (in seconds) to identify the search target.

Materials

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[14] Further details regarding the sample size/power analysis is provided in Appendix Four.

[15] Descriptive statistics for individual difference traits are provided in Appendix Five.

E-Prime (Psychology Software Tools, Inc.) was used to run the experiment and participants completed the study using a 60 Hz, 17-inch monitor. Images were selected from the NAPS (Marchewka et al., 2014) on the basis of their affective valence ratings and a total of 192 images were used for the visual search task; 64 positive, 64 neutral, and 64 negative images (identification numbers are provided in Appendix One, Supplementary Table 3). All images were presented in colour and measured 1600 x 1200 pixels. The target in each visual search trial consisted of either a letter T or letter L and these were embedded within the image. The target letters were displayed at 0, 90, 180, or 270-degree orientations in Arial font size 12 and were located either in the centre of the image (measuring 450 x 342 pixels) or the periphery of the image (located outside of the central area). To assess whether the stimuli sets differed according to valence a one-way analysis of variance (ANOVA) was conducted using SPSS. Mauchly's test indicated that the assumption of sphericity had been violated therefore degrees of freedom were corrected using Huynh-Feldt estimates of sphericity ($\varepsilon = .80$). Analysis showed a significant main effect of valence, F (1.61, 101.20) = 2819.30, $MSE = .19$, $p < .001$, $\eta_p^2 = .98$. Planned contrasts revealed that positive stimuli ($M = 7.70$, $SD = .34$) had increased valence scores compared to neutral stimuli ($M = 5.01$, $SD = .20$), F (1, 63) = 3199.01, $MSE = .15$, $p < .001$, $\eta_p^2 = .98$. Neutral stimuli had higher valence scores than negative stimuli ($M = 2.55$, $SD = .58$), F (1, 63) = 1003.20, $MSE = .39$, $p < .001$, $\eta_p^2 = .94$. To ensure that stimuli sets differed only in valence additional properties of luminance, contrast and entropy were compared across the three conditions. For luminance, Mauchly's test indicated that the assumption of sphericity had been violated therefore degrees of freedom were corrected using Huynh-Feldt estimates of sphericity ($\varepsilon = .90$). The ANOVA showed that the three stimuli sets did not differ in their luminance (neutral $M = 118.64$, $SD = 33.11$, positive $M = 120.55$, $SD = 30.47$, negative $M = 117.01$, $SD = 29.60$), F (1.80, 113.51) = .202, $MSE = 1102.96$, $p = .795$, $\eta_p^2 = .00$. The three sets were also similar in contrast (neutral $M = 65.10$, $SD = 19.92$, positive $M = 62.60$, $SD = 13.14$, negative $M = 62.82$, $SD = 12.22$), F (2, 126) = .656, $MSE = 187.47$, $p = .521$, $\eta_p^2 = .01$, and entropy (neutral $M = 7.50$, $SD = .36$, positive $M = 7.46$, $SD = .38$, negative $M = 7.52$, $SD = .38$), F (2, 126) = .491, $MSE = .145$, $p = .613$, $\eta_p^2 = .01$.

The Emotion Regulation Questionnaire (ERQ; Gross & John, 2003) was administered to assess habitual use of ER strategies. The 10-item self-report questionnaire includes questions in relation to how individuals regulate their emotions and provides scores on two ER strategies: cognitive reappraisal and expressive suppression. All items are reported on a 7-point scale from 1 to 7 (strongly disagree to strongly agree). Six questions assess cognitive reappraisal with a minimum score of 6 and a maximum score of 42. Four questions assess expression suppression with a minimum score of 4 and a maximum score of 28. For both ER strategies low scores indicate lower levels of habitual strategy use whilst high scores indicate higher levels of habitual strategy use. The NEO-FFI-3 Personality Inventory (NEO-FFI-3; McCrae & Costa, 2007) was administered to measure levels of extraversion. The 60-item self-report scale includes questions relating to personality characteristics and traits along a 5-point Likert scale from 0 (strongly disagree) to 4 (strongly agree). Each trait is measured by 12 questions, the minimum score for each trait is 0 (indicating lower levels) and the maximum is 48 (indicating higher levels). In the current study the trait of interest was extraversion, but the full inventory was administered.

Procedure

After providing written informed consent participants completed the ERQ and NEO-FFI-3. Participants were seated 22-inches from the screen and a chin rest was used to reduce head movement and increase comfort. Participants were then given full instructions about the task. Following this, participants were shown onscreen instructions and were asked to press the spacebar when ready to begin. The visual search task was based on that detailed in Bendall et al. (2019) and adapted from Brockmole and Henderson (2006). Trials began with the presentation of a fixation cross for 1000ms after which an image was presented with the letter T or L superimposed. This image remained until the letter was identified with participants pressing the T or L key on the keyboard. Feedback was then provided before the next trial was initiated. In total participants completed 192 trials presented randomly. There were 64 trials for each valence condition (positive, negative, and neutral), 50% of these included the letter T and 50% showed the letter L. In these 32 trials the target letter was presented at a randomly selected central location for 50% of the trials and at a randomly presented location in the periphery for the remaining 50% of trials. Targets were presented equally often at each of the 4 angles of rotation for each trial type (0, 90, 180, and 270-degrees).

5.5.4. Results

Data collected included accuracy (percentage correct; %) and response times (seconds; s). 96.48% of trials were completed accurately and participants took an average of 2.00s to correctly identify the target. 136 trials were terminated (0.01% of trials), and 116 trials (2.48% of total correct trials) were removed at ±2 standard deviations from the mean for reaction time. Outliers were removed at ±2 standard deviations from the mean resulting in two participants being removed based on accuracy, and a further participant was excluded based on reaction time.

Prior to measuring the impact of extraversion, cognitive reappraisal, and expressive suppression on the ability to detect and identify targets in emotional and neutral scenes, the differences in accuracy and reaction time across the conditions of stimuli valence was measured using two 1 x 3 ANOVAs. These were followed by planned contrasts that compared the positive and negative conditions to the neutral condition. Analysis of accuracy produced a significant effect of stimuli valence, $F(2, 92) = 6.052$, $p = .003$, $MSE = 5.731$, $\eta p^2 = .12$; Figure 5.1. Planned comparisons demonstrated that targets presented on neutral images were detected more accurately than targets presented on positive images, $M = 97.72\%$, $SD = 3.12\%$ vs $M = 96.63\%$, $SD = 3.33\%$, $F(1, 46) = 8.596$, $MSE = 13.554$, $p = .005$, $\eta p^2 = .16$. However, planned contrasts indicted that there was no difference in accuracy between neutral images and negative images ($M = 97.78\%$, $SD = 2.98\%$), $F(1, 46) = .139$, $p = .711$, $MSE = 12.376$, $\eta p^2 = .00$.

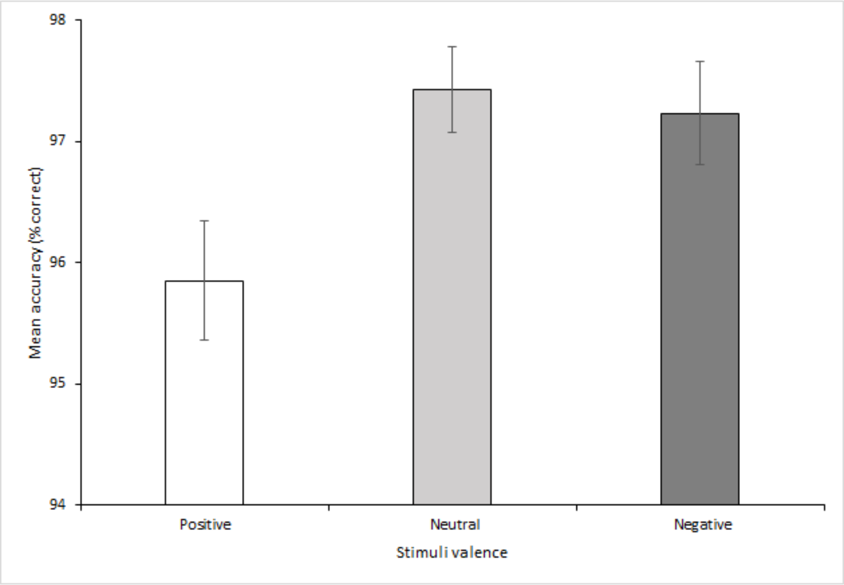

Figure 5.2. Mean accuracy (percentage correct) in the visual search task. Neutral trials were completed more accurately than positive trials. Error bars = standard error of the mean.

For reaction time there was a significant effect of stimuli valence, *F*(2, 92) = 21.235, *p* < .001, *MSE* = .048, ηp^2 = .32; Figure 5.2. Planned contrasts demonstrated that the difference between neutral images and positive images approached significance suggesting that identification of targets in neutral trials was completed quicker than identification of targets in positive images, *M* = 1.90s, *SD* = .64s vs *M* = 1.99s, *SD* = .73s, *F*(1, 46) = 3.952, *p* = .053, *MSE* = .081, ηp^2 = .08. Planned contrasts also show that identification of targets in neutral images was quicker than identification of targets in negative images (*M* = 2.16s, *SD* = .61s), *F*(1, 46) = 42.847, *p* < .001, *MSE* = .089, ηp^2 = .48.

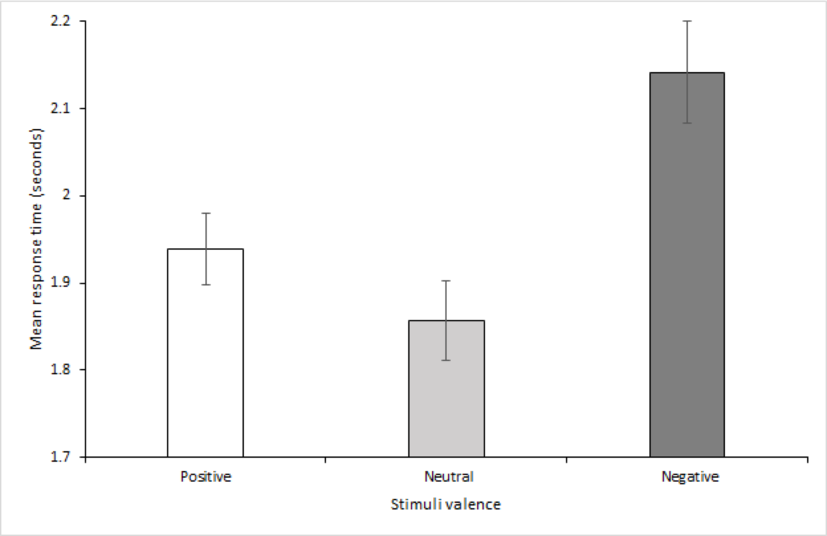

Figure 5.3. Mean response time (seconds) in the visual search task. Neutral trials were completed quicker than positive and negative trials. Error bars = standard error of the mean.

The effects of valence were further explored using 3 (stimuli valence; positive, neutral, and negative) x 2 (individual difference trait; high or low) mixed measures ANOVAs followed by planned comparisons. To avoid repetition only the effect of the traits and the interaction between traits and valence are presented. There was a non-significant effect of extraversion on accuracy, *F*(1, 44) = .073, *p* = .788, *MSE* = 6.954, ηp^2 = .00. The interaction between extraversion and stimuli valence was also non-significant, *F*(2, 88) = 2.001, *p* = .141, *MSE* = 8.590, ηp^2 = .04. The effect of extraversion on reaction time approached significance, *F*(1, 45) = .3.929, *p* = .054, *MSE* = .169, ηp^2 = .10; Figure

5.3. Individuals high in extraversion were quicker at correctly identifying the visual search target compared to individuals low in extraversion (*M* = 2.01ss, *SD* = .58 vs *M* = 2.20s, *SD* = .73s). For reaction time the interaction between extraversion and stimuli valence was non-significant, *F*(2, 88) = 1.346, *p* = .261, *MSE* = .098, ηp^2 = .03.

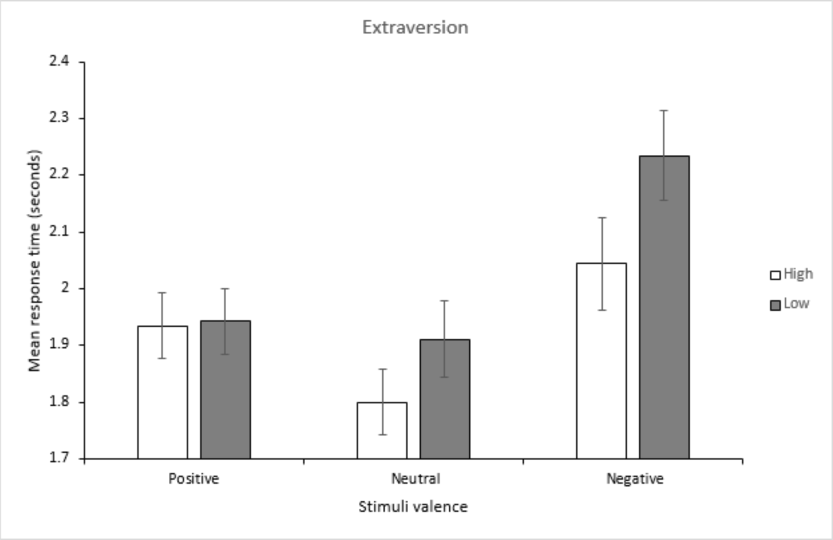

Figure 5.4. Mean response time (seconds) in the visual search task for extraversion. Individuals higher in levels of extraversion completed visual search trials quicker than individuals with lower levels of extraversion. Error bars = standard error of the mean.

There was a non-significant effect of cognitive reappraisal on accuracy, *F*(1, 44) = .241, *p* = .626, *MSE* = 6.928, ηp^2 = .01. The interaction between cognitive reappraisal and stimuli valence was also non-significant, *F*(2, 88) = 1.076, *p* = .345, *MSE* = 8.766, ηp^2 = .02. There was a significant effect of cognitive reappraisal on reaction time, *F*(1, 45) = 4.986, *p* = .031, *MSE* = .166, ηp^2 = .10; Figure 5.4. Individuals reporting higher levels of habitual cognitive reappraisal use were quicker at correctly identifying the search target compared to individuals reporting low habitual use (*M* = 2.01s, *SD* = .62s vs *M* = 2.17s, *SD* = .71s). For reaction time the interaction between cognitive reappraisal and stimuli valence was non-significant, *F*(2, 90) = 1.758, *p* = .178, *MSE* = .097, ηp^2 = .04.

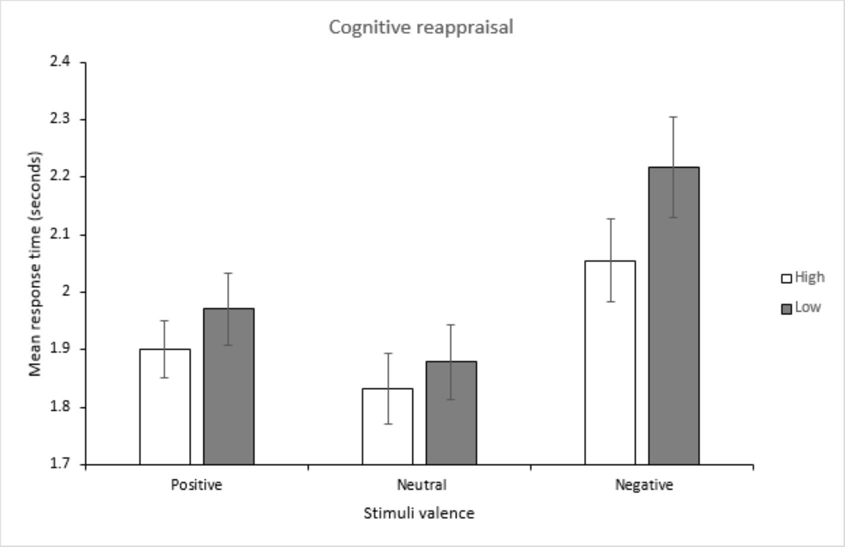

Figure 5.5. Mean response time (seconds) in the visual search task for cognitive reappraisal. Individuals higher in levels of cognitive reappraisal completed visual search trials quicker than individuals with lower levels of cognitive reappraisal. Error bars = standard error of the mean.

There was a non-significant effect of expressive suppression on accuracy, *F*(1, 44) = .011, *p* = .917, *MSE* = 6.964, ηp^2 = .00. The interaction between expressive suppression and stimuli valence was also non-significant, *F*(2, 88) = 1.906, *p* = .155, *MSE* = 8.607, ηp^2 = .04. There was a significant effect of expressive suppression on reaction time, *F*(1, 45) = 5.238, *p* = .027, *MSE* = .165, ηp^2 = .10; Figure 5.5. Individuals reporting higher levels of habitual expressive suppression use were quicker at correctly identifying the search target compared to individuals reporting low habitual use (*M* = 1.9s5, *SD* = .60s vs *M* = 2.24s, *SD* = .71s). For reaction time the interaction between expressive suppression and stimuli valence was non-significant, *F*(2, 90) = .220, *p* = .803, *MSE* = .101, ηp^2 = .01.

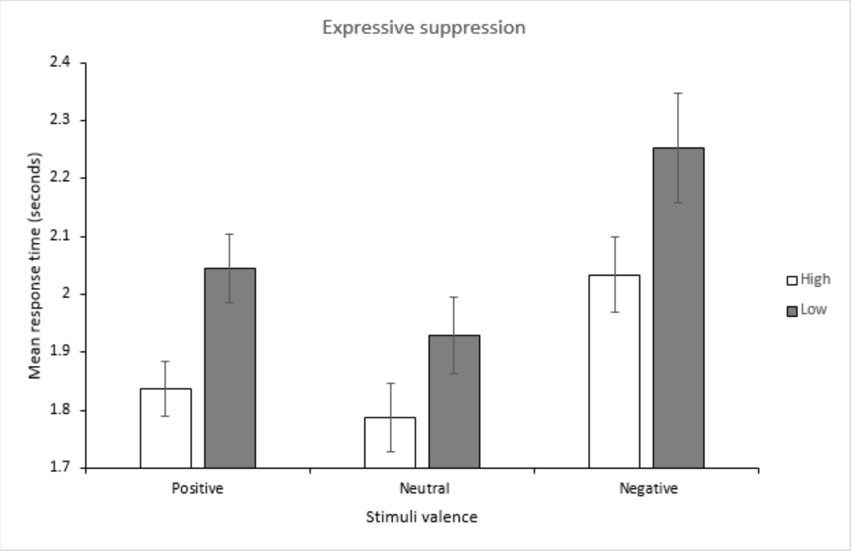

Figure 5.6. Mean response time (seconds) in the visual search task for expressive suppression. Individuals higher in levels of expressive suppression completed visual search trials quicker than individuals with lower levels of expressive suppression. Error bars = standard error of the mean.

As the effects of extraversion, cognitive reappraisal and expressive suppression were similar, a multiple regression was conducted to investigate their independent influences on attention (irrespective of stimuli valence). Initially, relevant regression assumptions were checked. The assumptions of normally distributed errors and homogeneity of variance and linearity were shown to be met after visual inspection of the histograms of standardised residuals, scatterplots of standardised residuals, and normal P-P plots of standardised residuals. Additionally, no outliers were present as indicated by an analysis of standardised residuals (standardised residual minimum = -1.871, standardised residual maximum = 2.396). The assumption of independent errors was met indicated by a Durbin-Watson value of 1.819. The assumption of non-zero variances was also met (all scores > 1.074). Importantly, no collinearity was present within the data as indicated by all tolerance scores > .724 and all variance inflation factors < 1.380.

A multiple linear regression indicated the overall model was significant, $F(3, 43) = 5.817$, $p = .002$, $R^2 = .289$. Cognitive reappraisal was a significant predictor of reaction time, $B = -98.49$, $SE\ B = 37.20$, $p = .011$, 95% CI [-173.50, -23.48]. Expressive suppression was also a significant predictor of reaction time, $B = -82.51$, $SE\ B = 31.04$, $p = .011$, 95% CI [-145.11, -19.91]. However, extraversion did not significantly predict reaction time, $B = -5.26$, $SE\ B = 5.06$, $p = .304$, 95% CI [-15.46, 4.94]. In sum, extraversion, cognitive reappraisal, and expressive suppression were shown to have separate influences on reaction time evidenced by the lack of any collinearity. Extraversion did not significantly predict reaction time. In contrast, both cognitive reappraisal and expressive suppression were significant predictors of reaction time where higher levels of these ER traits predicted quicker reaction time during the visual search task.

Discussion

The current study was designed to investigate whether the influence of stimuli valence on visual attention varies according to extraversion and trait levels of habitual ER strategy use. Participants completed questionnaires recording levels of extraversion and habitual use of two ER strategies; cognitive reappraisal and expressive suppression, followed by a visual search task where targets were presented within real-world scenes of varying emotional valence; positive, neutral, or negative.

As predicted, participants were less accurate at identifying targets presented within positive real-world scenes compared to neutral real-world scenes. Additionally, participants correctly identified the search target equally well when embedded within neutral and negative scenes. Previously, using the same visual search task, participants were more accurate at identifying targets within neutral real-world scenes compared to positive (but not negative) real-world scenes (Bendall et al., 2019). For reaction time, participants were slower to correctly identify a target when it was presented on a negative image compared to a neutral image, supporting our hypothesis and previous findings (Bendall et al., 2019). Additionally, although a less pronounced effect, participants were slower to accurately detect a target when it was displayed on a positive image compared to a neutral image, a finding not seen previously. Taken together, these results suggest that attention varies according to the emotional valence of real-world scenes. Moreover, the differing influences of positive and negative stimuli on reaction time and accuracy suggest that emotional stimuli may impact attentional processing style in different ways (see Bendall et al. 2019 for further discussion).

Importantly, habitual use of cognitive reappraisal and expressive suppression were shown to influence visual search performance. Individuals reporting more frequent habitual use of two ER strategies; cognitive reappraisal and expressive suppression, correctly identified search targets quicker than individuals reporting less frequent habitual use of these strategies. Cognitive reappraisal and expressive suppression were not correlated with one another and no collinearity was present between these variables. These findings, supporting our a priori hypotheses, suggest that increased use of ER strategies provides a performance benefit during visual search regardless of the emotional valence of the stimuli targets are presented within. It is important to note that whilst expressive suppression is often referred to as a maladaptive ER strategy, due to its association with increased negative affect and psychopathology (Aldao et al., 2010; Brockman et al., 2017; Latif et al., 2019; Suri & Gross, 2015), it is uniquely suited to confer benefits in the completion of the visual search task adopted in this study. Expressive suppression, within a regulation context, involves the inhibition or suppression of ongoing emotion-expressive behaviour. The current task required individuals to respond to a search target whilst ignoring or suppressing the real-world scenes that were presented simultaneously. Therefore, individuals who more frequently adopt expressive suppression as an ER strategy are likely to be skilled at suppressing information in daily life. Our findings demonstrating improved visual search performance in individuals who more often adopt expressive suppression and cognitive reappraisal suggests that these ER strategies may be linked to improved cognitive functioning, including visual attention. This argument is supported by previous research showing that successful ER is related to improved behavioural performance and neural activation during completion of a Stroop task (Compton et al., 2008). Together with the findings reported here, these studies suggest that ER is associated with improved executive functioning (e.g. cognitive control/response inhibition and visual search). One possible mechanism linking ER with improved visual search performance is visual working memory ability and this is an area for further investigation. In support, it has recently been shown that working memory training improves ER ability (Xiu et al., 2016, 2018).

Contrary to our hypothesis, extraversion did not impact attention. Previously, individuals higher in extraversion have been shown to exhibit a smaller attentional blink (MacLean & Arnell, 2010) suggestive of increased processing capacity. Moreover, extraversion has also been linked to performance in a change detection task, with individuals higher in extraversion showing improved accuracy (Bendall et al., 2020; Hahn et al., 2015). However, extraversion has also been shown to be associated with slower reaction times during a change detection task, as well as improved accuracy, indicative of a speed-accuracy trade-off (Bendall et al., 2020). An important consideration when discussing findings from cognitive tasks is the characteristics of the task employed. The current study adopted a visual search task that requires less processing effort compared to the change detection task adopted in previous studies (Bendall et al., 2020; Hahn et al., 2015) and may not have been sufficient to reveal any influence of extraversion. Nonetheless, the current finding furthers our understanding regarding the influence of extraversion on visual attention, demonstrating that extraversion does not impact reaction time in a visual search task involving the identification of a neutral target embedded within a real-world scene.

Neither extraversion, cognitive reappraisal, nor expressive suppression were shown to influence how accurately individuals identified the target in the visual search task. In contrast, individuals with higher levels of extraversion have previously displayed improved accuracy in a change detection flicker task compared to individuals with lower levels of extraversion (Bendall et al., 2020; Hahn et al., 2015). One reason for the lack of any accuracy-related effects in the current study may be due to differences in the tasks adopted by researchers. For instance, it has been shown that in studies investigating emotional processing, task difficulty can influence the effects of emotional conditions on behavioural performance as well as neural activation in cognitive control and ER-associated brain regions. Specifically, in an n-back working memory task, more errors were made when words were negatively-valenced and the task condition was difficult. Further, corresponding neural activation measured with functional near-infrared spectroscopy and the late positive potential also revealed an interaction between valence and task difficulty in the PFC (Kopf et al., 2013). Interactions between task difficulty and emotional conditions have also been observed during the multi-source interference task. Here, both threat and reward distractors impacted reaction time of responding during incongruent trials (difficult condition) but not during no distractor trials (easy condition). Additionally, threat distractors decreased the neural response in cognitive control brain regions during incongruent trials whereas they increased the same neural response during congruent trials (Jasinska et al., 2012). Future research is needed to 1) investigate whether affective individual difference traits such as extraversion and ER impact the effect of emotional stimuli on visual search, and, 2) seek to clarify whether any such influences are impacted by task difficulty.

Interestingly, neither extraversion, cognitive reappraisal, nor expressive suppression interacted with stimuli valence to influence visual search performance. These findings are surprising given that these traits are linked to improvements in affective reactivity with extraverts and individuals who habitually adopt ER strategies more successful in regulating and/or inhibiting emotional information. Moreover, adopting a psychometric approach, studies have shown that extraversion is positively related with attention to positive information and negatively correlated with attention to negative stimuli (Yu et al., 2016). However, findings within the literature are not consistent with Lou et al. (2016) demonstrating that extraversion had no influence upon attentional biases to emotional stimuli in a modified oddball task. For ER, it has been shown that individuals who more frequently adopt cognitive reappraisal are quicker to disengage from sad faces compared to positive faces in a cued emotional conflict task (Vanderhasselt et al., 2013). Moreover, healthy individuals and MDD patients, who suffer from impairments in the control of attention and emotion, show a relationship between their performance in an emotional Stroop task (when negative stimuli were presented as distractors) and ER task completion (Loeffler et al., 2019). One explanation for the lack of an interaction between stimuli valence and extraversion/ER in the current study could be that the task did not require sufficient attentional resources to reveal such effects (despite the task being able to identify main effects of stimuli valence and ER on visual search performance). For instance, task difficulty has been shown to influence the impact of emotional stimuli on working memory performance as well as performance during the multi-source interference task (Jasinska et al., 2012; Kopf et al., 2013). Therefore, future studies that adopt more challenging visual search paradigms may help to elucidate if affective traits interact with emotional valence to guide the allocation of attention. Such studies will help to develop our understanding of the individual differences involved in our ability to deploy attention within emotional situations.

The novel observation that habitual use of ER strategies influences the ability to correctly identify a neutral target within emotional real-world scenes may have implications for clinical research. Attentional training techniques have been shown to be successful as a neurobehavioural treatment of emotional disorders (Fergus & Bardeen, 2016; Haukaas et al., 2018; Knowles et al., 2016). Moreover, emotion regulation therapy has shown clinical improvements for individuals suffering from anxiety and depression (Fresco et al., 2017; Renna et al., 2018; Scult et al., 2019). Treatments and therapies that simultaneously target changes in the allocation of attention *and* increased habitual use of effective ER strategies may provide more efficacious interventions for individuals suffering from affective disorders.

In conclusion, using a visual search task encompassing real-world stimuli of varying emotional valence, we demonstrate that positive and negative stimuli influence visual attention. Accuracy to correctly identify targets was reduced when the stimuli was positive compared to when the stimuli were neutral. In contrast, response time was reduced when the stimuli were neutral compared to negative. Moreover, we also show that individuals higher in trait levels of two ER strategies; cognitive reappraisal and expressive suppression, were quicker at identifying search targets regardless of the emotional valence of the stimuli. These findings add to our knowledge regarding individual differences and their ability to impact the successful allocation of attention.

5.6. Chapter discussion

Experiment Four was conducted in an attempt to replicate the finding of Experiment Three showing that stimuli of positive emotional valence and negative emotional valence have differing influences on visual search. Moreover, the current experiment was designed to see if the beneficial impact of extraversion on change detection shown in Experiment Two extended to improvements in visual search performance in the current task. Crucially, Experiment Four also included self-report levels of two ER strategies: cognitive reappraisal and expressive suppression to permit the investigation of whether these individual difference traits are related to visual search performance. Lastly, Experiment Four was designed to test whether extraversion, cognitive reappraisal and expressive suppression interact with stimuli valence to impact visual search. Participants were required to locate a target letter (‘T’ or ‘L’) embedded within real-world scenes varying in emotional valence (positive, neutral, or negative). Following completion of the visual search task, participants completed self-report questionnaires assessing the personality trait extraversion and habitual use of two ER strategies: cognitive reappraisal and expressive suppression.

The observation that participants were less accurate at identifying targets when the scene was positive, and slower when the target was presented within negative scenes, replicate the findings from Experiment Three suggesting that this is a robust effect. However, the current experiment also provides some evidence to suggest that participants were slower to detect targets presented within positive scenes (compared to neutral scenes), an observation not seen in Experiment Three. It is important to note that this effect was much weaker than the effect of negative emotional valence (p = .053, ηp^2 = .08 vs p <

.001, $\eta p^2 = .48$). Therefore, taken together, these findings provide additional support for the argument that positive emotional scenes and negative emotional scenes impact selective visual attention in different ways by impacting processing style.

In contrast to the findings from Experiment Two, extraversion did not impact visual search performance in the current experiment. This was surprising given the results of Experiment Two and previous literature suggesting that extraverts show improved performance during change detection and demonstrate a smaller AB (Hahn et al., 2015; MacLean & Arnell, 2010). In the multifactorial analysis, the effect of extraversion on RT approached significance ($p = .054$, $\eta p^2 = .10$). However, when the post-hoc regression analyses were conducted to test for collinearity between extraversion, cognitive reappraisal and expressive suppression, extraversion did not significantly predict RT. One possibility is that the influence of extraversion on visual attention may differ based on task difficulty. For example, in a demanding change detection flicker task, Experiment Two and the findings from Hahn et al. (2015) demonstrate that extraverts perform this task more accurately than introverts. However, evidence from low prevalence visual search tasks characterised as repetitive and requiring lower levels of task difficulty, show that introverts perform these tasks more accurately than extraverts (Peltier & Becker, 2017). A key difference between the two tasks used in this thesis is that unlike the visual search task, the change detection flicker task requires an individual hold a representation in visual working memory. Therefore, a specific avenue for future work is to test whether extraversion is associated with visual working memory capacity, and whether visual working memory capacity mediates the relationship between extraversion and visual attention. Additionally, it will be important to see if the current non-significant effect is replicated using the same task, but it will also be beneficial for research to test if other visual search tasks provide evidence for an impact of extraversion on attention. Such studies may help to elucidate the precise attentional mechanisms that are related to extraversion.

Experiment Four provides novel findings regarding the impact of ER on visual search performance. Supporting the a priori hypotheses and showing for the first time that increased habitual use of two ER strategies are related to improved visual search performance, it was demonstrated that individuals with increased habitual use of cognitive reappraisal and expressive suppression completed visual search trials more quickly than individuals with lower levels of these traits. Importantly, habitual use of cognitive reappraisal and expressive suppression were not correlated with each other, and no collinearity was present. Although expressive suppression is considered a maladaptive ER strategy, and therefore one could intuitively assume that higher levels of this trait would be related to poorer task performance, this strategy is beneficial when considering the specific task requirements. Participants are required to ignore the emotional content presented within the visual scenes and identify the target as quickly and accurately as possible. Expressive suppression is characterised by the inhibition or suppression of ongoing emotion-expressive behaviour. Therefore, whilst use of this strategy in the long-term may be considered a risk factor for the development of affective disorders (Aldao et al., 2010), it is likely to have provided task-related benefits and allowed individuals to more easily suppress the emotional content of the scenes, and therefore identify the target quicker than individuals who are less likely to habitually adopt suppression-related regulation strategies.

Stimuli valence did not interact with extraversion, cognitive reappraisal, or expressive suppression to influence visual search performance. Considering previous research showing that these traits are linked to affective reactivity these results are somewhat surprising. One explanation is that the current task was not sufficiently difficult to reveal such interactions (although the task did show main effects of cognitive reappraisal and expressive suppression on visual search). For example, task difficulty has been shown to effect the influence of emotional stimuli during the multi-source interference task (Jasinska et al., 2012). Currently it is not known whether the emotional state of an individual (investigated in Experiment One and Experiment Two) interacts with the emotional valence of stimuli (investigated in Experiment Three and Experiment Four) to influence selective visual attention. Given the findings of Experiment Four demonstrating that habitual use of ER does not interact with stimuli valence to influence visual search, it was important to test whether the emotional valence of real-world scenes interacts with participant emotion (when individuals are more likely to be actively regulating their emotion) to guide the allocation of attention. This is investigated in the following experiment.

Chapter Six: The influences of emotion and affective traits on visual search in real-world scenes

6.1. Overview of Chapter Six

In this Chapter Experiment Five is presented. Experiment Five employed the same visual search task that was used in Experiment Three and Experiment Four. Participants were induced into positive, negative, and neutral emotional states before completing a visual search task encompassing emotional real-world scenes. Inter-individual differences in extraversion, anxiety and ER were recorded. Additionally, it is currently unknown whether brain regions associated with dual process models of ER and visual attention are differentially activated during visual search tasks on the basis of stimuli valence or participant emotion. Therefore, neural activity was recorded from the PFC using fNIRS. Consequently, the experiment had the following main aims. Firstly, whether participant emotion exerts independent and/or interactive influences when considered with the emotional valence of scenes to impact visual search. A second aim was to test whether inter-individual differences in extraversion, anxiety, and ER impact visual search. Related to this, the experiment also aimed to see if these traits interacted with emotion or stimuli valence to influence visual search. A final aim investigated whether participant emotion or stimuli valence influence PFC activation during the completion of a visual search task. As the effect of anxiety on attention has not yet been investigated, this Chapter begins by detailing research reviewing the associations between anxiety and selective visual attention. Following this, Experiment Five is presented. Finally, the Chapter concludes with a summary highlighting the main findings and their implications.

6.2. Anxiety

Anxiety is related to excess nervousness, fear, apprehension and worry and is often also characterised by physiological changes such as alterations in blood pressure and increased perspiration (American Psychiatric Association, 2013). Anxiety has been described as a mental state characterised by an intense sense of tension, worry or apprehension, relative to something adverse that might happen in the future (Saviola et al., 2020) and can be differentiated on the basis of state anxiety or trait anxiety. Trait anxiety is defined as a stable personality characteristic (Spielberger et al., 1983) and individual difference trait associated with the tendency to respond to situations with worry, whereas state anxiety is defined by momentary reactions to adverse events (Saviola et al., 2020). Anxiety can be both adaptive in guiding behaviour in the face of threat, or maladaptive when excessive and repetitive leading to the development of anxiety-related disorders including generalised anxiety disorder (American Psychiatric Association, 2013).

6.3. Influence of anxiety on selective visual attention

In a similar manner to the initial research investigating the influences of emotional stimuli on visual attention, studies probing the impact of anxiety on selective visual attention predominantly focus on anxiety-related attentional biases towards threat-related stimuli (Mogg & Bradley, 2016, 2018). Research has suggested that anxious individuals display a range of attentional biases including attentional orienting towards threat-related stimuli, a delayed disengagement from threat-related stimuli, or orientating away from such stimuli (Cisler & Koster, 2010; Mogg & Bradley, 2016). However, a growing number of studies have failed to show that anxious individuals demonstrate attentional biases towards threat-related stimuli (Cisler & Koster, 2010; Mogg & Bradley, 2016; Van Bockstaele et al., 2014). Further, the effectiveness of attentional bias modification threat-avoidance training for treating anxiety has been questioned (Mogg & Bradley, 2018). Whilst extensive research has revealed threat-related attentional mechanisms in anxiety there is a scarcity of research that has investigated the impact of anxiety on selective visual attention in non-threat-related emotional stimuli or situations. Research has shown that inter-individual differences in the ability to experience positive emotion provides resilience to stressful events (Fredrickson, 2001), and that positive emotion improves physiological recovery after exposure to threatening situations (Tugade & Fredrickson, 2004). These studies suggest that our experience of positive emotion is associated with stress reactivity, yet additional research has also shown that a tendency to allocate attention towards positive stimuli may also be associated with a reduced negative reaction to stress (Joormann et al., 2007). Therefore, developing our understanding of the relationship between anxiety and attention towards positive information may help to develop more effective psychological interventions, for example attentional bias modification training.

One study that did investigate the links between non-threatening positive stimuli, anxiety and attention used an attentional training paradigm within the context of stress recovery (Taylor et al., 2011). Participants completed a probe detection task that was specifically designed to promote processing of positive stimuli. After completion of the task participants were exposed to a stressor. Findings revealed that individual differences in social anxiety moderated the effects of the attentional training manipulation. Specifically, individuals with higher levels of social anxiety showed reduced allocation of attention towards positive cues, highlighting a potential link between the processing of positive emotional information and anxiety.

The relevance of emotional information has also been shown to impact anxiety-related attention bias during visual search (Dodd et al., 2017). Here, participants completed a visual search task requiring the identification of whether a target face presented in a crowd of faces with either happy, neutral, or angry expressions was old or young (emotion-irrelevant). In a second task, using the same stimuli arrays, participants were required to identify whether the target face was happy or angry (emotion-relevant). Anxiety was not associated with attention in the emotion-relevant task. However, in the emotion-irrelevant task, higher levels of anxiety were related to a bias for angry over happy faces. These findings suggest anxious individuals display an attentional bias towards task-irrelevant angry faces (compared to happy faces), whereas no such attentional bias is evident when these stimuli are task-relevant, suggesting that when emotional stimuli are task relevant this overrides the attentional bias seen towards task-irrelevant emotional stimuli. Further, the inclusion of a positive (happy face) condition helps to provide novel understanding regarding the role of positive stimuli in anxiety even though it suggests a lack of an attentional bias towards positive stimuli. However, no neutral condition was included in the experimental design and so it remains unknown whether an attentional bias towards happy faces compared to neutral faces is associated with anxiety.

A recent study that included a positive emotional condition within their experimental design aimed to investigate the link between anxiety and cognitive flexibility. The study was informed by attentional control theory, which proposes that anxiety is associated with deficits in top-down cognitive control and efficiency during tasks involving inhibition or shifting of working memory (Eysenck et al., 2007). Whilst the theory predicts deficits in top-down cognitive control, it also proposes an increased influence of bottom-up attentional processing as anxiety severity increases. Crucially, attentional control theory also predicts that these influences will be more pronounced when the stimuli are emotional representing difficulties in affective cognitive flexibility. Twivy et al. (2020) investigated the influences of anxiety on affective flexibility using both positive and negative emotional stimuli. Adopting a task-switching task (Malooly et al., 2013) it was demonstrated that more efficient shifting of attention from affective stimuli towards non-affective aspects of negative scenes was predictive of higher levels of anxiety measured seven weeks later, an observation that can be explained by the predictions of attentional control theory suggesting that anxious individuals display an avoidance bias towards negative stimuli. Further, less efficient shifting of attention from non-affective aspects of visual scenes towards affective aspects of positive scenes was also predictive of higher anxiety after seven weeks (Twivy et al., 2020). These findings highlight that the processing of positive emotional information within the context of affective flexibility is associated with anxiety. However, it remains unknown whether anxiety is related to visual search incorporating real-world scenes of positive and negative emotional valence. This is an avenue for future research and is investigated in Experiment Five.

6.4. The influences of emotion and affective traits on visual attention in real-world scenes: A functional near-infrared spectroscopy study[16]

6.4.1. Abstract

Emotional modification of attention benefits adaptive ongoing behaviour. Moreover, affective traits, emotion and attention are key considerations in psychopathology due to their associations with wellbeing and the development of psychiatric disorders. Research investigating affective influences on visual attention commonly focus on either the impact of the emotional state of an individual or the emotional salience of task-related stimuli. However, little research has sought to test whether an individual's emotional state interacts with the emotional valence of stimuli to influence selective visual attention. The current study adopted real-world scenes varying in their emotional valence to investigate the influences of emotion and affective traits on visual search. The dorsolateral prefrontal cortex is implicated in the cognitive control of attention and emotion and functional near-infrared spectroscopy was utilised to record changes in oxygenated hemoglobin. Additionally, affective traits were recorded to permit investigation of their possible interactions with emotion or stimuli valence. Findings demonstrate that the emotional valence of real-world scenes influences visual attention with positive scenes impairing accuracy to identify a target, whilst both positive valence and negative valence had a detrimental impact on reaction time to identify a target. Further, whilst there was no main

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[16] Bendall, R. C. A., Royle, S., Eachus, P., & Thompson, C. (2021). *The influences of emotion and affective traits on visual search in real-world scenes: A functional near-infrared spectroscopy study*. Manuscript in preparation.

effect of emotion, in some instances the emotion of a participant interacts with stimuli valence to impact attention. Additionally, affective traits were shown to interact with emotion and stimuli valence to guide the allocation of attention during visual search. Moreover, the dorsolateral and ventrolateral prefrontal cortex showed increased activation when participants were induced into a negative emotion condition, supporting a role in the regulation of emotion during attention. The current findings add to our knowledge regarding the neurocognitive mechanisms underpinning affective selective visual attention when searching real-world scenes.

6.4.2. Introduction

The selection of goal-relevant and emotionally salient information within the environment is crucial for effective and adaptive ongoing behaviour. Our emotional experiences also benefit ongoing adaptive behaviour through the modification of perceptual and attentional processes. Consequently, research investigating affective influences on visual attention commonly focus on either the emotional state of the individual or the emotional salience of stimuli used within behavioural tasks.

A key theoretical framework relating to the influence of emotion on attention (and cognition in general) is the broaden-and-build theory (Fredrickson, 2001). It proposes that positive emotion broadens visual attention whilst negative emotion narrows attention. Research purporting to support the theory demonstrates that individuals in a positive emotional state are more likely to adopt a global processing style, whereas individuals in a negative emotional state more frequently adopt a local processing style (Basso et al., 1996; Fredrickson & Branigan, 2005). Moreover, individuals suffer increased interference from flankers positioned further away from a central target when induced into a positive mood (Rowe et al., 2007). Additionally, research has shown that when in a positive mood participants make a greater number of fixations to stimuli presented in the periphery of a visual display compared to when in a neutral mood (Wadlinger & Isaacowitz, 2006). However, further research has failed to provide evidence to support emotion-related changes in the allocation of visuospatial attention as predicted by the broaden-and-build-theory (Bendall et al., 2020; Bendall & Thompson, 2015; Bruyneel et al., 2013; Grol & Raedt, 2014). Rather than influencing visuospatial attention, it has been proposed that emotion may instead impact attentional processing style (Bendall & Thompson, 2015; Taylor et al., 2017; Vanlessen et al., 2016).

The emotional valence of stimuli has also been shown to influence, or bias, selective visual attention (Carretié, 2014; Pool et al., 2016; Pourtois et al., 2013). Research adopting emotional stimuli has demonstrated that emotional distractors capture attention more than neutral distractors (Carretié, 2014). Additionally, targets comprising emotional information are detected quicker and more accurately than neutral targets (Eastwood et al., 2003; Williams et al., 2005). More recently it has also been demonstrated that when targets are imbedded within real-world scenes, the emotional valence of the scene impacts reaction time (RT) and accuracy dependent upon the precise valence of the scene (Bendall et al., 2020; Bendall et al., 2019). Specifically, accuracy to identify a target was reduced when embedded within positively valenced scenes, whilst RT was slower when the target was embedded within negatively valenced scenes.

However, considering the growing literature investigating either the influence of an individual's emotional state on visual attention, or the impact of stimuli valence on visual attention, there is a surprising lack of research that has sought to investigate their interactive influences on selective visual attention. One study that manipulated both the emotional state of participants and the emotional valence of experimental stimuli was conducted by Wadlinger and Isaacowitz (2006). Here the authors demonstrated that positive emotion broadened attention, but only when the stimuli were also positive, demonstrating a congruency effect. A further study has demonstrated that levels of depression interact with positive emotion and positive stimuli to influence selective visual attention (Grol & Raedt, 2014). These studies suggest that the emotional valence of stimuli can interact with the emotional state of the participant to influence the allocation of attention. However, it remains unknown whether such interactions are evident during visuospatial attention and visual search. Given the known associations between attentional mechanisms and the development of psychopathologies including affective disorders (Aldao et al., 2010; Yiend, 2010), this is an important avenue for future research and is investigated in the current study.

It is also important to consider inter-individual differences that may mitigate the impact of an individual's emotional state or the emotional valence of stimuli on selective visual attention. Studies have demonstrated that inter-individual differences in affective traits such as extraversion and emotion regulation (ER) can influence selective visual attention (Bebko et al., 2011; Bendall, Begley, et al., 2020; Bendall, Eachus, et al., 2020; Hahn et al., 2015; Rusting, 1998; Strauss et al., 2016). State anxiety, a temporary feeling of negative arousal, has also been shown to influence selective visual attention. Substantial research has demonstrated that individuals with greater levels of state anxiety and trait anxiety show attentional biases for threatening stimuli (e.g. Liu et al., 2019; Massar et al., 2011; Mogg & Bradley, 1998; Quigley et al., 2012). However, currently it is not known whether state anxiety interacts with the emotional content of real-world scenes to guide the allocation of attention during visual search.

A broad brain network encompassing frontal-parietal regions supports selective visual attention (Corbetta et al., 2008; Corbetta & Shulman, 2002; Miller & Cohen, 2001; Posner & Petersen, 1990). Whilst the visual cortex is the first brain region to receive and process visual information, prefrontal cortex regions are associated with cognitive control, top-down attentional processing and the regulation of emotion (Buhle et al., 2014; Curtis & D'Esposito, 2003; Dolcos et al., 2011, 2014; Doré et al., 2017; Miller & Cohen, 2001; Rossi et al., 2009). Research has shown that the dorsolateral prefrontal cortex (dlPFC) is involved in cognitive control of attention and ER. For instance, using transcranial direct current stimulation permitting causal inferences, stimulation of the dlPFC during a flanker task has been shown to increase conflict adaptation (Gbadeyan et al., 2016). Moreover, stimulation of the dlPFC during memory-guided attention results in faster detection of visual search targets (Wang et al., 2018). Stimulation of the dlPFC has also been shown to improve attention in clinical populations (Hauer et al., 2019). Converging evidence also suggests that the dlPFC is crucial for successful ER (for reviews see Buhle et al., 2014; Ochsner et al., 2012). For instance, adopting a novel paradigm without the explicit instruction to adopt ER, increased dlPFC activity during the viewing of affective stimuli was able to predict those individuals more likely to adopt ER (Doré et al., 2017). Moreover, the dlPFC is also associated with ER in clinical populations. For example, increases in dlPFC activity during ER can predict symptom severity in major depressive disorder (Heller et al., 2013), whilst stimulation of the dlPFC in borderline personality disorder patients increases ER and cognitive control (Molavi et al., 2020).

The studies discussed above demonstrate that the dlPFC is involved in cognitive control of attention and ER. It is therefore possible that activation of the dlPFC may be differentially associated with visual search within emotional real-world scenes when participants are in negative, neutral, or positive emotional states. The aim of the current study was to investigate the neurocognitive mechanisms underpinning visual search within real-world scenes that differed in their emotional valence whilst participants were induced into positive, neutral, and negative emotional states. This permitted an investigation of whether participant emotion and the emotional valence of real-world scenes interact to impact visual search. Additionally, the study also sought to investigate if inter-individual differences in extraversion, state anxiety and habitual use of ER strategies interact with participant emotion or stimuli valence to guide the allocation of attention during visual search. Participants were induced into positive, neutral, and negative emotional states before completing a visual search task where the emotional valence of the stimuli were either positive, neutral, or negative. Neural activation was measured using function near-infrared spectroscopy (fNIRS) which has been shown to be a suitable technique for measuring emotion-cognition interactions (Bendall et al., 2016; Doi et al., 2013). A rapid event-related design was utilised as they are especially useful when using techniques such as functional magnetic resonance imaging or fNIRS where the hemodynamic signal changes are slow, therefore permitting the inclusion of additional experimental trials and increased statistical power (Plichta et al., 2007).

6.4.3. Method

Participants

Sample size was calculated on an a priori basis. Assuming statistical power of .90 with an alpha criterion of .05 and an effect size of .25 suggested that a minimum sample of 36 participants was required[17]. In total, 48 participants (16 males, 32 females) who were staff and students from the University of Salford aged between 18 and 56 years (*M* = 30.10, *SD* = 9.47) participated in the study. All participants provided written informed consent and received a £10 inconvenience allowance. Ethical approval was granted by the School of Health Sciences Research Ethics Committee at the University of Salford.

Design

A mixed design was used with four independent variables. Emotion was induced in participants (within-participants; positive, neutral, and negative). Further within-participants variables were the emotional valence of the stimuli (positive, neutral, and negative) and the location of the visual search target (central or peripheral). Individual difference traits (state anxiety, extraversion, cognitive reappraisal, expressive suppression)

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[17] Further details regarding the sample size/power analysis is provided in Appendix Four.

comprised a between-participants variable and consisted of high or low groupings[18]. Dependent variables consisted of accuracy and RT during the visual search task and changes in oxygenated hemoglobin (oxy-Hb) recorded from the PFC with fNIRS.

Materials

The experiment was designed and run using E-Prime (Psychology Software Tools, Inc). To induce emotion, participants were presented with images of differing emotional valence from the International Affective Picture System (IAPS; Lang et al., 2008), an approach previously successful in manipulating participant emotion (e.g. Bendall & Thompson, 2015). Sixty images were shown to participants: 20 positive images (mean valence 7.66), 20 neutral images (mean valence 4.64), and 20 negative images (mean valence 2.33). The stimuli used for the visual search task consisted of 180 images of contrasting emotional valence taken from the Nencki Affective Picture System (NAPS; Marchewka et al., 2014): 60 positive images (mean valence 7.77), 60 neutral images (mean valence 4.51), and 60 negative images (mean valence 2.50). All stimuli were presented in colour and measured 1600 x 1200 pixels. Each trial included a target letter (‘T’ or ‘L’) shown in Ariel font size 12 in blue that was presented at varying degree orientations (0°, 90°, 180° or 270°) either in the centre (450 x 342 pixels) or periphery (outside of this area) of the image. Further detail regarding the visual search stimuli is described in detail elsewhere (Bendall, Eachus, et al., 2021; Bendall et al., 2019).

Participants completed self-report questionnaires to provide measures of extraversion, cognitive reappraisal, expressive suppression, and state anxiety. The NEO-FFI-3 Personality Inventory (NEO-FFI-3; McCrae & Costa, 2007) was administered to provide a measure of extraversion. Items include questions relating to personality characteristics along a 5-point Likert scale from 0 (strongly disagree) to 4 (strongly agree) with 12 items per trait resulting in a minimum possible score of 0 (indicating lower levels) and a maximum possible score of 48 (indicating higher levels). To assess habitual use of cognitive reappraisal and expressive suppression the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003) was administered. The 10-item scale includes 6 items assessing cognitive reappraisal with the remaining 4 items corresponding to habitual use of expressive suppression. All items are presented on a 7-point Likert scale ranging from 1

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[18] Descriptive statistics for individual difference traits are provided in Appendix Five.

(strongly disagree) to 7 (strongly agree). For cognitive reappraisal the minimum score is 6 the maximum score is 42, whilst for expressive suppression the minimum score is 4 and the maximum score is 28. Lower scores represent less frequent use of the strategy, whilst higher scores represent more frequent habitual use of the strategy. Lastly, the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983) was used to assess levels of state anxiety. The state anxiety section of the STAI consists of 20 items presented on a 4-point Likert scale ranging from 1 (almost never) to 4 (almost always) providing a possible minimum score of 20 (lower levels) and a possible maximum score of 80 (higher levels). Finally, the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988) was administered to provide self-report measure of positive and negative affect to confirm that the experimental emotion induction procedure was successful. The PANAS is a 20-item questionnaire consisting of questions describing positive and negative feelings and emotions. Respondents are required to ‘indicate to what extent you feel this way right now, that is, at the present moment’ on a scale from 1 (very slightly or not at all) to 5 (extremely). The minimum possible score for is 10 (lower affect) and the maximum possible scores is 50 (higher affect).

Oxy-Hb was recorded from the PFC with an fNIR Imager 1000 (fNIR Devices, LLC.) multichannel fNIRS system. This system has a sampling rate of 2Hz and provides 16 measurement optodes which were averaged to provide measures for four regions of interest corresponding to the dlPFC (optodes 1, 3, 13 and 15), vlPFC (optodes 2, 4, 14 and 16), dmPFC (optodes 5, 7, 9 and 11) and vmPFC (optodes 6, 8, 10 and 12). The headband was aligned to frontal polar 1 and frontal polar 2 of the International 10-20 system (Jasper, 1958; Figure 6.1). See Ayaz et al. (2010) for further details. Cognitive Optical Brain Imaging Studio (fNIR Devices, LLC) was used to record changes in oxy-Hb and subsequently exported to Homer3 (Boas et al., 2015) for processing (see below for further details).

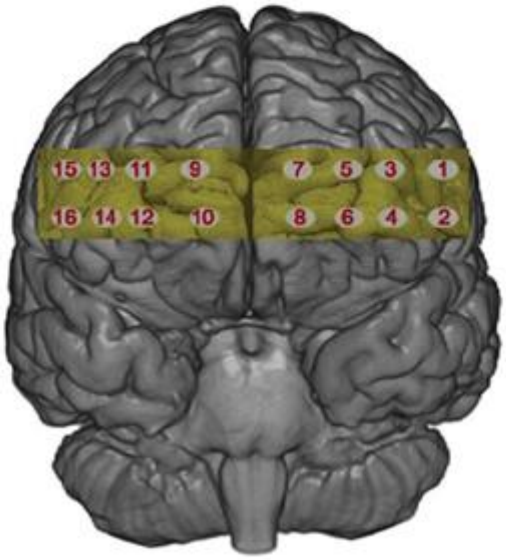

Figure 6.1. fNIRS probe location showing 16 optode sites on the prefrontal cortex

Procedure

Participants were seated approximately 22-inches from the monitor for the duration of the experiment. A chin rest was used to increase comfort and reduce head movements. Participants initially completed the ERQ, STAI and NEO-FFI-3 followed by the first emotion induction procedure and first block of visual search trials. The 20 emotion induction images from the IAPS were presented for 5000ms each in a random order separated by a 500ms interstimulus interval. Following this, participants completed the PANAS to record levels of positive and negative affect. Participants then began the first block of 60 visual search trials. Each experimental block contained 20 positive, 20 neutral, and 20 negative trials presented randomly. Stimuli were images from the NAPS with the target (‘T’ or ‘L’) embedded pseudorandomly in the image. In half the trials the target was presented centrally and in the remaining trials the target was presented peripherally. Participants were instructed to locate and identify the target by pressing the corresponding button on the computer keyboard. After each trial an interstimulus interval was presented (4000ms, 5000ms, 6000ms, 7000ms, 8000ms or 9000ms) to permit recording of event-related oxy-Hb. The three experimental blocks were counterbalanced with half the participants completing the positive emotion condition first followed by the neutral emotion condition and negative emotion condition, whilst the remaining participants completed the negative emotion condition first followed by the neutral emotion condition and positive emotion condition. Participants completed three blocks of trials all following the same procedure (viewing of IAPS images, completion of the PANAS, visual search trials).

Functional near-infrared spectroscopy data processing

fNIR data processing was carried out using Homer3 (Boas et al., 2015). In line with manufacturer specifications for the applied sensor band (Ayaz, 2005), channels with a mean raw light intensity of less than 400mV, or greater than 4000mV, were removed from further analysis before raw data was converted into changes in optical density (delta OD). Motion detection and correction was applied using a recursive targeted principal component analysis, following the procedure described in Yücel et al. (2014), before trials that still included motion artefacts within the analyses periods (-2 to 12 seconds) were removed. To remove signals produced by non-neurovascular physiology, a band pass filter (3^{rd} order Butterworth filter) was adopted to remove frequencies below 0.01Hz and above 0.2Hz. This approach was utilised to minimise effects of interference whilst still capturing the frequencies associated with neurovascular activity (Hocke et al., 2018). Filtered delta OD data was then converted into changes in concentration using differential path length factors of 6 for oxy-Hb (Strangman et al., 2003).

For visual search trials, a rapid event-related design and GLM approach was adopted. This approach assesses the data in terms of its similarity to a canonical haemodynamic response function, returning beta values that measure the ‘strength of fit’ of the data to this canonical model. An Ordinary least squares regression, with a canonical function consisting of a modified gamma function convolved with a box wave, was adopted (see Gagnon et al., 2012, 2011). Beta values were then extracted for oxy-Hb, across each participant, condition, and channel.

6.4.4. Results

Overall accuracy was 96.62% and participants took an average of 2.34s to correctly locate a target. Outliers were removed at ±3 standard deviations from the mean resulting in one participant being excluded from the analysis. Eighty-one trials (0.01% of total correct trials) were removed based on RT. Planned comparisons were conducted to compare positive and negative conditions against the neutral condition for both participant emotion and stimuli valence. Where the assumption of sphericity had been violated degrees of freedom were correct using Greenhouse-Geisser estimates of sphericity. Additionally, significant interaction effects were explored using *t*-tests where an adjusted significance threshold of $p = .0125$ was used due to multiple comparisons. Initially, to ensure that emotion was successfully induced, the positive and negative affect scores from the PANAS were analysed.

Affect scores

Analysis of the positive affect scores showed a significant effect of emotion, F (2, 88) = 23.54, MSE = 32.10, $p < .001$, $\eta_p^2 = .35$. Planned comparisons show that viewing positive stimuli significantly increased positive affect scores compared to viewing neutral stimuli (M = 30.11, SD = 9.45 vs. M = 23.22, SD = 9.05), F (1, 44) = 35.45, MSE = 60.24, $p < .001$, $\eta_p^2 = .45$. There were no differences in positive affect after viewing negative stimuli (M = 22.82, SD = 7.37) compared to neutral stimuli, F (1, 44) = .133, MSE = 54.11, $p = .717$, $\eta_p^2 = .00$.

Analysis of negative affect also showed a significant effect of emotion, F (1.463, 64.37) = 38.01, MSE = 32.35, $p < .001$, partial $\eta_p^2 = .46$. Planned comparisons show that viewing negative images significantly increased negative affect scores compared to viewing neutral stimuli (M = 20.11, SD = 8.35 vs. M = 12.38, SD = 3.96), F (1, 44) = 43.62, MSE = 61.70, $p < .001$, $\eta_p^2 = .50$. There was no difference in negative affect between the positive (M = 12.36, SD = 3.42) and neutral conditions, F (1, 44) = .001, MSE = 18.66, $p = .973$, $\eta_p^2 = .00$.

Visual search task

Two 3 (emotion; negative, neutral, and positive) x 3 (stimuli valence; negative, neutral, and positive) x 2 (location; central and peripheral) repeated measures ANOVAs were completed. For accuracy, the effect of location was non-significant suggesting that peripheral targets (M = 96.18%, SD = 2.88) were detected to the same level of accuracy as central targets (M = 97.05%, SD = 2.35), F (1, 45) = 2.97, MSE = 40.59, $p = .09$, $\eta_p^2 = .06$. There was a significant effect of stimuli valence, F (1.72, 77.51) = 9.05, MSE = 38.20, $p = .001$ $\eta_p^2 = .17$; Figure 6.2. Planned contrasts revealed that accuracy to identify targets on neutral images (M = 95.93%, SD = 2.26) was significantly higher than accuracy to identify targets on positive images (M = 94.03%, SD = 3.47), F (1, 45) = 12.12, MSE = 27.46, $p = .001$ $\eta_p^2 = .21$. There was no difference in accuracy between neutral stimuli valence and negative stimuli valence trials (*M* = 95.70%, *SD* = 2.66), *F* (1, 45) = .36, *MSE* = 13.26, *p* = .55, η_p^2 = .01.

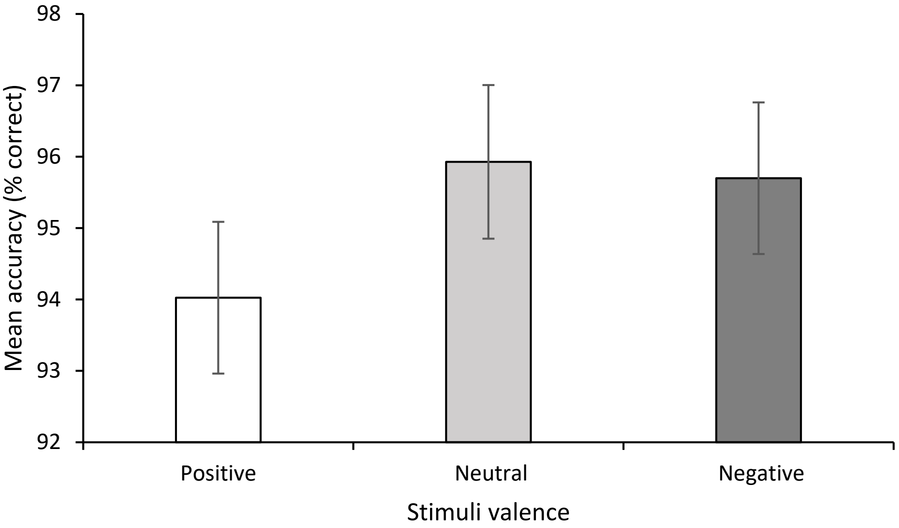

Figure 6.2. Mean accuracy (percentage correct) in the visual search task. Neutral trials were completed more accurately than positive trials. Error bars = standard error.

Analysis showed that participant emotion did not influence the accurate detection of target stimuli (negative: *M* = 92.67, *SD* = 2.79; neutral: *M* = 96.86, *SD* = 2.36; positive: *M* = 96.12, *SD* = 4.13), *F* (1.07, 47.92) = 1.62, *MSE* = 1594.56, *p* = .21, η_p^2 = .04. There were no significant interactions between location, stimuli valence and participant emotion, all *F*'s < 1.49, all *p*'s > .213 and all η_p^2 < .03.

Analysis of accuracy revealed that the interaction between expression suppression, location and stimuli valence approached significance, *F*(2, 88) = 2.898, *MSE* = 21.13, *p* = .06. Planned contrasts showed a non-significant interaction for location and expressive suppression during neutral trials and positive trials, *F*(1, 44) = .751, *MSE* = 13.708, *p* = .39. However, there was a significant interaction for location and expression suppression during neutral trials and negative trials, *F*(1, 44) = 7.189, *MSE* = 91.652, *p* = .01; Figure 6.3 and Figure 6.4. This interaction was driven by a significant decrease in accuracy for individuals high in expressive suppression when identifying peripheral targets (*M* = 92.17, *SD*, 10.58) compared to central targets (*M* = 95.03, *SD* = 9.52) during negative stimuli valence trials, *t*(23) = 3.848, *p* = .001. *d* = .79.

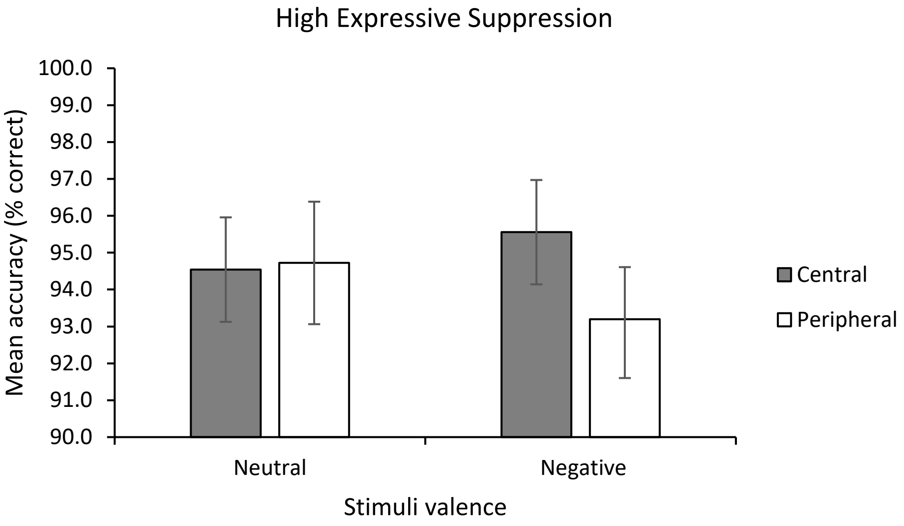

Figure 6.3. Mean accuracy (percentage correct) in the visual search task for individuals with higher levels of expressive suppression. Central trials were completed more accurately than peripheral trials during negative scenes but not neutral scenes. Error bars = standard error.

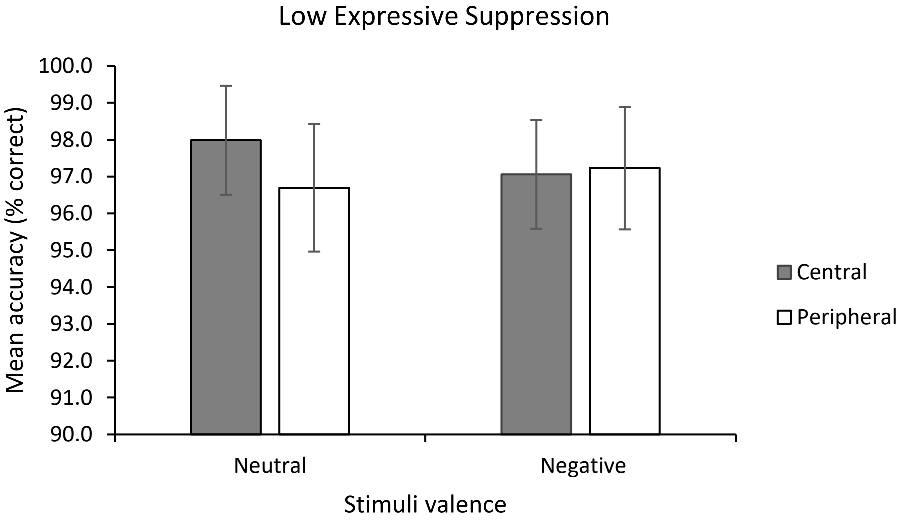

Figure 6.4. Mean accuracy (percentage correct) in the visual search task for individuals with lower levels of expressive suppression. No differences in accuracy were evident between central and peripheral trials during neutral scenes and negative scenes. Error bars = standard error.

Analysis of accuracy also revealed a significant interaction between extraversion, location and emotion, $F(2, 88) = 4.253$, $MSE = 33.971$, $p = .017$. Contrasts showed a non-significant interaction for location and extraversion during neutral emotion and negative emotion conditions, *F*(1, 44) = .638, *MSE* = 26.473, *p* = .853. However, there was a significant interaction for location and extraversion during neutral emotion and positive emotion, *F*(1, 44) = 8.703, *MSE* = 21.053, *p* = .005; Figure 6.5 and Figure 6.6. This interaction was driven by a significant increase in accuracy for individuals lower in extraversion when identifying central targets (*M* = 95.03, *SD* = 9.52) compared to peripheral targets (*M* = 92.17, *SD*, 10.58) during positive emotional states, *t*(26) = 3.548, *p* = .002. *d* = .74.

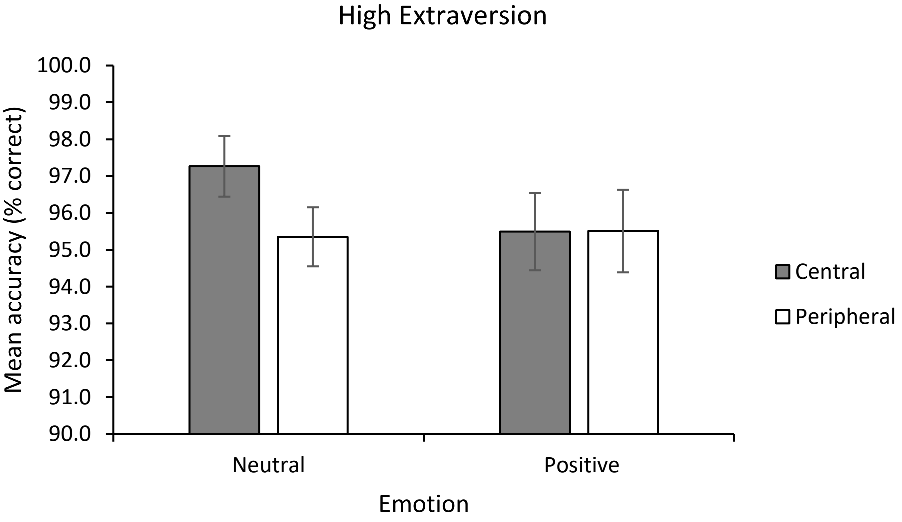

Figure 6.5. Mean accuracy (percentage correct) in the visual search task for individuals with higher levels of extraversion. No differences in accuracy were evident between central and peripheral trials during neutral emotion and positive emotion conditions. Error bars = standard error.

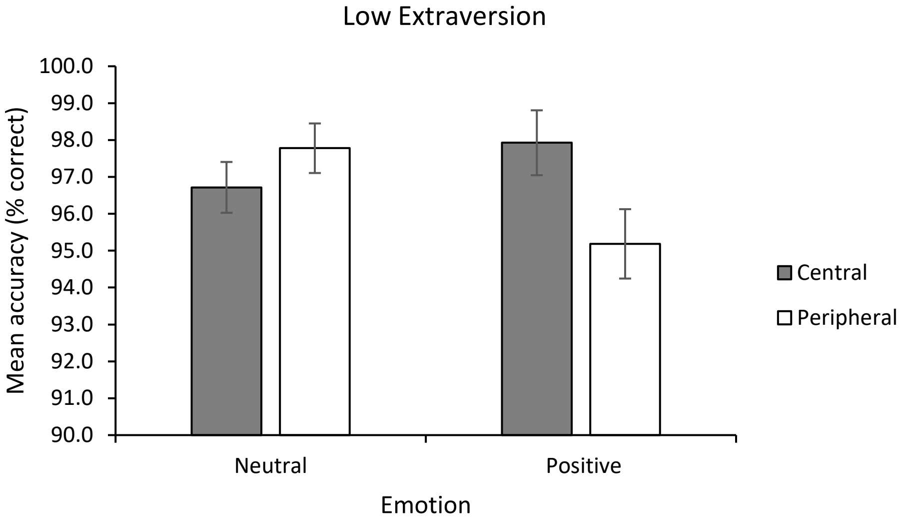

Figure 6.6. Mean accuracy (percentage correct) in the visual search task for individuals with lower levels of extraversion. Central trials were completed more accurately than peripheral trials during the positive emotion condition but not the neutral emotion condition. Error bars = standard error.

There was also a significant interaction between state anxiety, stimuli valence and participant emotion, *F*(4, 176) = 2.793, *MSE* = 37.642, *p* = .028. Contrasts showed a significant interaction for neutral stimuli trials and positive stimuli trials during neutral emotion and negative emotion conditions, *F*(1, 144 = 5.956, *MSE* = 88.331, *p* = .019. This interaction was driven by a significant decrease in accuracy for individuals low in state anxiety during positive stimuli valence trials (*M* = 83.59, *SD*, 28.90) compared to neutral stimuli valence trials (*M* = 87.28, *SD* = 30.48) during positive emotion trials, *t*(22) = 2.406, *p* = .025. *d* = .50. However, after adjusting for multiple comparisons this effect was non-significant. For accuracy there were no further significant individual difference main effects or interactions between individual difference traits and location, stimuli valence and emotion, all *F*'s < 2.336 and all *p*'s > .09.

Analysis of RT to correct trials showed a significant effect of location, *F* (1, 45) = 162.31, *MSE* = 1.05, *p* < .001 η_p^2 = .78. Centrally located targets were identified quicker than peripherally located targets (*M* = 1.89s, *SD* = .40 vs. *M* = 2.80s, *SD* = .63). There was also a significant effect of stimuli valence, *F* (2, 90) = 4.79, *MSE* = .80, *p* = .01, η_p^2 = .10; Figure 6.7. Contrasts showed that neutral stimuli valence trials were completed quicker than negative stimuli valence trials (*M* = 2.21s, *SD* = .50 vs. *M* = 2.41s, *SD* = .59), *F* (1,

45) = 7.82, *MSE* = .51, *p* = .008, η_p^2 = .15. Neutral stimuli valence trials were also completed significantly faster than positive stimuli valence trials (*M* = 2.41s, *SD* = .57), *F* (1, 45) = 6.21, *p* = .016, η_p^2 = .12. The effect of emotion on RT was non-significant (negative: *M* = 2.30s, *SD* = .67; neutral: *M* = 2.34s, *SD* = .67; positive: *M* = 2.39s, *SD* = .47), *F* (1.69, 76.12) = .29, *MSE* = 1.94, *p* = .716, η_p^2 = .01.

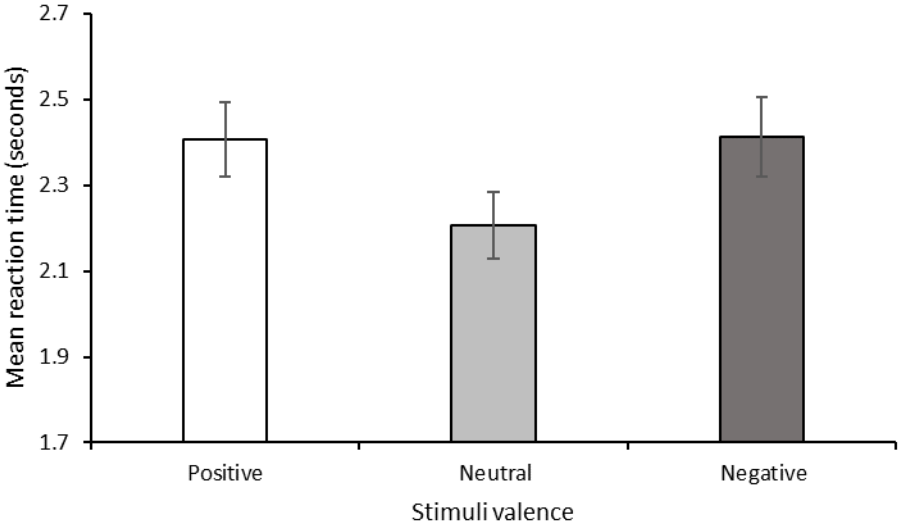

Figure 6.7. Mean reaction time (seconds) in the visual search task. Targets were identified quicker when presented within neutral scenes compared to when presented within positive or negative scenes. Error bars = standard error.

The interaction between location and stimuli valence was significant, *F* (2, 90) = 3.53, *MSE* = .82, *p* = .033, η_p^2 = .08. There was no interaction between location and stimuli valence when comparing target RTs in neutral and negative images, *F* (1, 45) = 2.31, *MSE* = .56, *p* = .136, η_p^2 = .05, but there was a significant interaction when comparing neutral and positive images, *F* (1, 45) = 6.86, *MSE* = .56, *p* = .012, η_p^2 = .13; Figure 6.8. RT was quicker for neutral stimuli valence trials when the target was centrally located compared to when presented in the periphery (*M* = 1.64s, *SD* = .46 vs. *M* = 2.79s, *SD* = .80), *t*(20.55) = -4.050, *p* = .001, *d* = 1.49. In contrast, there was no difference in RT to locate peripheral targets for neutral stimuli valence and positive stimuli valence trials, *t*(20.55) = -4.050, *p* = .001, *d* = 1.49.

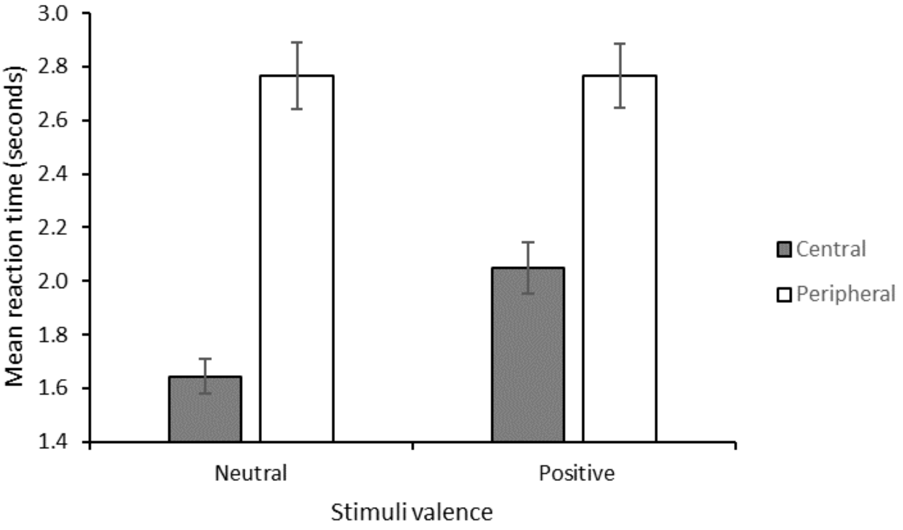

Figure 6.8. Mean reaction time (seconds) in the visual search task. Central targets were identified quicker when presented within neutral scenes compared to positive scenes. There was no difference in reaction time to identify peripheral targets between neutral scenes and positive scenes. Error bars = standard error.

The interaction between emotion and location was significant, *F* (2, 90) = 6.43, *MSE* = .58, *p* = .002, η_p^2 = .13; Figure 6.9. The planned contrasts showed no interaction for neutral and positive emotion, *F* (1, 45) = 2.58, *MSE* = .38, *p* = .116, η_p^2 = .05. However, RT was different for neutral and negative emotion conditions, *F* (1, 45) = 11.31, *MSE* = .43, *p* = .002, η_p^2 = .20. RT to detect central targets was quicker when participants were induced into a neutral emotion condition compared to a negative emotion condition, (*M* = 1.77s, *SD* = .51 vs. *M* = 2.18, *SD* = 1.01), *t*(44) = -3.001, *p* = .004, *d* = .52. In contrast, for the neutral emotion condition and negative emotion condition there were no differences in RT to identify peripheral targets (*M* = 2.92, *SD* = .97 vs. *M* = 2.76, *SD* = .70), *t*(43) = -1.063, *p* = .294, *d* = .14.

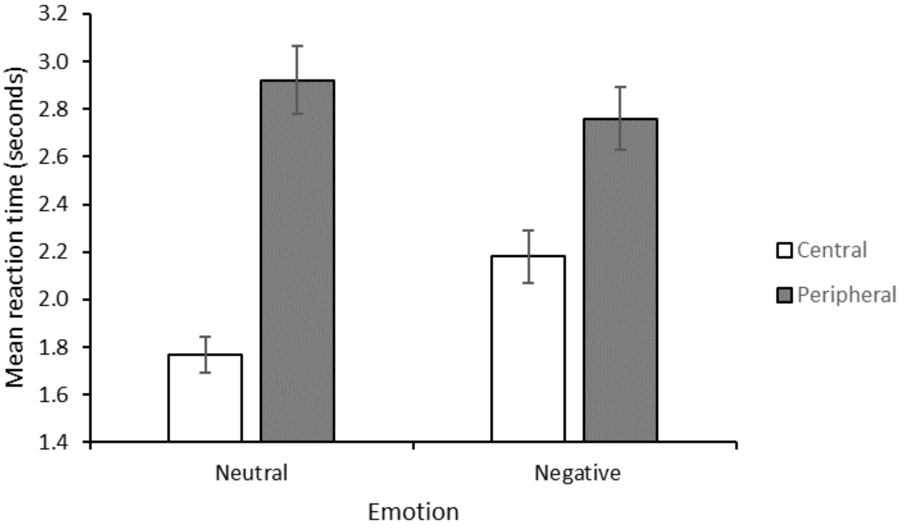

Figure 6.9. Mean reaction time (seconds) in the visual search task. Central targets were identified quicker when in neutral emotion compared to negative emotion. There was no difference in reaction time to identify peripheral targets between neutral emotion and negative emotion conditions. Error bars = standard error.

The interaction between emotion and stimuli valence was significant, F (2.73, 122.80) = 8.97, MSE = .98, p < .001, η_p^2 = .17. The planned contrasts showed no interaction during neutral emotion and negative emotion conditions for neutral stimuli valence trials and negative stimuli valence trials, F (1, 45) = 1.46, MSE = 1.48, p = .234, η_p^2 = .03. However, planned comparisons showed that RT under neutral emotion and positive emotion conditions was different for neutral stimuli valence trials and negative stimuli valence trials, F (1, 45) = 10.17, MSE = 1.70, p = .003, η_p^2 = .18. The difference in RT for neutral stimuli valence trials for neutral emotion and positive emotion conditions was significant, (M = 2.41, SD = .85 vs. M = 2.16, SD = .60), t(45) = 2.420, p = .020, d = .34. However, when correcting for multiple comparisons this effect does not reach statistical significance. There was no difference in RT for negative stimuli valence trials under positive emotion and neutral emotion conditions (M = 2.62, SD = .85 vs. M = 2.44, SD = .87), t(46) = -1.288, p = .204, d = .20.

Planned comparisons also showed an interaction during neutral emotion and positive emotion conditions for neutral stimuli valence trials and positive stimuli valence trials, F (1, 45) = 11.45, MSE = 1.69, p = .001, η_p^2 = .20. The difference in reaction time for neutral stimuli valence trials for neutral emotion and positive emotion conditions was significant, ($M = 2.41$, $SD = .85$ vs. $M = 2.16$, $SD = .60$), $t(45) = 2.420$, $p = .020$, $d = .34$. However, once corrected for multiple comparisons this effect was non-significant. RT for positive stimuli valence trials did not differ for neutral emotion and positive emotion, ($M = 2.17$, $SD = .61$ vs. $M = 2.39$, $SD = .72$), $t(45) = 1.926$, $p = .06$, $d = .31$. Additional planned comparisons showed an interaction between neutral emotion and negative emotion for neutral stimuli valence trials and positive stimuli valence trials, $F(1, 45) = 23.40$, $MSE = 2.89$, $p < .001$, $\eta_p^2 = .34$; Figure 6.10. Comparisons showed that RT during neutral stimuli valence trials was similar for negative emotion compared to neutral emotion ($M = 2.41$, $SD = .87$ vs. $M = 2.14$, $SD = .54$), $t(43) = 1.873$, $p = .068$, $d = .38$. In contrast, RT for positive stimuli valence trials was longer for the negative emotion condition compared to the neutral emotion condition, ($M = 2.78$, $SD = 1.08$ vs. $M = 2.15$, $SD = .62$), $t(43) = -4.028$, $p < .001$, $d = .72$. There was no significant effect of emotion or an interaction between location, stimuli valence and emotion, all F's < 5.37, all p's $> .709$ and all $\eta_p^2 < .01$.

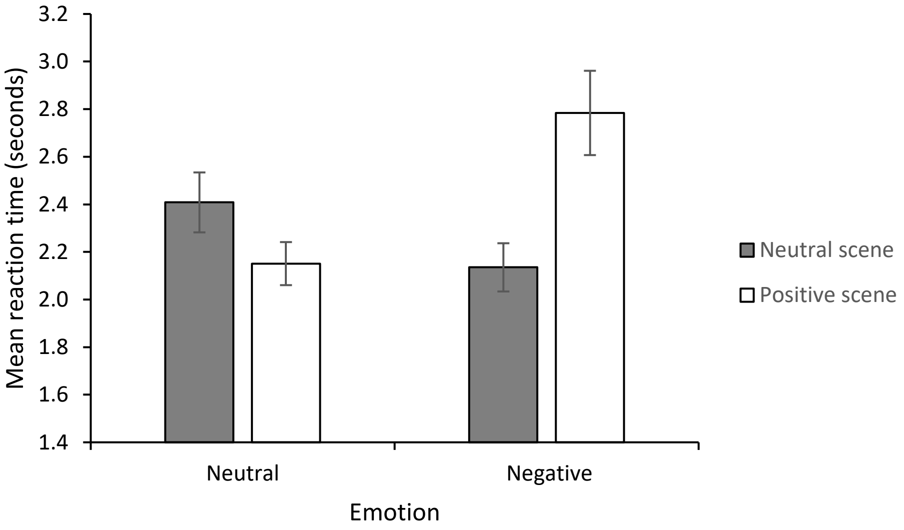

Figure 6.10. Mean reaction time (seconds) in the visual search task. Targets embedded within positive scenes were identified quicker when induced into a neutral emotion compared to a negative emotion. There was no difference to detect targets embedded within neutral scenes when induced into neutral emotion or negative emotion. Error bars = standard error.

The effect of expressive suppression on RT to correctly identify a target was significant, *F* (1, 44) = 4.406, *MSE* = .469, *p* = .042, η_p^2 = .09; Figure 6.11. Individuals with lower levels of expressive suppression took longer to identify the target compared to individuals with higher levels of expressive suppression (*M* = 2.50s vs. *M* = 2.20s).

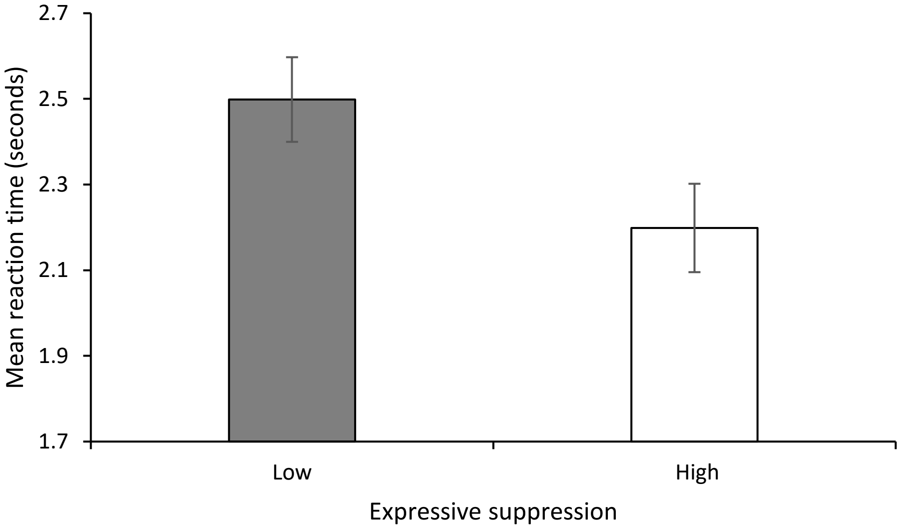

Figure 6.11. Mean reaction time (seconds) in the visual search task. Individuals with higher levels of habitual use of expressive suppression were quicker to identify search targets. Error bars = standard error.

Analysis of RT also revealed a significant interaction between cognitive reappraisal and emotion, *F*(2, 88) = 3.503, *MSE* = 1.130, *p* = .034, η_p^2 = .07; Figure 6.12. Planned contrasts showed that the interaction for neutral emotion and positive emotion was non-significant, *F*(1, 44) = 2.231, *MSE* = .507, *p* = .142, η_p^2 = .05. However, contrasts showed a significant interaction for neutral emotion and negative emotion, *F*(1, 44) = 6.607, *MSE* = .797, *p* = .014, η_p^2 = .13. This interaction was driven by a significant reduction in RT for individuals high in cognitive reappraisal during the neutral emotion condition (*M* = 2.24, *SD* = .52) compared to the negative emotion condition (*M* = 2.47, *SD* = .53), *t*(24) = -2.308 *p* = .030. *d* = .46. However, after adjusting for multiple comparisons this effect was non-significant.

The effect of state anxiety on RT approached significance, *F*(1, 44) = 3.825, *MSE* = .474, *p* = .057, η_p^2 = .08. There is tentative evidence to suggest that individuals with higher levels of state anxiety were slower to identify the target compared to individuals with lower levels of state anxiety (*M* = 2.20s vs. *M* = 2.48s).

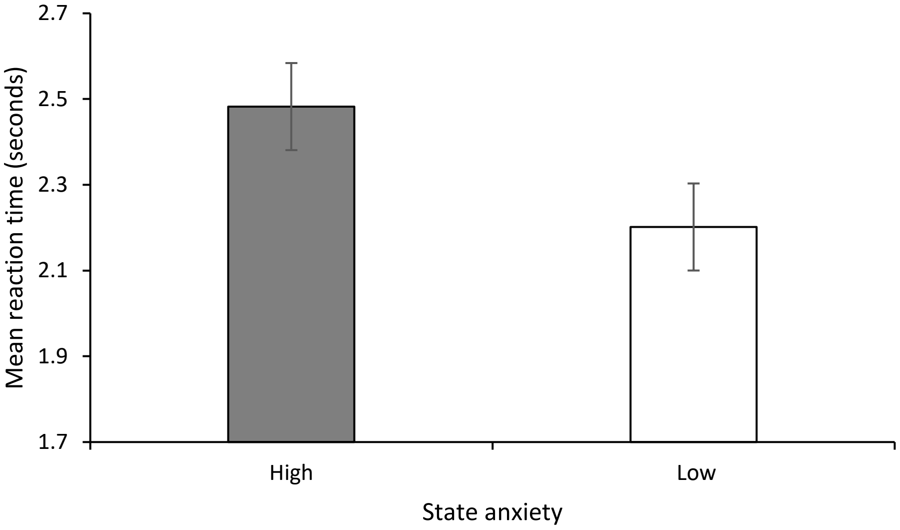

Figure 6.12. Mean reaction time (seconds) in the visual search task. Individuals with higher levels of state anxiety were quicker to identify search targets. Error bars = standard error.

Additionally, the interaction between state anxiety and location was significant, *F*(1, 44) = 4.881, *MSE* = .970, *p* = .032, η_p^2 = .10; Figure 6.13. This interaction was driven by a greater difference in RT for central targets compared to peripheral targets for participants with higher levels of state anxiety (*M* = 1.95, *SD* = .47 vs. *M* = 3.00s, *SD* = .74), *t*(23) = -9.833, *p* < .001, *d* = 1.68, compared to individuals with low state anxiety *(M* = 1.93, *SD* = .63 vs. *M* = 2.74s, *SD* = .95), *t*(22) = -8.297, *p* < .001, *d* = 1.01[19].

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[19] Although the *p* values for the two statistical analyses are both *p* < .001, differences are evident when directly comparing the corresponding effect sizes (*d* = 1.68 vs *d* = 1.01).

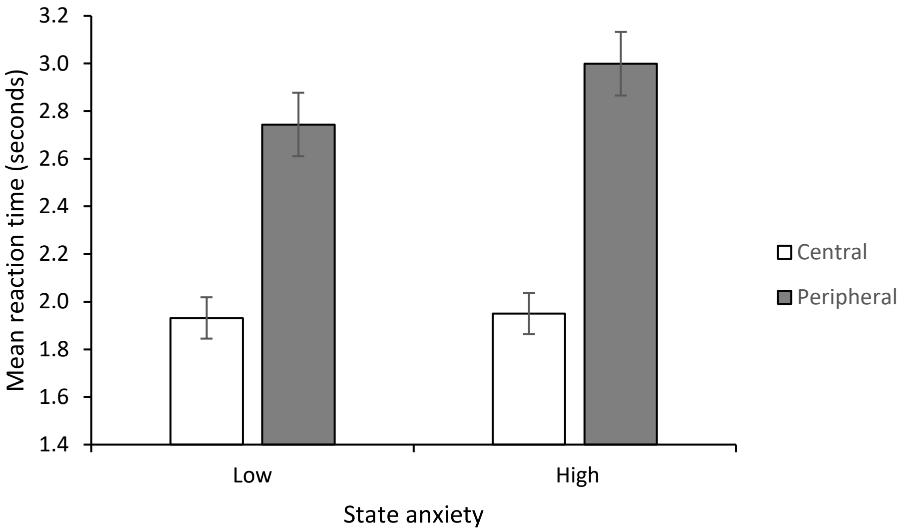

Figure 6.13. Mean reaction time (seconds) in the visual search task. Central targets were identified quicker than when presented in the periphery and this difference was increased for individuals higher in levels of state anxiety compared to individuals with lower levels of state anxiety. Error bars = standard error.

Oxygenated hemoglobin

For the dlPFC, the effect of emotion approached significance, *F* (1.705, 69,899) = 3.218, *MSE* = 3.884E-12, *p* = .054, η_p^2 = .07; Figure 6.14. Planned contrasts demonstrated that dlPFC oxy-Hb was increased for participants induced into negative emotion (*M* = -1.328E-7) compared to neutral emotion (*M* = -4.710E-7), *F* (1, 41) = 5.487, *MSE* = 1.698E-12, *p* = .024, η_p^2 = .12. The planned contrast for neutral emotion and positive emotion (*M* = 2.483E-8) approached significance, *F* (1, 41) = 3.869, *MSE* = 3.124E-12, *p* = .056, η_p^2 = .09. The effect of stimuli valence was non-significant, *F* (2, 82) = .833, *MSE* = 3.646E-12, *p* = .439, η_p^2 = .02. The interaction effect was also non-significant, *F* (4, 164) = .696, *MSE* = 3.406E-12, *p* = .596, η_p^2 = .00.

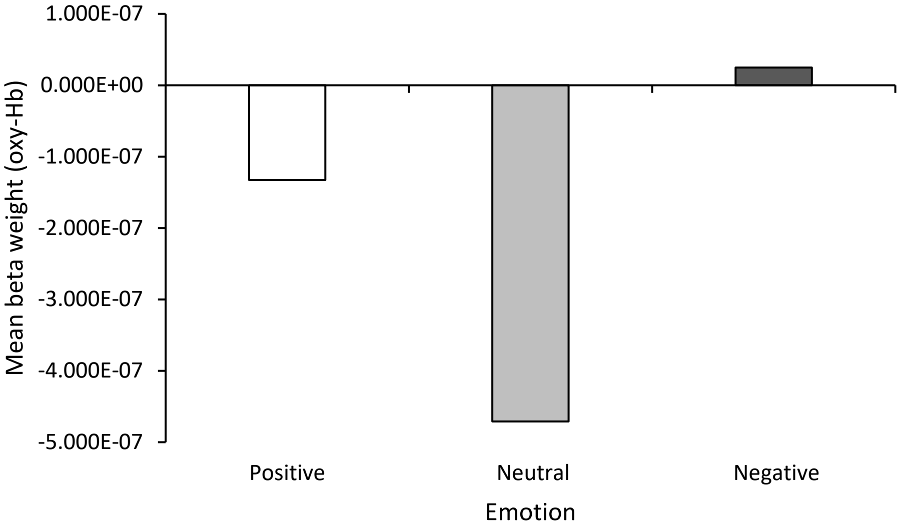

Figure 6.14. Mean beta weight (oxy-Hb) in the dlPFC. Activation was higher during the negative emotion condition compared to the neutral emotion condition.

For the vlPFC, the effect of emotion approached significance, *F* (1.418, 60.956) = 3.406, *MSE* = 3.451E-12, *p* = .055, η_p^2 = .07; Figure 6.15. Planned contrasts suggested that vlPFC oxy-Hb was increased for participants induced into negative emotion (*M* = 1.282E-7) compared to neutral emotion (*M* = -5.491E-7), *F* (1, 43) = 4.199, *MSE* = 3.469E-12, *p* = .047, η_p^2 = .09. However, there were no differences in vlPFC oxy-Hb between neutral emotion and positive emotion (*M* = -2.691E-8), *F* (1, 43) = 3.702, *MSE* = 2.496E-12, *p* = .061, η_p^2 = .08. The effect of stimuli valence was also non-significant, *F* (1.491, 64.127) = 2.903, *MSE* = 1.576E-11, *p* = .077, η_p^2 = .06. The interaction between emotion and stimuli valence was non-significant, *F* (1.897, 81.558) = 1.940, *MSE* = 1.708E-11, *p* = .152, η_p^2 = .04. For the dmPFC and vmPFC the results were non-significant, all *F* values < 2.702, all *p* values > .080, all η_p^2 < .01.

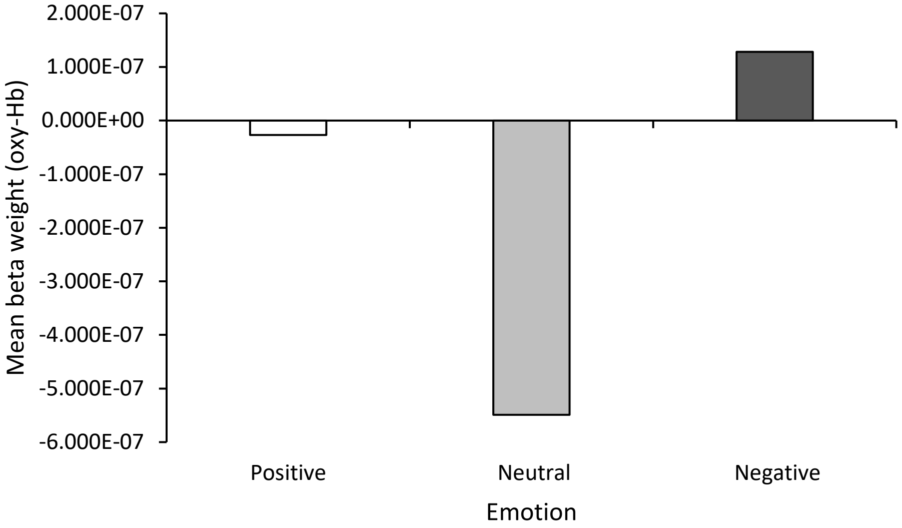

Figure 6.15. Mean beta weight (oxy-Hb) in the dlPFC. Activation was higher during the negative emotion condition compared to the neutral emotion condition.

6.4.5. Discussion

The current experiment was designed to investigate the neurocognitive mechanisms supporting emotional attention in real-world scenes. Specifically, the study permitted the investigation of whether emotion and affective traits can interact with the emotional valence of stimuli to impact visual attention. Further, fNIRS was utilised to allow the impact of affective influences on PFC activity to be assessed. Initially, self-report measures of extraversion, cognitive reappraisal, expressive suppression, and state anxiety were recorded. Next, participants were induced into positive, neutral, and negative emotional states before completing a visual search task. During the task participants were required to identify a target that was embedded within real-world scenes of positive, neutral, and negative emotional valence.

Replicating previous findings, the emotional valence of real-world scenes was shown to influence visual search (Bendall, Eachus, et al., 2020; Bendall et al., 2019). Accuracy to identify targets was reduced when the scene was positive compared to neutral. Within the affective science literature, the influences of positive emotional stimuli on visual attention has been relatively neglected compared to the impact of negative emotional stimuli (Bendall et al., 2016; Carretié, 2014). A recent study investigating the effect of emotional information on gist identification did include a positive valence condition. Participants were initially presented with four real-world scenes of varying emotional valence. Following this, one of the initial four real-world scenes was presented and participants were required to report the gist of this scene. The study demonstrated that when the cued scene was positive gist identification was improved compared to when the cued scene was negative. Additionally, the presentation of positive real-world scenes within the four scene display resulted in a decrease in gist identification for subsequent neutral scenes (Porubanova et al., 2020). This suggests that positive scenes are prioritised in visual processing and is supported by the findings of the current study demonstrating that positive scenes capture attention (compared to neutral scenes) preventing full attention to the target. These studies highlight the importance of including positive emotional conditions within affective science studies. The omission of either positive or negative valence conditions may lead to inaccurate interpretations. For example, without the inclusion of a positive emotional valence condition, a lack of any effects as a result of negative emotional valence may lead researchers to conclude that emotional valence has no impact on attention. Alternatively, without the inclusion of either a positive or negative condition authors may interpret an effect of either negative or positive stimuli as a valence specific effect whereas this could represent a more general impact of emotional valence.

Stimuli valence was also shown to impact RT during visual search replicating prior work (Bendall, Eachus, et al., 2021; Bendall et al., 2019). Targets were identified quicker when embedded within neutral scenes compared to when embedded within either positive or negative scenes. This demonstrates that when the emotional valence of a real-world scene is not related to ongoing task demands it is still able to capture attention and impact visual search performance compared to neutral scenes. Moreover, for RT there was also an interaction between the emotional valence of real-world scenes and the location of visual search targets. When targets were presented in the periphery of the scene there were no differences in RT for neutral scenes and positive scenes. However, when targets were presented centrally, targets were identified quicker when embedded within neutral scenes compared to positive scenes. This novel finding suggests that the emotional valence of real-world scenes may influence the visuospatial allocation of attention. For instance, the interaction for target location and positive-neutral scenes suggests that when we are in a positive environment our ability to identify a neutrally valenced target is reduced and that this detrimental impact is more pronounced when we need to locate and identify a target that is presented in the centre of our visual environment compared to the periphery. Whilst a negatively valenced environment also impacts our attention (evidenced with longer RTs to identify targets) this influence is the same regardless of the location of the target. These initial findings provide the basis for further work to develop our understanding of the mechanisms underpinning the observed influences of emotional real-world scenes on visual attention. For instance, the use of experimental tasks such as the dot probe task, as well as the recording of eye-movements, may help to elucidate whether the effects are driven by attentional biases towards emotional real-world scenes or difficulties in disengagement from these stimuli. Additionally, the use of eye-tracking during behavioural tasks allows temporal changes in the allocation of overt attention to be investigated.

When considered independently, the emotional state of participants had no impact on visual attention. Further, there was no evidence for a broadening of visual attention as a result of positive emotion, or a narrowing of attention due to negative emotion, in contrast to the predictions made by the broaden-and-build theory (Fredrickson, 2001). Support for the broadening effect of positive emotion and the narrowing effect of negative emotion is mixed (Bendall et al., 2020; Bendall & Thompson, 2015a; Bruyneel et al., 2013; Grol & Raedt, 2014; Rowe et al., 2007; Wadlinger & Isaacowitz, 2006). The current findings are in agreement with previous research adopting different tasks measuring visual attention such as a change detection flicker task (Bendall et al., 2020; Bendall & Thompson, 2015a) and flanker task (Bruyneel et al., 2013). Instead, it has been argued that emotion may impact processing style rather than a broadening of visuospatial attention (Bendall & Thompson, 2015; Taylor et al., 2017; Vanlessen et al., 2016).

However, emotion did interact with target location for neutral and negative emotion conditions. Central targets were identified quicker when participants were induced into a neutral emotion condition compared to a negative emotion condition, whereas there was no difference in RT to identify peripherally located targets for neutral and negative emotional conditions. This result suggests that in some instances negative emotion does impact selective visual attention whereby negative emotion has a detrimental effect on the RT to identify centrally presented targets. One interpretation is that individuals induced into negative emotional states have fewer resources available to devote to the current task as they are simultaneously regulating the negative emotional state and therefore perform worse when induced into a negative emotional state. However, this impact on visual attention may be specific to our allocation of attentional resources towards central regions of our visual environment. This suggestion is supported by the finding showing increased activation in the dlPFC and vlPFC, brain regions associated with ER (Buhle et al., 2014; Kim et al., 2019; Ochsner et al., 2012), during the negative emotion condition compared to when participants were induced into a neutral emotion condition. The dlPFC and vlPFC are known to have direct and indirect connections with limbic region structures including the amygdala (Ray & Zald, 2012) and the current findings suggest that these regions show increased activation during negative, but not positive or neutral emotional states during a visual search task, suggesting an emotional valence specific effect. Future work adopting neuromodulation techniques may be able to provide causal inferences building upon the correlational findings demonstrated in the current study.

There is a scarcity of research that has investigated if participant emotion and stimuli valence interact to guide the allocation of attention. However, one study that did include measures of emotional state and stimuli valence demonstrated that positive emotion broadened attention, but only when the stimuli were also positive, suggesting that the effect of emotion was mood-congruent (Wadlinger & Isaacowitz, 2006). In the current experiment participant emotion was also shown to interact with the emotional valence of the scenes used in the visual search task. There was no difference in the RT to detect targets within neutral valence scenes when participants were induced into either a neutral or negative emotional state. However, participants look longer to identify targets embedded within positive emotional valence scenes when they were induced into a negative emotional state compared to a neutral emotional state. The main effect of stimuli valence on RT reported above, showing a slowing of RT for positive stimuli valence trials compared to neutral stimuli valence trials, appears to be more pronounced for individuals induced into a negative emotional state compared to a neutral emotional state. It is possible that when considered in isolation the emotional state of an individual does not impact visual attention using the current experimental task (although negative emotion does interact with target location to guide the allocation of attention). However, when the emotional valence of stimuli is also measured, individuals induced into a negative emotional state appear to be more impacted by the positively valenced scenes compared to when they are in a neutral emotional state, suggesting that the interaction between emotion and stimuli valence is not always emotion-congruent as previously reported (Wadlinger & Isaacowitz, 2006).

A further aim of the current study was to investigate if the affective traits extraversion, cognitive reappraisal, expressive suppression, and anxiety can interact with a participant's emotional state or the emotional valence of scenes to impact selective visual attention. There was no main effect of extraversion on visual search performance. However, for accuracy, a three-way interaction between extraversion, target location and participant emotion was evident. Individuals with lower levels of extraversion identified central targets more accurately than peripheral targets when induced into a positive emotional state, whereas there were no differences when these individuals were induced into a neutral emotional state, or for individuals with higher levels of extraversion. A previous study has demonstrated that individuals with higher levels of extraversion perform better in a change detection task (Hahn et al., 2015), whilst extraversion has also been shown to interact with participant emotion to impact visual search performance (Bendall et al., 2020). The current findings suggest that under certain situations individuals with lower levels of extraversion perform better during a simple visual search task than individuals with higher levels of extraversion.

The main effect of state anxiety on RT to identify visual search targets approached significance (*p* = .057). The current findings tentatively suggest that individuals with higher levels of state anxiety may take longer to identify targets compared to individuals with lower levels of state anxiety. However, this finding requires further investigation to test whether state anxiety does influence visual search performance during emotional real-world scenes. The interaction between state anxiety and target location was significant. Although individuals with lower levels of state anxiety *and* higher levels of state anxiety took longer to identify peripherally located targets, this difference was greater for individuals with higher levels of state anxiety. This observation suggests that participants with higher levels of state anxiety take longer to identify peripheral targets than individuals with lower levels of state anxiety. Attentional control theory (Eysenck et al., 2007) predicts that anxious individuals suffer from deficits in top-down cognitive control during tasks involving inhibition and simultaneous increases in the influence of bottom-up attentional processing. Participants in the current study were required to inhibit the content presented within the scenes and to identify a search target. Therefore, the finding that anxious individuals perform worse in the current visual search task support the predictions made by attentional control theory. Additionally, the findings suggest that anxious individuals may find it more difficult to allocate attention to peripheral regions compared to less anxious individuals. However, attentional control theory also proposes that deficits in cognitive control and inhibition would be amplified in situations where stimuli are emotional (reflecting difficulties in affective cognitive flexibility). In the current study anxiety did not interact with stimuli valence to influence selective visual attention. Therefore, this result fails to provide support for an emotional valence specific effect predicted by attentional control theory. Taken together, the effects of state anxiety provide some support for the predictions made by attentional control theory and provide novel observations suggesting that state anxiety can impact the detection of neutral targets embedded within real-world scenes regardless of the valence of the stimuli.

For expressive suppression, analysis of accuracy to identify a target revealed a significant interaction between the emotional valence of scenes and target location. Individuals with higher levels of expressive suppression identified central targets more accurately than peripheral targets when the scene was negative compared to when the scene was neutral. No such differences were evident for individuals lower in levels of expressive suppression. Moreover, individuals with higher levels of expressive suppression were quicker to identify search targets regardless of the emotional content of the scene replicating previous findings (Bendall, Eachus, et al., 2021). Whilst expressive suppression is associated with long-term costs including increased negative affect and the development of psychopathologies (e.g. Aldao et al., 2010; Gross & John, 2003; Latif et al., 2019), expressive suppression is likely to provide immediate benefits in regulating emotion. It has recently been shown that individuals who more frequently adopt expressive suppression as an ER strategy are better able to regulate their attention and emotional experience during a focussed attention task, suggestive of an association between expressive suppression and attentional control (Dolcos, Bogdan, et al., 2020). The results from the current experiment showing that individuals who more frequently adopt expressive suppression demonstrate enhanced visual search performance support these initial findings. This raises the possibility that concurrently training individuals in the use of expressive suppression alongside attentional training interventions may improve emotional wellbeing in individuals with either a diagnosed affective disorder or those who are identified as at risk of their occurrence.

Cognitive reappraisal did not influence visual search performance in the current study failing to replicate earlier findings (Bendall, Eachus, et al., 2021). There was some evidence to suggest that participant emotion interacts with cognitive reappraisal, although this result was non-significant after controlling for multiple comparisons (*p* = .030). Although expressive suppression is often described as a maladaptive ER strategy, whilst cognitive reappraisal is thought to be an adpative strategy, it is possible that improved performance in the current task is benefitted by expressive suppression and not cognitive reappraisal. Participants were required to ignore or suppress the emotional content in the real-world scenes to locate and identify a search target. Those individuals who more frequently adopt expressive suppression are likely to be more skilled at using such strategies and therefore are quicker at identifying search targets. Whilst cognitive reappraisal is a successful ER strategy for longer-term wellbeing, the use of such strategies may not be advantageous in the current task. These findings suggest that ER strategies often deemed maladaptive may provide benefit during some tasks but not others. Moreover, it has recently been suggested that research focussing on ER should investigate the interaction of situational and dispositional factors in assessing the effectiveness of different ER strategies (Kobylińska & Kusev, 2019). Such studies regarding the influences of ER strategy use on selective visual attention are warranted.

In conclusion, the current study demonstrates that emotional real-world scenes impact selective visual attention to impair performance during a visual search task replicating previous findings. Importantly, the current study was designed to investigate whether participant emotion and affective traits interact with stimuli valence to guide the allocation of attention during visual search. When considered in isolation, the emotional state of participants had no impact on visual search. However, the emotional state of participants did interact with stimuli valence, extraversion, and target location suggesting that under some circumstances negative emotion impairs visual search performance. Increased neural activation of the dlPFC and vlPFC during the visual search task was evident when participants were induced into a negative emotional state (compared to a neutral or positive emotional state) suggesting that these brain regions are involved in negative emotion-attention interactions. Further, novel findings show that affective traits interact with target location, stimuli valence and participant emotion suggesting that these are important considerations in future research instigating affective influences on visual attention. These initial findings warrant further investigation to disentangle whether the effects shown in the current study can be explained by either an attentional bias towards emotional stimuli or trouble disengaging from such stimuli.

6.5. Chapter discussion

Experiment Five was conducted in an attempt to replicate the findings from Experiment Four showing that cognitive reappraisal and expressive suppression, but not extraversion, influence visual search in real-world scenes. A measure of state anxiety was also included to assess whether inter-individual differences in state anxiety influence selective visual attention in emotional real-world scenes. Additionally, Experiment Five was designed to allow the investigation of whether the emotional state of an individual influences selective visual attention in a simple visual search task. Previously, Experiment One and Experiment Two investigated the effect of emotion on change detection, and so it was important to investigate if emotion influences visual search in a less demanding task. Whilst experiment One and Experiment Two investigated the effect of emotion on attention, Experiment Three and Experiment Four tested the effect of stimuli valence on attention. Consequently, Experiment Five was completed to investigate the interactive influences of emotion and stimuli valence on attention. The experiment also permitted the investigation of whether the emotional valence of real-world scenes and affective traits interact to impact visual search. Finally, neural activation was recorded from the PFC with fNIRS to assess the recruitment of brain regions associated with emotional processing and attention based on participant emotion and stimuli valence during a visual search task.

Participants completed self-report questionnaires providing levels of extraversion and state anxiety as well as habitual use of two ER strategies: cognitive reappraisal and expressive suppression. Participants were then induced into either a positive emotional state or a negative emotional state (counterbalanced across participants) before completing the PANAS to assess their current affective state and the success of the emotion induction procedure. Participants then completed a block of visual search trials. Neutrally valenced targets comprising the letter ‘T’ or ‘L’ were embedded within real-world scenes of varying emotional valence (positive, neutral, or negative) and were presented randomly. Once the first block had been completed participants were induced into a neutral emotional state, provided self-report levels of affect and completed another block of visual search trials. Finally, participants completed the third and final emotion induction (positive or negative depending on the first emotion induction) followed by the completion of PANAS and the last block of visual search trials.

Replicating the findings from Experiment Three and Experiment Four, accuracy to identify targets was reduced for positive scenes compare to neutral scenes. Due to the reported replication crisis in psychological science (Aarts et al., 2015; Maxwell et al., 2015) it is increasingly important to replicate research studies giving confidence that the original findings were not due to random/systematic error or false positives. Across three experiments accuracy to identify search targets was reduced when the scene was positive, whilst no differences in accuracy to identify a target was evident when the scene was negative. Therefore, these reproducible findings provide strong support for the argument that stimuli consisting of positively valenced real-world scenes have a detrimental impact on visual search when the valence of the scene is task-irrelevant. The current experiment also demonstrated that the emotional valence of real-world scenes impacts the time take taken to correctly identify a visual search target. RT to identify search targets was slower for both positive and negative scenes compared to neutral scenes replicating Experiment Four. However, Experiment Three provided evidence to suggest that only negative scenes had an impact on RT to identify targets. Moreover, the effect of negative scenes on RT appears to be greater than that of positive scenes as indicated by the corresponding *p* values and effect sizes from Experiment Four ($p < .001$, $\eta p^2 = .48$ vs $p = .053$, $\eta p^2 = .08$) and Experiment Five ($p = .008$, $\eta_p{}^2 = .15$ vs $p = .016$, $\eta_p{}^2 = .12$). Therefore, the results suggest that negative real-world scenes slow the identification of targets when the valence of the scene is task-irrelevant. Furthermore, there is evidence to suggest that positive real-world scenes slow the identification of targets, although this effect is weaker and less robust than the observed effect of negative scenes. Considering both the accuracy and RT results, these findings provide evidence to suggest that negative and positive real-world scenes may impair visual search in different ways even when the valence of the scene is task-irrelevant. For negative scenes (and perhaps also positive scenes), participants took longer to locate the search targets, suggestive of impaired localisation of the target, but when they did find the target, they could identify the target with a high level of accuracy. This provides some support that negative emotional scenes cue a local processing style. In contrast, for positive real-world scenes, accuracy to identify the target was reduced, suggesting that participants were allocating attention at a global level (they could locate the target, but had difficulty in identifying the target) suggestive of an impact on identification of the search target.

Moreover, there was also a significant interaction between stimuli valence and target location. This was driven by slower RTs to identify central targets when the scene was positive compared to when the scene was neutral, whereas there was no difference in RT to identify targets presented in the periphery when the scenes were neutral or positive. This suggests that the effect of positive scenes on RT described above may be driven by a slowing of RT to identify centrally located targets. These findings suggest that positive scenes may impact the spatial allocation of attention. However, this finding was not observed in Experiment Three and so further investigation of possible interactions between stimuli valence and the spatial allocation of attention are warranted. The differing influences of positive and negative scenes suggests that their influences may be valence specific and highlights the importance of including both conditions within studies. For example, it has recently been demonstrated that positive and negative images have contrasting influences on memory-based guidance of visual search (Zinchenko et al., 2020).

Experiment One and Experiment Two found no effect of emotion on selective visual attention when considered in isolation. However, these experiments adopted a change detection flicker task which is a demanding task. Therefore, the possibility remained that any influence of positive or negative emotion was masked by the high task demand. For instance, task difficulty has been shown to modulate the impact of emotional stimuli on neural activation in brain regions associated with emotional processing and cognitive control (Jasinska et al., 2012). Moreover, using EEG, the early posterior negativity response for pleasant and unpleasant stimuli (compared to neutral stimuli) has been shown when task demand is low but not when task demand is high (Schupp et al., 2007). Further, these initial experiments purposefully adopted stimuli of neutral real-world scenes and so it remained a possibility that emotion impacts visual attention in a congruent manner as has been previously demonstrated (Wadlinger & Isaacowitz, 2006). The current experiment adopted a simple visual search task incorporating real-world scenes of varying emotional valence and suggested that when considered in isolation participant emotion has no impact on selective visual attention. This result builds upon the findings from Experiment One and Experiment Two and fail to provide any evidence in support of the broaden-and-build theory.

There was also an interaction between participant emotion and stimuli valence. Individuals induced into a negative emotional state took longer to identify targets embedded in positive scenes compared to when they were induced into a neutral emotional state. Further interactions between the emotional state of participants and stimuli valence were evident from the planned comparisons, although these were not significant after controlling for multiple comparisons (*p* = .020). Previously, two studies investigating selective visual attention have demonstrated interactions between emotional state and stimuli valence (Grol & Raedt, 2014; Wadlinger & Isaacowitz, 2006). The findings from the current study suggest that in some instances when the emotional state of the participant is incongruent to the emotional valence of the scene containing the search target RT is slowed (negative emotional state and positive emotional scenes). These initial findings provide further support to the argument that the emotional state of an individual may influence visual search in specific situations. Experiment Five was the only experiment to simultaneously investigate the effects of participant emotion and stimuli valence and therefore further research is needed to try and replicate these initial observations.

Experiment Five also permitted the investigation of whether extraversion, cognitive reappraisal, expressive suppression, and state anxiety influence visual search in emotional real-world scenes. When considered in isolation there was no effect of extraversion on visual search performance. However, extraversion did interact with target location and participant emotion to influence how accurately visual search targets were identified. For individuals lower in levels of extraversion, centrally located targets were identified more accurately than peripherally located targets when individuals were induced into a positive emotional state. In contrast, no such differences were evident when individuals with lower levels of extraversion were induced into a neutral emotional state, or for individuals higher in levels of extraversion. This finding suggests that in some circumstances the emotional state of individuals interacts with extraversion to influence visuospatial attention – evidenced by the improvements in accuracy to identify centrally located targets compared to peripherally located targets. The broaden-and-build theory would predict that in a positive emotional state an individual would more accurately identify peripheral targets. However, this result suggests that the opposite may be true for individuals lower in levels of extraversion. Experiment Two suggested that individuals with higher levels of extraversion performed more accurately during a change detection flicker task. The results from Experiment Five suggest that the relationship between extraversion and visual attention may be task dependent. One possibity is that task load mediates the association between extraversion and visual attention. Previously, visual search tasks incorporating a low task load demonstrated that introverts outperforms extraverts (Peltier & Becker, 2017), whereas more challenging visual search tasks show that extraverts perform better than introverts (Hahn et al., 2015). Further experimental studies are required to see if this initial observation is replicated.

In the current study cognitive reappraisal has no impact on visual search performance either independently or in an interactive manner with emotion or stimuli valence once post-hoc analyses had been corrected for multiple comparisons. These findings were somewhat unexpected given the results of Experiment Four showing that greater habitual use of cognitive reappraisal was associated with quicker RT in the visual search task. However, expressive suppression did impact visual search with individuals reporting less frequent use of this ER strategy taking longer to identify search targets. This observation replicates the finding in Experiment Four and suggests that the influence of expressive suppression on visual search within real-world scenes may be stronger than the influence of cognitive reappraisal. Moreover, expressive suppression was shown to interact with stimuli valence and target location. Centrally located targets were identified more accurately than peripherally located targets when embedded within negative emotional scenes for individuals who more frequently adopt expressive suppression. No such differences were evident for neutrally valenced stimuli or for individuals with lower habitual use of expressive suppression. This result builds upon the earlier finding showing improvements in RT for individuals who more frequently adopt expressive suppression as an ER strategy, showing that in certain instances these individuals also show improved accuracy during visual search.

Experiment Five also sought to investigate if state anxiety influences selective visual attention. The effect of state anxiety on RT approached significance (p = .057) tentatively suggesting that individuals with higher levels of state anxiety take longer to detect targets in the visual search task. Moreover, the interaction between state anxiety and target location was significant. Whilst centrally presented targets were detected quicker than peripherally located targets for individuals with lower levels of state anxiety and individuals with higher levels of state anxiety, this difference was greater for individuals with higher levels of state anxiety. This observation suggests that for individuals with higher levels of state anxiety it may be a slowing of RT during trials where the target is peripherally located that is responsible for driving the marginal main effect of state anxiety on RT. Whilst these results provide novel observations regarding the influences of state anxiety on selective visual attention, the lack of any interactions with stimuli valence are unexpected. Both state anxiety and trait anxiety have been shown to impact neural and behavioural responses to emotional stimuli including angry and threatening faces as well as real-world scenes of differing emotional valence (Bishop et al., 2004; Blicher et al., 2020; Chronaki et al., 2018; Fox et al., 2001). The current findings suggest that when the emotional valence of stimuli is task-irrelevant the emotional valence of real-world scenes may not interact with anxiety to influence selective visual attention.

Finally, Experiment Five demonstrated increased dlPFC and vlPFC neural activation when participants completed the visual search task in a negative emotional state compared to a neutral or positive emotional state, regardless of the emotional valence of the scenes. These findings were not shown for vmPFC or dmPFC suggesting that the effects are specific to lateral regions of the PFC. These regions have been strongly associated with emotional processing, negative emotion, and ER, and have both direct and indirect anatomical connections with the amygdala (Dolcos et al., 2011; Kim et al., 2019; Ochsner et al., 2012; Ozawa et al., 2014; Pessoa, 2017; Ray & Zald, 2012). Previous studies show that negative emotion influences PFC activity during completion of a working memory task under negative but not neutral emotion conditions (Ozawa et al., 2014). The findings reported here extend these findings to show that dlPFC and vlPFC activity is increased during a visual search task when participants are induced into a negative emotional state but not when induced into either a neutral or positive emotional state. Whilst there was no evidence for a detrimental main effect of negative emotion on performance in the visual search task, negative emotion did interact with target location. RT to correctly identify central search targets was slower under negative emotion conditions to neutral emotion conditions suggesting that under certain circumstance negative emotion influences selective visual attention and that this effect may reflect changes in the allocation of spatial attention. Future research adopting simultaneous EEG and eye-tracking approaches may help to elucidate the relationships between spatial attention under negative emotion conditions during visual search.

Chapter Seven: General Discussion

7.1. Review of the research aims and objectives

The main aims of the thesis were to investigate the impact of an individual's emotion during selective visual attention, and secondly, to explore the role of emotional real-world scenes when searching for an embedded target of neutral valence. As the research progressed an additional aim was developed to include the investigation of affective traits and their impact on the relationship between emotional factors and top-down selective visual attention.

Specifically, the experiments were designed to test 1) whether positive emotion broadens attention and/or whether negative emotion narrows visuospatial attention, 2) if the emotional valence of complex real-world scenes influences selective visual attention, 3) if the emotional state of an individual interacts with the emotional valence of stimuli to influence selective visual attention, 4) whether affective individual differences influence selective visual attention, 5) if affective individual differences interact with emotional state and/or emotional stimuli valence to influence selective visual attention, and 6) whether PFC activation is related to the emotional state of an individual or the emotional valence of stimuli during selective visual attention.

To accomplish the aims of the thesis several methodological approaches were utilised. Five experiments were conducted adopting two experimental paradigms to investigate the influences of participant emotion, stimuli valence, and affective individual differences on selective visual attention. A change detection flicker task was used to assess the effect of participant emotion on attention in neutral scenes, whilst a visual search task measured attention to neutral targets embedded within task-irrelevant emotional real-world scenes. The first two experiments utilised the change detection flicker task, with the first experiment including fNIRS (Chapter Two), whilst the second experiment also investigated affective personality traits (Chapter Three). The second paradigm was a visual search task that measured attention to neutral targets embedded within task-irrelevant emotional real-world scenes. The first experiment using this task was presented in Chapter Four. In Chapter Five, this initial study was replicated and extended with the inclusion of personality traits and levels of habitual use of ER strategies. The final experiment, incorporating fNIRS and presented in Chapter Seven, included the manipulation of participant emotion and stimuli valence as well as the inclusion of affective individual difference traits. The key findings of the thesis are briefly stated below.

- Independently emotion did not influence selective visual attention during a change detection flicker task utilising neutral real-world scenes
- Individuals with higher levels of extraversion demonstrate improved change detection performance compared to individuals with lower levels of extraversion
- Extraversion interacts with negative emotion to influence change detection
- Task-irrelevant positive and negative real-world scenes influence visual search towards a neutral target
- More frequent habitual use of ER strategies improves visual search performance
- Negative emotion increases dlPFC and vlPFC neural activation during visual search

Below, a discussion of the key findings from the series of experiments is presented. Next, due to the growing importance of understanding inter-individual differences in the neurocognitive mechanisms supporting cognition and emotional processing, two papers are presented that highlight some significant recent findings and provide suggestions on future research directions. Finally, the Chapter will end with a conclusion.

7.2. The influence of emotion on selective visual attention

In the first two experiments in this thesis participants completed a change detection flicker task (Rensink et al., 1997). During a change detection flicker task an individual is required to conduct a visual search to identify a change made between two images (A – A`) which alternate until the change is identified. Importantly, the two images are separated by an ISI usually comprising a blank screen. The ISI masks the motion transients that would normally allow a change to be rapidly detected therefore masking a bottom-up signal of the change (Beck et al., 2006; Rensink et al., 1997). It is suggested that as the change does not capture attention, this impairs visual encoding of the of the change into visual short-term memory requiring individuals to adopt a top-down effortful visual search (Andermane et al., 2019). Changes are difficult to detect taking up to ~20 seconds, whereas changes are easily identified when no ISI is used (Shapiro, 2000). The inability of individuals to identify a change is termed ‘change blindness’ (Rensink et al., 1997). These initial experiments using the change detection flicker paradigm used real-world scenes of neutral valence. Targets were located either in the centre of the scene or in the periphery to allow investigation of whether positive emotion broadens attention and/or whether negative emotion narrows attention.

Whilst the change detection flicker task is a challenging task to complete, Experiments Three, Four and Five consisted of a simple visual search task that was based on a task originally developed to investigate contextual cueing in real-world scenes (Brockmole & Henderson, 2006a). This approach was modified for the purposes of the current thesis whereby experiments presented a target consisting of a letter ‘T’ or ‘L’ embedded within real-world scenes from the NAPS (Marchewka et al., 2014). Crucially, the real-world scenes varied in their emotional valence to test if the emotional valence of task-irrelevant stimuli influences visual search. Moreover, targets were presented either within the centre of the visual scene or in the periphery to allow the investigation of any broadening or narrowing of attention due to emotion.

In the two experiments adopting the change detection flicker paradigm participants were experimentally induced into positive, neutral, and negative emotional states. The broaden-and-build theory (Fredrickson, 1998; 2001) is an influential theoretical model which provides a framework regarding the influences of emotion on cognition and behaviour including visual attention. It is predicted that positive emotion broadens attentional scope whilst negative emotion narrows attentional scope. Initial research adopting the global-local processing task has been cited as evidence to support some of the emotion-attention predictions made by the theory suggesting that positive emotion leads to a broadening of attention (Basso et al., 1996; Derryberry & Tucker, 1994; Fredrickson & Branigan, 2005; Gasper & Clore, 2002). Further research utilising different tasks have also provided support for the predictions made by the broaden-and-build theory suggesting that visuospatial attention is broadened under conditions of positive emotion (Rowe et al., 2007; Wadlinger & Isaacowitz, 2006). However, recent work has cast doubt on the assertion that visuospatial attention is broadened when in a positive emotional state (Bruyneel et al., 2013; Grol & Raedt, 2014; Jiang et al., 2011; Martin & Kerns, 2011; Wegbreit et al., 2015). Moreover, these studies contain several limitations including the lack of either a positive or negative emotion condition, the use of abstract arrays rather than more complex and realistic real-world scenes, or they do not measure the visuospatial allocation of attention and instead measure processing style.

The results from the change detection experiments show that changes were detected quicker and more accurately when they were in the centre of the scene compared to when located in the periphery. This finding demonstrates that visual attention followed the expected pattern with resources allocated to the centre of a scene before attending to the periphery (Rensink et al., 1997; Tatler, 2007). However, when considered in isolation, the emotional state of participants had no impact on the speed nor accuracy to identify changes to neutral scenes. Further, there was no evidence to suggest that positive emotion broadened attentional scope, nor that negative emotion narrowed attentional scope. Therefore, these findings fail to provide support for the predictions made by the broaden-and-build theory (Fredrickson, 1998; 2001).

Earlier studies that have provided evidence in support of the broadening effect of positive emotion on attention in accordance with the broaden-and-build theory have used different experimental paradigms to assess visual processing. The experiments within the current thesis specifically manipulated the location of changes or targets (located either in the centre or periphery) and therefore provided a direct measure of visuospatial attention within real-world scenes. Previous studies have required participants to make a judgement about one feature of a single stimulus or a small set of similar stimuli (e.g. Basso et al., 1996; Derryberry & Tucker, 1994; Fredrickson & Branigan, 2005; Rowe et al., 2007). For example, it is suggested that studies using tasks such as the global-local task have measured *visual processing style* rather than specifically investigating *visuospatial attention*. Therefore, such studies are not suitable for testing the influence of emotion on either a broadening or narrowing of visuospatial attention and may help to explain the differences in findings.

It has also been argued that positive emotion impacts the balance between internally and externally directed attention via changes in cognitive control rather than a broadening of visuospatial attention (Vanlessen et al., 2016). Vanlessen et al. provide an alternative theoretical framework that is suggested can account for the contrasting effects of positive emotion on attention seen in previous research. At a broad level attention has been described as a distinction between external and internal attention (Chun et al., 2011). Here, external attention encompasses the selection and modulation of sensory information including visuospatial space, points in time, as well as modality specific input. Internal attention describes the selection, modulation and maintenance of internally generated information such as task goals, responses, as well as working memory and long-term memory (Chun et al., 2011). Vanlessen et al. argue that positive emotion modulates our attentional focus between external and internal attention based on current task demands (instead of a general broadening of attention due to positive emotion). When task load and cognitive control requirements are low, positive emotion promotes externally focussed attentional processing, which can result in a broadening of attentional scope. However, when task load and cognitive control demands are high, this bias towards an external attention is reduced. Moreover, it is suggested that negative emotion biases individuals towards internally focussed attentional processing. These predictions are partially supported by the current work. Experiment One and Experiment Two adopted a challenging change detection flicker task requiring high levels of cognitive control and no influence of positive emotion was evident, thus supporting the predictions made by Vanlessen et al. Experiment Five adopted a simple visual search task requiring lower levels of cognitive control and so therefore it would be predicted that an effect of positive emotion would be seen. However, positive emotion had no impact on accuracy or RT to identify targets and emotion did not interact with target location. Therefore, whilst the theoretical framework proposed by Vanlessen et al. may help to explain conflicting findings seen in experiments examining the effect of positive emotion on attention, they may not accurately predict findings relating to the influence of emotion on visuospatial attention and visual search.

Whilst the change detection experiments suggested that when considered independently emotion had no impact on attention, Experiment Two demonstrated that emotion can interact with levels of extraversion to influence change detection accuracy and RT to identify changes. Here it was shown that when induced into a negative emotional state, accuracy was improved for individuals with higher levels of extraversion compared to individuals with lower levels of extraversion, whereas there were no differences in accuracy when participants were induced into a neutral or positive emotional state. Moreover, when induced into a neutral emotional state, RT was quicker for individuals lower in levels of extraversion compared to those individuals with higher levels of extraversion, whilst there was no difference in RT to identify changes when induced into a negative emotional state on the basis of extraversion. This interaction appears to be driven by a slowing of RT under negative emotion conditions for individuals with lower levels of extraversion. Therefore, when considering the interaction between emotion and extraversion for accuracy and RT, there is evidence to suggest that negative emotion has a detrimental impact on visuospatial attention, but only for individuals with lower levels of extraversion.

It is possible that differences in ER ability provide a mechanistic explanation for these findings. ER recruits brain regions associated with visual attention, cognitive control and ER (e.g. Buhle et al., 2014; Curtis & D'Esposito, 2003; Miller & Cohen, 2001; Ochsner et al., 2012; Rossi et al., 2009). Successful regulation of emotion may result in additional resources being available for the allocation of attention during the demanding top-down change detection task. It is possible that individuals with higher levels of extraversion are better at regulating negative emotion and therefore do not suffer from detriments in performance observed in individuals with lower levels of extraversion. Evidence to support this argument is provided from analysis of negative affect scores completed after the negative emotion induction. Here, individuals with lower levels of extraversion displayed heightened negative reactivity in response to the negative emotion induction compared to individuals with higher levels of extraversion. Moreover, higher levels of extraversion have been shown to be associated with improved ER and negatively correlated with emotional dysregulation (Kokkonen & Pulkkinen, 2001), poor ER is related to the development of affective disorders (Aldao et al., 2010), and affective disorders are associated with lower levels of extraversion (American Psychiatric Association, 2013; Shankman & Klein, 2003). These findings suggest that negative emotion, extraversion, and ER are closely associated.

Experiment Five adopted a simple visual search task and induced participants into positive, neutral, and negative emotional states. Replicating the findings from the change detection experiments, when considered in isolation emotion had no impact on attention during visual search. These results extend the findings from a challenging change detection experiment to an easier visual search task. Previously, task difficulty has been shown to influence the relationship between emotion and visual attention (Jasinska et al., 2012; Maekawa et al., 2018; Schupp et al., 2007) so it was important to investigate if task difficulty may have masked any influence of emotion on attention in the change detection experiments. Using two visual attention tasks that vary in their difficulty, the current findings suggest that when considered independently emotion has no impact on top-down selective attention during visual search. However, more direct manipulations of task difficulty within the same task are needed to explore the possible influences of task difficulty in relation to the impact of emotion on visuospatial attention. Given that previous studies have not investigated emotional influences on visual search, the current results raise the possibility that the emotional state of an individual (when considered independently) does not influence this specific aspect of attention.

However, emotion did interact with the location of search targets to influence visual search. Targets were identified quicker when they were presented within the centre of the scene when an individual was induced into a neutral emotional state compared to when in a negative emotional state, whereas there was no difference in RT to identify targets embedded within the periphery of the scene when in a neutral or negative emotional state. Although this finding suggests that in some instances the emotional state of an individual can influence visual attention, it contradicts the predictions made by the broaden-and-build theory, which suggests that under negative emotion conditions visual attention is narrowed. The finding that central targets are identified more slowly when in a negative emotional state compared to a neutral emotional state provides contradictory evidence of a narrowing of visual attention under negative emotion conditions.

Motivational intensity refers to the tendency to either approach a positive situation or stimulus or avoid a negative situation or stimulus. Researchers have argued that the broadening or narrowing influences of emotional state on visual attention are due to their motivational intensity rather than the emotional valence per se. Positive emotions high in approach motivation include enthusiasm, desire, and appetitive states, whilst examples of positive emotions low in approach motivation include joy and amusement. Disgust is an example of a negative emotional state high in approach motivation, whilst sadness is an example of a negative emotional state low in approach motivation. It has been shown that positive emotion which is high in approach motivation narrows attentional breadth (Domachowska et al., 2016; Gable & Harmon-Jones, 2008). Moreover, negative emotional states low in motivational intensity have been shown to broaden attention, whilst negative emotional states high in motivation intensity demonstrated a narrowing of attention (Gable & Harmon-Jones, 2010). Whilst these studies show that it is important to consider motivational intensity in studies investigating affective influences on attention, the studies adopted a global-local task. As discussed previously, it is argued that such tasks are not suitable for measuring influences on visuospatial attention and instead measure processing style. Research has also shown that motivational intensity interacts with item location to influence memory. For instance, individuals in a positive emotional state high in approach motivation demonstrate improved memory for centrally presented information, reflective of increased attentional focus and processing. In contrast, for individuals in a positive emotional state low in approach motivation, memory was enhanced for peripheral information (Gable & Harmon-Jones, 2010). Further work has shown that negative emotional states with differing intensity have contrasting influences on the scope of attention. A high intensity negative emotional state increased memory for centrally presented items, whereas a low intensity negative emotional state increased memory for peripherally located items (Threadgill & Gable, 2019). The focus of the current experiments was not related to motivation intensity and so it is unknown whether the induced emotional states were high or low in approach motivation. Therefore, further research is needed to specifically test whether motivational intensity impacts the effect of emotional states on *visuospatial* attention and the predictions made by the broaden-and-build theory.

Laboratory manipulations of participant emotion are common in affective science research investigating the role of emotion on aspects of cognition and behaviour. Given the lack of significant main effects of induced emotion on behavioural visual search indices, it remains possible that the emotion induction procedures used within the current thesis were unsuccessful. However, each emotion induction procedure was validated with the use of self-report questionnaires assessing levels of positive and negative affect. These analyses reliably produced strong effects to suggest that participant emotion was successfully manipulated in the experiments. Moreover, participant emotion was shown to interact with other variables (e.g. extraversion) to influence visual search, providing evidence that in some situations participant emotion did impact visual search and therefore suggesting the emotion induction was successful. Additionally, at the neural level, a main effect of emotion was evident in Experiment Five. Taken together, it is argued that the emotion induction procedures were successful, but that in the current experiments emotion did not exert any independent effects on behavioural measures of top-down selective visual attention. Some of the significant interaction effects including participant emotion were related to the negative emotion condition, and previous research has suggested that negative emotion inductions are more effective than positive emotion inductions (Fernández-Aguilar et al., 2019; Westermann et al., 1996; Zhang et al., 2014), which may be due to increased baseline positive emotion in healthy individuals (Diener & Diener, 1996). Therefore, it is also possible that the negative emotion manipulation was more successful than the positive emotion induction (although this is not supported by the self-report affect scores). Differing methods of manipulating emotion have been adopted by researchers in this field. Like previous studies (e.g. Anderson et al., 2011; Gable & Harmon-Jones, 2008), the experiments in this thesis presented participants with real-world images taken from published databases (IAPS; Lang et al., 2008; NAPS; Marchewka et al., 2014) that were specifically chosen on the basis of their emotional valence. Other emotion manipulation procedures include the use of rewards to induce positive emotions such as providing gifts to participants as well as gaining points or financial rewards in games (Gable & Harmon-Jones, 2010; Yang et al., 2013). However, such approaches may also impact approach motivation and therefore present a possible confound (Vanlessen et al., 2016). An additional type of emotion induction requires participants to focus on internally generated information. For example, participants can be asked to recall positive or negative autobiographical memories and use mental imagery relating to specific situations and experiences (Huntsinger, 2012; Zhang et al., 2014). Although different emotion induction procedures have been shown to differ in their effectiveness at inducing the desired psychological state in participants, it remains unknown whether the use of these contrasting approaches are related to the mixed findings seen in the literature investigating the impact of emotion on visual attention. A direct comparison within the literature is problematic due to the different experimental tasks adopted. Instead, future work could investigate the impact of differing emotion induction procedures within the same experimental and analytical framework.

The experiments presented within this thesis were not intended to investigate the temporal dynamics unfolding during visual search. However, the inclusion of eye movements in further research will help to elucidate the influences of participant emotion and stimuli valence on the temporal dynamics during visual search. For example, it would be possible to assess which information presented within a scene is prioritised and for the temporal moment-by-moment mechanics of visual search to be investigated based on affective influences. For instance, when searching for a difference between two images, participants have been shown to make point-by-point comparisons until a change is detected. Following this, attention narrowed and the duration of fixations increased (Galpin & Underwood, 2005). Additionally, eye movement metrics and behavioural measures can be included within statistical models and this may help to strengthen the interpretation of experimental findings. For instance, when behavioural measures of change detection were correlated with measures of extraversion and neuroticism both personality traits were significantly associated with change detection accuracy. However, when eye movement metrics were included within the regression model the relationship between neuroticism and change detection was non-significant (Hahn et al., 2015). This suggests that once eye movements were accounted for neuroticism was not related to change detection. In studies that include emotional stimuli, the inclusion of eye movement measures would also provide information regarding whether attention is orientated towards or away from the emotional elements of the scene. For example, the use of eye tracking has shown that pleasant scenes are more able to capture attention compared to unpleasant scenes (Fernández-Martín & Calvo, 2016). Moreover, recent research has applied research on attentional biases towards emotional stimuli to develop attentional training paradigms based on gaze-contingent feedback (Dai et al., 2019; Sanchez-Lopez et al., 2019; Sanchez et al., 2016). These initial studies suggest that such approaches are successful in modifying attention and can improve clinical symptoms in affective disorders. A more comprehensive understanding regarding the associations between emotion, stimuli valence and attention will help to improve such attentional bias modification therapies.

7.3. Influences of stimuli valence on selective visual attention

Whilst Experiments One and Two (and Five) were designed to probe the influence of emotion on visual attention, Experiments Three, Four and Five manipulated the emotional valence of real-world scenes to test their effects on visual attention. Whilst experiments using artificial and simple stimuli arrays have revealed many important principles underpinning selective visual attention, they are not very well suited to explain how we allocate attention in meaningful real-world situations. Given the importance of studying attentional processes using more meaningful and representative stimuli, it is surprising that this area of research has not received more focus given the growing literature adopting artificial and simple arrays. Moreover, within the attention-emotion literature, there is also a lack of research that has investigated top-down selective visual attention during visual search when search targets are neutral (as opposed to manipulated based on their valence or arousal). Visual search towards neutral items in our environment is used every day and in certain situations our current goal will be to search for a neutrally valenced target whilst our visual scene contains emotionally salient stimuli.

Across three experiments accuracy to identify targets was reduced when targets were embedded within positive scenes compared to when embedded within neutral scenes. However, there were no differences in how accurately targets were identified between negative scenes and neutral scenes. These findings provide strong evidence to suggest that positive emotional real-world scenes have a detrimental impact on visual search. Across the three experiments that manipulated stimuli valence there was also strong evidence to suggest that the valence of real-world scenes impacts RT to correctly identify a search target. Experiments Three, Four and Five all demonstrated that RT to identify search targets embedded within negative real-world scenes was slower compared to when search targets were embedded within neutral real-world scenes. There was also evidence to suggest that RT to identify targets embedded within positive real-world scenes was slower compared to when targets are embedded within neutral real-world scenes. However, this effect appears to be less robust than the influence of negative scenes. For instance, Experiment Three provided no support for an influence of positive scenes on RT during visual search, whereas Experiment Five did provide evidence for an effect of positive scenes on visual search RT, whilst the effect in Experiment Four approached significance. Therefore, it appears that the detrimental impact of stimuli valence on RT during visual search within real-world scenes appears to be stronger when the scene is negative compared to when it is positive. Increased RTs when searching for a target within negative real-world scenes (and to a lesser extent positive real-world scenes) compared to neutral scenes is suggestive of increased bottom-up attentional capture. Indeed, a key theoretical role of bottom-up processing involves the fast (automatic) detection of salient information in the environment (Carretié, 2014). Additionally, a meta-analysis including studies requiring deployment of top-down attention towards a target whilst distractors are simultaneously presented (similar to the visual search task in Experiments Three, Four and Five) demonstrated a greater influence of emotional distractors compared to neutral distractors (Carretié, 2014). The ability of emotional distractors to capture attention in a bottom-up manner has also been shown to be dependent upon the level of difficulty in the ongoing task. For example, when task load was manipulated within studies, a greater effect of emotional distractors on bottom-up attentional compared to neutral distractors disappeared under the highest task load conditions (Erthal et al., 2005; Junhong et al., 2013).

Taken together, the effects of stimuli valence on accuracy and RT suggest that positive valence and negative valence may impact visual search in different ways even when the valence-related stimuli are task-irrelevant. Indeed, recently it has been demonstrated that images of positive valence and negative valence have contrasting influences upon memory-based guidance of visual search (Zinchenko et al., 2020). Adopting a contextual-cueing task where target-distractor stimuli were embedded within task-irrelevant images of positive, neutral, or negative valence, it was shown that negative images improved contextual cueing whereas positive images reduced contextual cueing effects. Moreover, the enhanced contextual cueing for negative images was suggested to be a result of increased learning of target-distractor associations rather than improved retrieval from context memory (Zinchenko et al., 2020). Taken together, the findings from this study and the current thesis suggest that emotional stimuli may have valence specific effects on visual search and highlight the importance of including both conditions within attention-emotion research.

The levels-of-focus hypothesis suggests that positive emotions are associated with an enhanced focus on internal, accessible information, and promote a global processing style (global processing is the most ‘usual’ and accessible strategy). In contrast, negative emotions prevent a focus on internal information and instead bias individuals to adopt a more local processing style (Clore et al., 2001). The results from Experiments Three, Four and Five showing impaired accuracy in identifying search targets embedded within positive scenes are suggestive of impaired *identification* of the search target. Participants may have been allocating attention using a global processing strategy, thus lacking processing at a local level, resulting in reduced ability to correctly identify the search target. In contrast, longer RTs to identify targets embedded within negative scenes (with no impact on accuracy), suggests that *localisation* of the target was impaired. Participants may have taken longer to locate the target when embedded within negative scenes due to a lack of attentional focus at the global level, yet when they did find the target, they could identify it with a higher level of accuracy. One possibility is that the presentation of the emotional real-world scenes cued specific processing strategies – i.e. global and local processing strategies. However, this explanation is tentative, and the task used in the current study is different from those used to investigate global-local processing.

Additionally, there was also some evidence to suggest that RT to identify targets embedded within positive scenes was also increased, although this effect is less robust than the comparable effect on RT due to negative scenes. Further research is required to test these predictions, and this is an avenue for future work.

Experiment Five demonstrated that scene valence was shown to interact with an individual's emotional state to influence RT. Under neutral emotional states, there was no difference in RT to identify search targets when embedded within neutral or positive valence scenes. However, when participants were induced into a negative emotional state, RT was longer when the scene was positive compared to when the scene was neutral. This finding suggests that in some instances the emotional state of an individual may be able to interact with the valence of real-world scenes to influence visual search. Experiment Five was the only study (out of the three studies that manipulated stimuli valence) that provided strong evidence for a slowing of RT to identify search targets when the scene was positive. It appears that this main effect may be at least in part driven by a slowing of RT to identify search targets in positive scenes under negative emotion conditions. One possibility is that when the emotional state of an individual is incongruent to the visual scene this impairs visual search. Additional interactions between emotional state and stimuli valence were observed in Experiment Five, however these did not remain significant once corrected for multiple comparisons. It has previously been suggested that positive emotion broadens attention but only when the stimuli are also positive demonstrating a congruency effect (Wadlinger & Isaacowitz, 2006). Moreover, emotional state, stimuli valence and self-report levels of depressive symptoms have also been shown to interact to effect visual attention (Grol & Raedt, 2014). Additional studies adopting a range of different methodological approaches are required to see if the interaction between negative and neutral emotional states for neutral and positive scenes is a reproducible effect.

The selection of experimental stimuli is crucial in psychological science and especially in research investigating visual attention. The experiments in this thesis that manipulated stimuli valence used real-world scenes from a rigorously tested affective stimuli database – the NAPS (Marchewka et al., 2014). Such databases provide normative ratings for various aspects of each image including valence as well as their physical characteristics. Going further than several previous studies within the emotion-attention literature, stimuli were selected based on their valence whilst also controlling for additional possible influences. The three stimuli sets used within the current thesis (positive, neutral, and negative valence) were controlled so that each set was similar in their contrast, luminance, complexity, and entropy as these physical characteristics have been shown to influence visual attention (Bradley et al., 2007; Codispoti & De Cesarei, 2007; De Cesarei et al., 2017).

However, as is often unavoidable with stimuli chosen based on valence, the three stimuli sets also differed in their levels of arousal. Arousal is frequently linked to valence whereby negatively valenced stimuli are highly arousing whilst positively valenced scenes are rated as low in arousal (Lindquist et al., 2016). Therefore, it is not possible to reject the argument that the effects of stimuli valence within the current thesis were not due to variations in arousal rather than the manipulation of valence. Indeed, there is also evidence to suggest that arousal, rather than valence, modulates attention. For example, participants have been shown to spend longer looking at highly arousing images regardless of their valence (Lang et al., 1993), suggesting that arousal, but not valence, impacts attention. Using a spatial cueing task, Vogt et al. (2008) have also found that participants take longer to disengage their attention from highly arousing images than from images low in arousal, and that differences in valence had no impact on attentional disengagement. Arousal, but not valence, has also been shown to influence the AB (Anderson, 2005; Arnell et al., 2007) as well as attentional interference (Schimmack, 2005). These findings all indicate that in some instances arousal impacts attention regardless of valence, despite other researchers arguing that valence has the predominant influence on visual attention (Astudillo et al., 2018).

Stimuli valence and stimuli arousal have also been shown to interact to guide the allocation of attention. For instance, performance on a digital parity task was reduced when highly arousing images were negatively valenced compared to when they were positively valenced, whereas performance was reduced for positive images compared to negative images low in arousal (Fernandes et al., 2011). Interactive influences of arousal and valence have also been found in research using a dual-task rapid serial visual presentation task. Here, second target identification was improved for trials where the target was negative and highly arousing compared to when the target was negative and low in arousal. In contrast, when the second target was positive, it was identified more accurately when stimuli were low in arousal compared to high in arousal (Saxton et al., 2020). Further research using a dot probe task has also provided evidence in support of an interactive effect of valence and arousal on visual attention. Sutton and Lutz (2019) suggest that all negative images attract attention (regardless of their arousal), whilst only positive images that are also highly arousing attract attention (positive images low in arousal will not attract attention). There are varying findings regarding the independent effects of valence and arousal and the interactive effects of valence and arousal. This may be due to several factors, such as the nature of the tasks used, the type of stimuli or the emotion induction procedure, as well as individual differences in affective reactivity. More research is needed to explore the relative influences of valence and arousal on attention and visual search.

Within the change detection flicker task experiments that were designed to investigate the influence of participant emotion and personality traits on visual search, the stimuli consisted of neutrally valenced real-world scenes. Therefore, currently it is not known whether comparable influences of stimuli valence reported in Experiment Three, Experiment Four, and Experiment Five would be evident in a change detection flicker task. One study that did investigate emotional valence on change detection demonstrated that changes were identified more quicky when stimuli were negative or positive compared to neutral (Graham, 2008). However, in a further experiment, changes within negative images were detected more quickly compared to when the stimuli were positive or neutral (Graham, 2008). Future research investigating the influences of participant emotion on change detection are required to build upon the findings reported in this thesis. One avenue for investigation would be to incorporate stimuli of differing emotional valence whilst simultaneously manipulating participant emotion. Such experiments would permit the investigation of whether participant emotion and stimuli valence interact to influence change detection ability.

The use of real-world scenes in attention research is often somewhat neglected when compared to research using abstract arrays. Whilst this is itself one reason for the need for such research, adopting real-world scenes confers several advantages including increased similarity to the real-world and enhanced ecological validity. However, one consequence of using such stimuli is that it becomes more difficult to control for certain scene elements. For instance, in the experiments that manipulated stimuli valence, whilst the overall valence of the scene was precisely manipulated, the specific location of the emotional content within each scene was not able to be included within the analytical framework. Consequently, it is possible that within each scene the specific emotional elements were located in different regions. It has been shown that attention is initially directed to the centre of a visual scene before being allocated to peripheral regions (Rensink et al., 1997; Tatler, 2007), perhaps due to central scene regions often including the gist aspects of the images (Rensink, 1997). The change detection studies in this thesis used neutrally valenced real-world scenes. However, currently it is not known whether the specific location of changes made to real-world scenes in respect of the key emotional information within each scene influences change detection. This is one avenue for future research. In a similar manner, the experiments in this thesis that manipulated stimuli valence within a visual search task, were not able to take account of the key emotional elements of the scene. Thus, whilst the location of the search target was precisely controlled so that it was presented pseudorandomly either in the centre or periphery of the scene, and the emotional valence of the scene was precisely manipulated, it was not possible to test whether the spatial relationship between the key emotional element within the image and target location interact to guide the allocation of attention. Such investigations adopting an inter-individual differences approach are an important avenue for investigation. For instance, theoretical predictions based on selective visual attention would suggest that the emotional elements of real-world scenes would be more likely to capture attention in a bottom-up manner. Therefore, the spatial relationship between the emotional scene element and target location may mediate the relationship between overall stimuli valence and behavioural indices. Moreover, this relationship may be further influenced dependent upon whether the emotional elements promote approach/avoidance tendencies or facilitate initial orientating or disengagement biases.

7.4. The influences of affective traits on selective visual attention

7.4.1. Extraversion and neuroticism

Due to the contradictory findings in the literature describing the effects of emotion on visual attention it is important to investigate other factors which may be contributing to these mixed results. One such approach is to investigate inter-individual differences that may influence attention. Three Experiments in this thesis investigated the influence of affective personality traits on visual search. Extraversion and neuroticism feature in models of psychopathology and are associated with affective reactivity (Clark, 2005; Watson et al., 1994). Extraverts report higher levels of wellbeing and more frequent positive experiences compared to introverts (Costa & McCrae, 1980; John et al., 2008) and extraversion is associated with optimism, enjoyment of social contact and reward sensitivity (DeNeve & Cooper, 1998; DeYoung, 2013; Diener et al., 1992; Eysenck, 1990; John et al., 2008; Smillie, 2013; Smillie et al., 2012; Watson et al., 1994). In contrast, neuroticism is associated with emotional instability, increased reactivity to stress and aversive environmental stimuli and reflects the tendency to experience more frequent negative emotion (Hettema et al., 2020; John et al., 2008; Watson et al., 1994).

Few studies have investigated the influences of extraversion and neuroticism on selective visual attention. However, research has shown that both extraversion and neuroticism are associated with the AB suggesting differences in the capacity of visual attention (Bredemeier et al., 2011; MacLean & Arnell, 2010). Moreover, extraverts have been shown to be slower to shift their attention away from positive stimuli, whilst in contrast introverts are slower to shift their attention away from negative stimuli, suggesting that extraversion is related to differences in attentional disengagement dependent upon the valence of the stimuli (Derryberry & Reed, 1994). These initial studies suggest that extraversion and neuroticism may exert main effects upon top-down selective visual attention as well as interactive effects with emotional influences (e.g. individual emotion or stimuli valence) to guide the allocation of attention. However, little research has tested such interactive influences and no previous study has investigated possible interactions between these personality traits and emotion during visual search. Experiment Two in this thesis provided such an investigation.

Experiment Two in this thesis examined whether extraversion and neuroticism impact the ability to detect a change made to a neutrally valenced real-world scene using a change detection flicker task. Individuals with higher levels of extraversion located changes more accurately than individuals with lower levels of extraversion replicating previous findings (Hahn et al., 2015). A possible explanation is provided by Eysenck (1982) who suggests that extraverts have additional cognitive resources compared to introverts. This hypothesis is supported by the studies demonstrating that individuals higher in levels of extraversion show a reduced AB (e.g. MacLean & Arnell, 2010). The change detection flicker task is a challenging task that requires participants to hold a representation of the image in their mind and then subsequently compare it to the changed image. The current results suggest that extraverts have more resources to create and store a visual representation and so perform better during the task.

However, individuals with higher levels of extraversion were slower to identify changes. These findings suggest that in relation to extraversion, participants displayed a speed-accuracy trade-off in their performance. It is possible that as introverts find the change detection task challenging, they have an earlier quitting threshold which manifests as quicker RTs, but crucially also reduced accuracy. Recent findings from low prevalence visual search studies also provide evidence that extraversion is associated with a speed-accuracy trade-off in performance. Low prevalence visual search tasks are designed so that targets are rarely presented and are normally characterised by a high miss rate. Studies investigating low prevalence visual search have been used in an attempt to identify inter-individual differences associated with real-world behaviours such as baggage screening and radiology assessments (Peltier & Becker, 2017). Such studies reveal opposing influences on performance to that observed in this thesis with introverts more accurate but slower to identify search targets (e.g. Peltier & Becker, 2017). One possible explanation is that introverts are suggested to have a higher base level of arousal allowing them to perform repetitive and boring tasks at a higher level compared to extraverts (Eysenck, 1967). Taken together, these findings suggest that levels of extraversion may have differing influences on visual search performance dependent upon the specific task characteristics such as task difficulty or target prevalence. Moreover, as discussed above (The influences of emotion on selective visual attention), extraversion was shown to interact with emotion to influence change detection.

Neuroticism did not influence change detection either when considered in isolation or in an interactive manner when including the emotional state of participants. Previously, neuroticism has been shown to be negatively correlated with attentional control (Bredemeier et al., 2011). Additionally, individuals higher in levels of neuroticism have been shown to be more impacted by distractors during visual search compared to individuals with lower levels of neuroticism (Wallace & Newman, 1998). Whilst previous research adopting a change detection task initially demonstrated that neuroticism was negatively correlated with accuracy to identify changes, after including eye movement metrics within their analytical framework this relationship was no longer significant (Hahn et al., 2015). This demonstrates the importance of including eye movement measures in attention research. Taken together with the findings reported in this thesis it is suggested that neuroticism does not impact attention when measured using a change detection flicker task. However, it remains unknown whether change detection performance would differ based on neuroticism (or extraversion) when the scenes consist of positively valenced or negatively valenced stimuli, and this is an avenue for future investigation given the evidence suggesting that both traits are associated with affective and attentional processing.

The influence of extraversion on selective attention was also investigated in Experiment Four and Experiment Five which adopted a simple visual search task. When considered in isolation, extraversion had no impact on the accuracy nor RT to identity search targets, contrasting with the findings from Experiment Two. This raises the possibility that extraversion may only influence top-down visual search in specific situations based upon ongoing task requirements. Unlike the simple visual search task, successful completion of the change detection task requires an individual to hold a representation of the scene in visual working memory. Our limited visual working memory capacity is considered one of the basic characteristics of visual working memory (Luck & Vogel, 1997) and it is partially responsible for our inability to quickly detect a change between two otherwise identical scenes, as is the case during a change detection task (Becker & Pashler, 2002; Rensink, 2002). This suggests that the enhanced performance of extraverts seen during the change detection task in Experiment Two and in previous research (Hahn et al., 2015) may be due to an increased visual working memory capacity compared to introverts. However, there is limited research that has investigated differences in visual working memory capacity based on levels of extraversion. Early research suggested that extraverts demonstrate improved recall in a pair-associated work task (Howarth & Eysenck, 1968). However, extraversion was not related to visual working memory capacity in a visual digit span task, although it was related to concurrent brain activation (Fink et al., 2005). Similar research adopting an AB paradigm suggests that extraverts have increased attentional resources compared to introverts (MacLean & Arnell, 2010). Together, this limited set of studies provides some evidence that extraverts possess additional attentional resources. Further work is needed to more thoroughly test the suggestion that the increased performance of extraverts during change detection is underpinned by an enhanced attentional capacity.

Experiment Five provided evidence to suggest that extraversion interacts with participant emotion and target location to guide the allocation of attention during visual search. This effect was due to introverts more accurately identifying centrally located targets than peripherally located targets when they were induced into a positive emotion condition. No such differences were observed when introverts were induced into a negative emotional state or for individuals with higher levels of extraversion. This finding suggests that in some situations individuals with lower levels of extraversion may perform better during simple visual search tasks. Indeed, this is supported by findings demonstrating improved accuracy of introverts during low prevalence visual search tasks (Peltier & Becker, 2017). However, this interaction was not expected on an a priori basis, nor would this effect be predicted by theoretical models including the broaden-and-build theory (Fredrickson, 2001; Fredrickson, 1998) or the level-of-focus hypothesis (Gasper & Clore, 2002). Moreover, for accuracy, no significant two-way interactions were evident between participant emotion, target location or extraversion. Therefore, the interaction between extraversion, participant emotion and target location requires further investigation and needs to be interpreted cautiously.

7.4.2. Cognitive reappraisal and expressive suppression

Experiment Four and Experiment Five investigated whether habitual use of two ER strategies influences visual search. Prior research has shown links between ER and visual attention. For example, individuals show reduced dwell time towards arousing areas of unpleasant images compared to when the same individuals passively view unpleasant images (Bebko et al., 2011; Manera et al., 2014; van Reekum et al., 2007). Moreover, differing patterns of eye movements have been observed on the basis of the specific ER strategy adopted (Strauss et al., 2016). However, these studies explicitly instructed participants to regulate their emotion using specific strategies and so it is important to investigate if habitual use of ER strategies is also associated with differences in the allocation of visual attention during visual search. Supporting the predictions of the thesis, individuals reporting higher levels of habitual use of cognitive reappraisal and expressive suppression were quicker to correctly identify visual search targets. Further, Experiment Five also demonstrated that individuals with more frequent habitual use of expressive suppression more accurately identified search targets compared to individuals reporting lower habitual use of expressive suppression. These novel findings are the first to show that more frequent habitual use of these ER strategies are associated with improved visual search performance. Moreover, the current findings suggest that visual search performance is benefited by increased habitual use of ER strategies considered to be both adpative (cognitive reappraisal) and maladaptive (expressive suppression) in respect of their associations with the development of affective disorders (Aldao et al., 2010). Whilst expressive suppression is associated with long-term negative consequences such as increased risk of developing clinical conditions (Aldao et al., 2010), the use of this strategy in the present moment may confer benefits to individuals. Expressive suppression involves the suppression or inhibition of information with the goal of changing ones emotion. Therefore, considering the task used in the current thesis, it is likely that individuals more skilled at using expressive suppression may be better able to inhibit the task-irrelevant real-world scenes and thus are quicker and more accurate at identifying the search targets.

However, the interactions between expressive suppression or cognitive reappraisal and participant emotion or stimuli valence were non-significant. Given the non-significant main effect of participant emotion on visual search within the experiments, the lack of an interaction between habitual ER strategy use and emotion is more likely. However, reproducible effects of stimuli valence on both the accuracy to identify visual search targets as well as RT to correctly identify search targets were observed. Considering the significant main effects of ER strategy use on visual search performance, as well as the strong theoretical links between ER and attention (Barrett et al., 2004; Gross, 1998; Hofmann et al., 2012; Ochsner et al., 2009; Posner & Rothbart, 1998; Viviani, 2013), the lack of any interactions between stimuli valence and ER strategy use is unexpected. The findings suggest that whilst increased habitual use of expressive suppression and cognitive reappraisal provide performance benefits during visual search, this influence is not related to the valence of the stimuli used within the task, even though the valence of the stimuli also exerts a significant effect on visual search performance. Research has shown that cognitive reappraisal cannot be explained solely by attentional deployment (Livingstone & Isaacowitz, 2018). For instance, the instruction to adopt reappraisal influenced self-report scores of negative affect beyond the impact of attention to emotional scene elements (Manera et al., 2014). Moreover, cognitive reappraisal and expressive suppression success was shown to be similar when individuals had their attentional constrained and whilst under free viewing conditions (Bebko et al., 2011; Urry, 2010). Therefore, whilst attention may be one mechanism supporting ER it is unlikely to be the only mechanisms underpinning ER. One possibility is that individuals with greater habitual use of expressive suppression and cognitive reappraisal have additional cognitive resources available to them, but within the current visual search task these resources (or lack of) were not impacted by the valence of the stimuli. Recent research has suggested that ER is associated with improvements in cognitive efficiency (Barkus, 2020) as well as working memory

(Xiu et al., 2016, 2018) and this is one possible mechanism explaining the performance benefit associated with increased habitual ER strategy use.

7.4.3. State anxiety

The previous literature that has investigated influences of anxiety on visual attention has predominantly focussed on attentional biases towards threat-related stimuli (Cisler & Koster, 2010; J. Liu et al., 2019; Massar et al., 2011; Mogg & Bradley, 2016, 2018; Quigley et al., 2012). Within such studies a range of biases have been reported including attentional orientating towards threat-related stimuli and prolonged disengagement from threat-related stimuli (Cisler & Koster, 2010; Mogg & Bradley, 2016). However, no previous studies have investigated if anxiety impacts visual search within real-world scenes containing images of differing emotional valence. Experiment Five, which adopted a simple visual search task employing real-world scenes varying in their emotional valence, provides tentative evidence to suggest that anxiety does impact visual search ability. Here it is suggested that individuals with higher levels of anxiety were slower to accurately identify visual search targets. However, this effect only approached significance (p = .057) and therefore needs to be interpreted cautiously. The interaction between anxiety and target location was significant. Whilst peripheral targets were detected more slowly than central targets for individuals with lower *and* higher levels of anxiety, this difference was greater for individuals with higher levels of anxiety. The interaction between stimuli valence and anxiety was non-significant. This suggests that within the current task the effects of anxiety on visual search are not impacted by the valence of real-world scenes. Although the negative valenced scenes used in the current experiment were not specifically chosen to contain threatening scenes, it is still unexpected that anxiety did not interact with stimuli valence to guide the allocation of attention given previous findings (Cisler & Koster, 2010; Liu et al., 2019; Massar et al., 2011; Mogg & Bradley, 1998; Quigley et al., 2012). However, whilst recent research using EEG to record visual evoked potentials has demonstrated that anxiety impacts goal-directed processing evident from reductions in the P300 amplitude towards target stimuli, and increases the C1 amplitude to irrelevant stimuli, differences in brain activations associated with visual processing did not vary dependent upon their emotional content (Rossi & Pourtois, 2017). Moreover, the participants in Experiment Five were from a subclinical sample. Previous research has shown that individuals with generalised anxiety disorder show enhanced bottom-up processing of threat-related distractors (MacNamara & Hajcak, 2010), whereas such observations were not found in individuals with subclinical anxiety (Bishop et al., 2007; MacNamara & Hajcak, 2009). Therefore, it may be that enhanced bottom-up processing of emotional or threat-related stimuli may only be evident in clinically anxious individuals. The research studies discussed above support the findings from the current thesis.

Taken together, these findings provide the first evidence to suggest that individuals with higher levels of anxiety demonstrate reduced visual search performance when searching for targets within real-world scenes compared to individuals with lower levels of anxiety irrespective of emotional valence. Additionally, there is evidence to suggest that those individuals with higher levels of anxiety, may exhibit an increased slowing of RT to identify peripherally located targets compared to individuals with lower levels of anxiety. This finding suggests that anxiety may exert an influence upon the visuospatial allocation of attention. However, anxiety had no impact on the RT to identify centrally located targets and so further studies are needed to investigate these initial findings.

The influence of inter-individual differences on emotion-attention interactions enables the identification of those individuals who may be better able to control the impact of emotion or stimuli characteristics during top-down selective visual attention. Such research may help to identity those who are more vulnerable or resilient when experiencing emotional situations. Therefore, research investigating inter-individual differences has the potential to develop more effective treatments and translational therapies related to clinical conditions where attention is a key mechanism linking behaviour and psychopathology (e.g. depression; Keller et al., 2019). Moreover, psychometric approaches can be easily administered in a cost-effective manner. Recently, a freely available personality questionnaire was administered online and was able to identify relationships between personality traits and symptoms of affective disorders (Wilks et al., 2020). The current study provided novel findings regarding the influence of extraversion, anxiety, cognitive reappraisal, and expressive suppression on emotion-attention interactions. However, future studies would benefit from adopting a more nuanced approached. For instance, the current thesis investigated the impact of trait levels of extraversion and neuroticism on affective visual search. Much less is known regarding the relationship between personality facets and attentional processes, although recently personality facets including politeness and emotional stability have been associated with visual-spatial tasks (Carbone et al., 2019).

7.5. The influences of emotion and stimuli valence on PFC activation during selective visual attention

Developing our understanding of the neural mechanisms supporting selective visual attention, emotional processing and attention-emotion interactions will aid in the development of more effective treatments for a range of clinical conditions. A broad fronto-parietal network encompassing both distinct and shared networks underpins top-down and bottom-up selective visual attention (Buschman & Kastner, 2015; Corbetta et al., 2008; Corbetta & Shulman, 2002; Driver, 2001; Hopfinger et al., 2000; Miller & Cohen, 2001; Posner & Petersen, 1990). Areas of the PFC that are involved in top-down selective visual attention are also involved in the regulation of emotion (Buhle et al., 2014; Curtis & D'Esposito, 2003; Dolcos et al., 2011; Rossi et al., 2009). For instance, the dlPFC has been shown to be associated with conflict adaption during a flanker task (Gbadeyan et al., 2016), memory-guided attention and the detection of visual search targets (Wang et al., 2018), change detection (Beck et al., 2001; Tseng et al., 2010), as well as the likelihood of an individual voluntarily adopting ER (Doré et al., 2017). Moreover, dlPFC stimulation has been shown to improve attention in clinical populations and increases in dlPFC activity during ER are able to predict symptom severity in MDD (Hauer et al., 2019; Heller et al., 2013). Given the evidence suggesting PFC activity is associated with change detection (and visual attention in general), as well as emotional processing and top-down cognitive control networks, Experiment One and Experiment Five tested whether PFC activation is impacted by participant emotion and stimuli valence during top-down selective visual attention.

Using fNIRS, Experiment One investigated whether PFC activation was influenced by the viewing of images varying in their emotional valence, and secondly, whether PFC activation varied according to participant emotion during a change detection flicker task. When freely viewing real-world scenes, emotional valence had no impact on PFC oxy-Hb activity. Previous studies investigating the neural processing of emotional images using fNIRS have reported conflicting results, and it appears that the analytical framework used by researchers may influence study findings and conclusions. For example, when comparing changes in PFC oxy-Hb during the passive viewing of stimuli against baseline activity, decreased activity has been seen in response to positive stimuli (Hoshi et al., 2011). For neutral and negative stimuli, both increases and decreases in PFC oxy-Hb have been observed (Hoshi et al., 2011; Ozawa et al., 2014). However, in alignment with the current findings, a further study found no effect of stimuli valence on oxy-Hb activation (Herrmann et al., 2003). In contrast, when Ozawa et al. (2014) measured changes in PFC oxy-Hb *between* different emotion conditions (rather than measuring emotion conditions against baseline oxy-Hb), previously significant effects of emotional stimuli valence on PFC oxy-Hb were non-significant. This suggests that the analytical framework chosen by researchers can have an impact on their results and interpretations. However, a separate study also using group analyses did show that PFC oxy-Hb was increased during the viewing of negative stimuli compared to neutral stimuli (Glotzbach et al., 2011). Moreover, recently fNIRS has been able to show distinct PFC oxy-Hb activation patterns for different types of positive emotion (Hu et al., 2019), as well as hemispheric activation patterns when processing emotional sounds (Gruber et al., 2020). Experiment One compared PFC oxy-Hb during free viewing of positive, neutral, and negative real-word scenes, but found no effect of emotion. These images were presented during an emotion induction procedure that was crucial to address the main aims of the study. The emotion induction procedure was validated with the completion of self-report measures of affect. Whilst the study revealed no behavioural influences of emotion on change detection (discussed previously), and no differences in PFC oxy-Hb during the viewing of positive, neutral, and negative stimuli, the affect scores strongly suggested that participant emotion had been successfully manipulated. Taken together, this suggests that participants were viewing the images during the emotion induction procedure and that the emotion induction had the desired effect, but that the emotional valence of the images had no influence on PFC oxy-Hb. The analytical approach adopted here, consisting of comparing changes in oxy-Hb between emotion conditions, is more conservative compared to analysing the data in relation to baseline levels of activity. Therefore, it is possible that an alternative analytical framework may have provided different results. Future studies may benefit from including both comparisons within their analyses. Moreover, recently it has been demonstrated that using a combination of fNIRS and EEG improves neural identification of affective states compared to utilising either neuroimaging modality in isolation (Sun et al., 2020). This suggests that the use of multiple sources of neural processing can enhance the ability to detect emotion. Future studies adopting such approaches may help to refine our understanding of the PFC neural mechanisms involved in emotion-attention interactions.

Experiment One demonstrated increased PFC oxy-Hb during completion of the change detection task compared to when participants freely viewed the emotion induction images. This main effect was evident in nine channels corresponding to the dlPFC, vlPFC and mPFC. However, there was no effect of participant emotion on oxy-Hb during completion of the change detection trials. Taken together, these findings suggest that the dlPFC, vlPFC and mPFC were recruited during change detection, providing evidence for their involvement in top-down selective visual attention, but that activation of these regions did not vary on the basis of participant emotion during completion of the change detection task. Previously, using fNIRS, the emotional state of participants has been shown to influence PFC oxy-Hb during the completion of cognitive tasks. For instance, naturalistic measures of emotion have been shown to be correlated with PFC oxy-Hb during completion of a working memory task. Here, increased levels of self-reported negative emotion were correlated with lower levels of PFC oxy-Hb. In an additional study investigating emotion and working memory, presentation of negative images prior to completing an n-back task increased oxy-Hb compared to the presentation of neutral images. Despite these studies providing contradictory influences of emotion they suggest that emotion may influence PFC oxy-Hb during the completion of working memory tasks. The findings from Experiment One suggest that such findings may not extend to a change detection flicker task.

Experiment Five also investigated emotion-related neural mechanisms underpinning attention. Whilst Experiment One employed a change detection flicker task, participants in Experiment Five completed a visual search task whereby they were required to identify a target presented within real-world scenes of varying emotional valence. Participants completed three experimental blocks of trials (including stimuli of positive, neutral, and negative valence) under differing emotion conditions (positive, neutral, and negative emotion). Four regions of interest were created corresponding to the dlPFC, vlPFC, dmPFC and vmPFC. Planned comparisons demonstrated that oxy-Hb was increased in the negative emotion condition for the dlPFC and vlPFC compared to when participants were induced into a neutral emotion condition. The effect of emotion on dmPFC and vmPFC oxy-Hb was non-significant. Therefore, there is evidence to suggest that negative emotion selectively impacts dlPFC and vlPFC regions, but not the dmPFC and vmPFC during visual search. One possible mechanism is that when participants were induced into a negative emotion condition, they recruited the dlPFC and vlPFC to regulate their emotion, whereas the regulation of a positive emotion condition did not require or recruit these PFC regions. This interpretation is supported by findings showing increased dlPFC and vlPFC activation during instructed ER (Buhle et al., 2014; Kim et al., 2019; Ochsner et al., 2012). Frequently, studies investigating emotion-attention interactions fail to include both a positive and negative condition in experiments. The findings from the current study suggest that it is important to do so as valence specific effects were observed.

However, the main effect of emotion on behavioural measures of visual attention were non-significant. Given the increased activation of the dlPFC and vlPFC during the negative emotion condition, it could be expected to simultaneously observe less accurate or slower identification of visual search targets under the negative emotion condition. Regions of the PFC are involved in both selective visual attention and ER and so in negative emotion conditions (compared to neutral or positive emotion conditions) participants may devote additional resources to the regulation of emotion and therefore have fewer available resources to devote to successful completion of the visual search task. Despite the lack of a main effect of emotion on visual search performance, an interaction between emotion and target location was evident. Whilst there was no difference in RT to identify peripheral targets for negative and neutral emotion conditions, participants induced into a negative emotion condition were slower to identify targets presented centrally compared to individuals induced into a neutral emotion condition. Therefore, there is some evidence to suggest that negative emotion had a detrimental impact on visual search and that simultaneously increased oxy-Hb was observed in the dlPFC and vlPFC. Although the emotional state of the participant had an impact on PFC oxy-Hb during the visual search task, the emotional valence of the stimuli within each trial did not impact PFC oxy-Hb, despite stimuli valence producing strong and reproducible behavioural effects. Additionally, the interaction between participant emotion and stimuli valence was non-significant. Therefore, during the current visual search task it appears that participant emotion, but not stimuli valence, is associated with changes in PFC oxy-Hb.

Experiment One and Experiment Five both measured PFC oxy-Hb during the completion of a visual search task during positive, neutral, and negative emotion conditions revealing differing findings. However, the visual search tasks used in the experiments were different and this raises the possibility that negative emotion is related to dlPFC and vlPFC activity during a simple target identification task, but not during a change detection flicker task. One possibility is that as the change detection flicker task is a challenging task, any influences of emotion were masked as participants were required to devote all their cognitive resources towards completion of the task. Moreover, the two experiments adopted different analytical approaches. Whilst both experiments compared oxy-Hb between emotion conditions (rather than compared to a baseline measure), Experiment One used a blocked analysis whereby oxy-Hb within each of the emotion blocks was averaged, whereas Experiment Five adopted an event-related analysis (due to the valence of the visual search stimuli varying within blocks). Although unlikely, it is therefore possible that the differences in the analytical frameworks adopted in the experiments may have influenced the findings.

The two experiments in this thesis that investigated the influence of emotion and stimuli valence on PFC oxy-Hb used fNIRS. This neuroimaging methodology has several advantages including its low cost and non-invasive application that reduces experimental set up time whilst reducing levels of discomfort for participants. Further, compared to other hemodynamic neuroimaging approaches such as fMRI, fNIRS has increased temporal resolution. However, fNIRS is only able to record changes in oxy-Hb and deoxy-Hb from cortical brain regions approximately 1-2cm from the scalp. Therefore, it is not able to record changes in activation from subcortical bran regions and networks associated with emotional processing – e.g. the amygdala. Due to the hemodynamic response (measured in fMRI and fNIRS) taking on average ~12 seconds future work investigating emotion-attention interactions would benefit from using techniques with improved temporal precision such as EEG. This would allow specific components of attentional processing to be investigated revealing more detailed information on the impact of emotion and stimuli valence on top-down selective visual attention. Moreover, EEG can be combined with eye tracking systems to provide fixation event-related potentials. Such experiments would be able to provide powerful insight into the temporal patterns of eye movements and simultaneous brain activity during early and late stages of visual processing.

Given the need for increased research aimed at developing personalised treatments for clinical conditions such as MDD, it is important to understand the neurocognitive mechanisms supporting inter-individual differences in aspects of cognition that are impaired such as those underpinning selective visual attention. Moreover, a personalised psychiatric approach (also referred to as precision psychiatry) will depend on enhancing our understanding of the inter-individual differences associated with the neurocognitive mechanisms supporting ER and emotional recovery. The following two sections discuss important recent studies aiming to progress this line of research and provide suggestions for further areas of investigation. The first article discusses a recent change in focus within ER research moving beyond experimental designs where participants are explicitly instructed when to adopt ER and instead investigating the neurocognitive mechanisms underpinning voluntary ER.

7.6. The neural mechanisms able to predict future emotion regulation decisions[20]

Emotion regulation is crucial in maintaining healthy psychological wellbeing, and its dysregulation is often linked to a range of neuropsychiatric disorders including depression. The neurobiological underpinnings of cognitive reappraisal, an emotion regulation strategy, have been shown to include the amygdala and regions of the prefrontal cortex. A novel study by Doré et al. (2017) has demonstrated that neural activity in these regions during uninstructed visualization of affective stimuli can successfully predict which individuals are more likely to subsequently employ emotion regulation, and under what circumstances.

The ability to respond daily to life's events is crucial to psychological wellbeing, resilience, and physical health. Consequently, emotion regulation, broadly defined as the initiation of a conscious or non-conscious effort to start, stop, or modulate an emotion, has a crucial role in protecting an individual from a range of psychopathologies including anxiety, depression, eating disorders and substance-related disorders (Aldao et al., 2010). Therefore, understanding the neurobiological mechanisms supporting emotion regulation will help to develop interventions to improve emotion dysregulation in individuals with a range of disorders.

One such emotion regulation strategy is cognitive reappraisal, where individuals attempt to explicitly reinterpret the meaning of an emotional stimulus or event with the goal of altering the nature, magnitude, or duration of the emotional response (Ochsner et al., 2012). The neuroscientific study of cognitive reappraisal has made significant progress in identifying the neural circuits involved in emotion regulation during the last decade (Buhle et al., 2014; Ochsner et al., 2012). Neuroimaging studies have revealed that

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[20] Bendall, R.C.A. (2017). The neural mechanisms able to predict future emotion regulation decisions. *Journal of Neurophysiology*, 118(3), 1824-1827.

emotion regulation recruits a network of regions involved in top-down cognitive control. These include areas of the prefrontal cortex (PFC) including the dorsolateral prefrontal cortex (dlPFC), dorsomedial prefrontal cortex (dmPFC), ventromedial prefrontal cortex (vmPFC) and ventrolateral prefrontal cortex (vlPFC), which allow individuals to apply top-down cognitive control mechanisms. These PFC regions have been shown to regulate (both up- and down-regulate) activity in the amygdala, a subcortical limbic system structure involved in detecting emotional reactivity via direct and indirect structural connections (Buhle et al., 2014).

Research has recently begun to focus on individual differences in emotion regulation rather than group averages. Within the field of emotion regulation individual variation is not considered statistical noise. Instead, individual differences in the ability to regulate emotion may determine vulnerability and resilience in the face of affective stressors. Consequently, understanding the neural mechanisms underpinning individual differences in successful emotion regulation may aid clinical assessment of interventions and provide more effective translational therapies.

Facial electromyography, a technique that measures muscle activity by recording electrical impulses when muscle fibres contract, can be employed to index an objective measure of trait-like individual differences in emotion regulation and is able to predict amygdala-PFC functional connectivity (Lee et al., 2012). Moreover, using diffusion tensor imaging, it has been shown that increased use of emotion regulation is predictive of stronger amygdala-PFC microstructure fibre tract pathways, whilst trait anxiety is negatively correlated with amygdala-PFC connectivity (Eden et al., 2015). These studies adopting individual difference approaches demonstrate that PFC regions and the amygdala are implicated in emotion regulation at both the anatomical and functional level in healthy individuals.

Whilst progress has been made towards identifying brain circuits involved during emotion regulation, it remains unknown whether neural mechanisms can be used to predict emotion regulation decisions. Previous research investigating the neural circuitry underpinning emotion regulation has not given participants the choice as to whether or not to regulate their emotion, and instead employed experimental designs where individuals are instructed to adopt emotion regulation strategies and neural activation is recorded. Consequently, the neural mechanisms predicting the decision to regulate emotional responses were until recently unknown. This has important implications as the decision to purposefully regulate one’s negative emotion has been shown to be a protective factor for well-being (Sheppes et al., 2014). A recent study by Doré et al. (2017) has provided some novel insights to this issue. Here the authors attempted to a) reveal the neural processes supporting individual decisions to regulate emotional responses, and b) determine whether brain activity can be used to predict emotion regulation decisions.

Participants initially underwent training in the emotion regulation strategy cognitive reappraisal to ensure they understood what a choice to regulate emotion would involve. This included experimenter-guided training in positive reappraisal (i.e. focussing on the potential positive aspects of a negative stimulus or situation) and minimizing reappraisal (i.e. focussing on potential neutral aspects of a negative stimulus or situation). Participants then completed an emotion regulation task where they were able to practice using these strategies. Subsequently, the researchers determined brain regions known to be involved in emotion regulation on an a priori basis (vlPFC, dlPFC, dmPFC, and amygdala), and used functional magnetic resonance imaging (fMRI) to record activity from these areas during a negative image viewing task. Participants were required to view a series of negative images and rate how positive and how negative the images made them feel using a 5-point scale (‘How positive do you feel’ and ‘How negative do you feel’). Importantly, participants were free to think about the images in any manner and were not instructed to regulate their emotional response to the images. The second part of the study, completed outside the fMRI scanner, involved an emotion regulation choice task in which participants were presented with negative images (some previously seen in the initial image viewing task and some novel images) and asked to decide whether to regulate their emotion or simply to view the images passively. Participants recorded their emotion regulation decision by selecting either ‘look naturally’ or ‘reappraise’ in response to each image.

This paradigm allowed Doré and colleagues to demonstrate that specific neural mechanisms, engaged during uninstructed visualization of emotional stimuli, are able to successfully predict subsequent behavioural choices concerned with the regulation of emotional response. At the individual level, using a model-based analysis, more frequent decisions to employ cognitive reappraisal were predicted by greater activity in the vlPFC, dlPFC, dmPFC, and amygdala. These results were similar for both old and new images in the emotion regulation choice task. Further, these relationships were still evident after controlling for self-report ratings of positive and negative affect, demonstrating that increased activation of these neural circuits during the viewing of negative images predicted the decision to regulate emotion independently of participant's subjective emotional experience whilst viewing negative images. Moreover, Doré and colleagues also investigated whether brain activity could predict the specific events for which the decision to regulate emotion is most likely. This was operationalized by conducting analysis at the level of the stimulus and by using a whole brain activity pattern that had previously been shown to be associated with emotion reappraisal (Buhle et al., 2014). At the stimulus level, trial-to-trial differences in whole brain pattern activity predicted the decision to regulate emotion to a specific stimulus. A model including this distributed brain pattern, in addition to PFC and amygdala regions, performed better at predicting the decision to regulate emotion to a given stimulus than a model only including self-report data and affective ratings of stimuli. This result demonstrates that stimulus-level variability in brain pattern expression can be used to predict which stimuli individuals are more likely to employ cognitive reappraisal.

Doré et al. (2017) revealed important findings moving towards a more individualized science of emotion regulation (Doré et al., 2016) and translational neuroscience approach – going beyond experimentally directed emotion regulation and instead being able to predict who will freely choose to regulate their emotion and under what circumstances. Using individual variability in neural responses to negative stimuli, it was demonstrated that decisions to deploy cognitive control of emotion can be predicted by neural processes during earlier emotional experience. However, due to the nature of the correlational design, it is not possible to make any inferences about causality in the relationship between neural activation during affective experience and subsequent decisions to regulate emotion. Future experimental work should build upon these findings using neurostimulation techniques such as repetitive transcranial magnetic stimulation (rTMS) and/or transcranial direct current stimulation, which allow for experimental manipulation of specific neural circuits. For instance, rTMS has recently been used to causally infer that inhibitory disruption of the right dlPFC influences early affective processing as evidenced by altered neurophysiological response and impaired behavioural performance (Zwanzger et al., 2014).

The investigation of negative emotion regulation and/or dysregulation is of central importance to understanding the neural mechanisms involved during emotion regulation in healthy individuals and clinical populations. However, within the emotion science literature it has been documented that a bias exists whereby positive conditions (e.g. positive mood, positive experimental stimuli, or positive emotion regulation conditions) are often not included, and this limits the conclusions that can be made about affective processing. There are instances when individuals need to regulate positive emotional experiences, and currently the neural processes involved during such responses are less well understood. Thus, it is recommended that future research includes both positive and negative experimental conditions.

In Major Depressive Disorder increases in dlPFC activity when regulating emotion has been shown to predict reductions in symptom severity in depressive patients (Heller et al., 2013). However, it is unknown whether the neural circuits underpinning the decisions to regulate emotion are able to predict behaviour and symptom severity reduction in clinical populations. Doré et al. (2017) indeed suggest that future work could investigate whether clinical disorders show disruption in their ability to deploy emotion regulation, and importantly research needs to focus on instances of uninstructed emotion regulation (i.e. investigations of the decision whether to regulate emotion rather than experimental designs where individuals are explicitly told to regulate their emotion). Crucially, however, research adopting a more individualized approach to the investigation of the decision to regulate emotion needs to move beyond the laboratory adopting study designs better able to capture real-world behaviour. Using fMRI, it has been demonstrated that dlPFC activity in response to reward responses recorded in the laboratory are able to predict behavioural reactivity of real-world positive emotion. This relationship was established by correlating dlPFC activity with behavioural response following a reward given in natural environments (Heller et al., 2015). Future translational neuroimaging investigations of emotion regulation decisions should aim to adopt such techniques. Consequently, this will help to understand the neural basis of such decision making in healthy individuals and patient populations in real-world settings, and aid in the development and evaluation of therapeutic interventions.

Although not discussed in detail by Doré et al. (2017), their finding also showed that bilateral precuneus activity were positively correlated with emotion regulation decisions. The precuneus, part of the posteromedial portion of the parietal lobe, has been shown to be involved in broad aspects of cognition including production/alteration of subjective experience, integration of internal and external information, visual mental imagery, episodic memory recall, and self-referential processing (for a review see Cavanna & Trimble, 2006). Further, recent evidence has suggested that this cortical area forms part of the neural circuit activated during another emotion regulation strategy – attentional deployment – where attention is directed with the goal of changing one’s emotional response (Ferri et al., 2016). Ferri and colleagues demonstrated that task-dependent coupling between the precuneus and amygdala is increased during visual attentional deployment, suggesting that the precuneus is involved in the regulation of amygdala reactivity to emotional stimuli when emotion regulation involves shifts in attention. Moreover, the strength of coupling between the precuneus and amygdala predicted attentional deployment success, and individual differences in trait reappraisal were positively correlated with amygdala-precuneus connectivity. Considering these observations in combination with those of Doré et al. (2017) suggests that the precuneus may be part of a network of neural circuits involved in multiple emotional regulation strategies. Indeed, it has been suggested that individuals may simultaneously use attentional deployment and cognitive reappraisal during emotion regulation (see Ferri et al., 2016). However, as the precuneus was not identified as a brain region of interest on an a priori basis by Doré and colleagues (in relation to its involvement in cognitive reappraisal), caution is needed when interpreting this observation. Further research is needed to reveal the precise role of the precuneus in emotion regulation (see below).

Doré et al. (2017) have provided evidence to suggest that neural activity during affective experience can predict the individuals who are more likely to subsequently deploy cognitive control of emotion, and for what stimuli emotion regulation is most likely. This novel methodology should help to direct emotion regulation research towards a more individualized translational neuroscience approach. A number of avenues for future research have been identified. Firstly, researchers need to include positive emotion conditions within their experimental designs to test whether the neural mechanisms evident during negative emotion regulation are similar to those adopted during positive emotion regulation. Additionally, the use of neurostimulation techniques will allow researchers to infer causality between underlying neurobiological mechanisms and emotion regulation. It will also be advantageous for research to adopt study designs that allow the measurement of real-world behaviour in both healthy individuals and clinical populations. This will be crucial for the development and evaluation of translational therapeutic interventions. Further, an individualized approach that acknowledges the role of the individual in emotion regulation will aid development of our understanding of individual difference traits that can be targeted for therapeutic intervention. Lastly, recent evidence has suggested that the precuneus may be part of the neural circuit involved in emotion regulation, and future work should try to reveal the exact role of this brain region. For example, it is not known whether the primary involvement of the precuneus during emotion regulation is related to the alteration of subjective experience, integration of internal and external information, self-referential processing, attentional deployment, or a combination of these processes.

In summary, using an elegantly designed study adopting an individualized translational neuroscience approach, Doré et al. (2017) revealed that increased neural activation in the PFC and amygdala during uninstructed affective experience can successfully predict individuals who are more likely to regulate their emotional responses. Further, trial-to-trial variability of a brain activity pattern previously shown to be related to emotion regulation was able to predict emotion regulation at the stimulus level. This novel approach to the study of emotion regulation will be especially valuable when applied to clinical populations and the development of translational therapeutic interventions.

The research described above takes a similar approach to the investigation of ER and visual attention in the current thesis. Whilst Doré et al. (2017) were focussed on the neural mechanisms underpinning ER, crucially they designed a novel approach that was able to measure the brain networks associated with the decision to deploy ER. In a similar manner, the investigation of ER in the current thesis did not explicitly request participants to adopt specific ER strategies. Instead, the aim was to assess if habitual use of two ER strategies influenced emotion-attention interactions. Given the predicted influence of negative emotion in cueing a focus towards internal attention (Vanlessen et al., 2016), as is seen in depressive states and during rumination (Nolen-Hoeksema, 2000; Whitmer & Gotlib, 2013), it is also important to develop understanding of additional constructs that may offer potential as therapeutic targets. Once such construct is decentering as research has shown that enhanced decentred thinking via mindfulness practice is able to reduce depressive symptoms (Garland et al., 2015). The following article discusses the role of decentering as a mediator in the relationship between vmPFC activity during a stressor and subsequent positive emotion during stress recovery.

7.7. Decentering mediates the relationship between vmPFC activation during a stressor and positive emotion during stress recovery[21]

The stress response has profound implications on health and behaviour and stress is considered a risk factor for the development of psychopathologies including depression. The neural mechanisms supporting successful stress recovery are not fully understood, however a novel study by Yang et al. demonstrates that vmPFC activation during a stressor is related to improved stress recovery, and that decentering is able to mediate this relationship, suggesting a role during stress recovery. It was also revealed that vmPFC activation at different time points during the stressor predicts altering aspects of stress recovery, an observation that was only possible due to the adoption of change-point analysis.

The World Health Organization has cited stress as the health epidemic of the 21st Century. The ability to respond to life’s stressors has important implications for physical and mental health; stress is the most common risk factor for developing mood disorders including major depressive disorder (MDD; Risch et al., 2009), and the regulation of emotion has been shown to play an important role in protecting individuals from developing various psychopathologies including substance-related disorders, anxiety and depression (Aldao et al., 2010). Additionally, regulation of both negative emotion and positive emotion are important features of the stress response. One mechanism through which positive emotion is able to impact stress is by facilitating stress recovery (Waugh et al., 2012). Consequently, understanding the neurobiology underpinning successful stress recovery, alongside factors that mitigate stress recovery, will aid in the development of treatments and interventions concerned with improving individuals’ physical and mental health.

Greater cognitive resource availability during stress recovery may aid successful deployment of stress regulation strategies such as decentering, a meta-cognitive strategy enabling one to modify their experience from within one’s subjective experience onto that experience, and viewing one’s experiences in a more objective manner. Bernstein et al's. (2015) metacognitive processes model of decentering includes three interrelated processes; meta-awareness, disidentification from internal experience, and reduced reactivity to

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[21] Bendall, R.C.A., & Royle, S. (2018) Decentering mediates the relationship between vmPFC activation during a stressor and positive emotion during stress recovery. *Journal of Neurophysiology*, 120 (5), 2379-2382.

thought content. Prefrontal cortex (PFC) brain regions underpin cognitive processes involved in top-down control of emotion, as well as subcortical affective structures. The dorsolateral prefrontal cortex (dlPFC), ventrolateral prefrontal cortex (vlPFC), and dorsal anterior cingulate cortex (dACC) are involved in top-down regulation of emotion, and have been shown to moderate activity in subcortical systems (e.g. the amygdala) underpinning affective reactivity (Ochsner et al., 2012). Whilst there is no direct anatomical pathway connecting the dlPFC and the amygdala (Ray & Zald, 2012), it has been suggested that the dACC may serve as a mediation hub, allowing the dlPFC to exert an indirect influence on amygdala response (Ochsner et al., 2012). It has also been hypothesized that the vmPFC, which provides information about positive emotion and whose activity is positively correlated with PFC activation and negatively correlated with amygdala activation during emotion regulation (Ochsner et al., 2012), may act as a mediator within the dlPFC-amygdala pathway due to its anatomical connections with the amygdala and PFC regions (Ray & Zald, 2012). Although progress has been made advancing understanding of the role positive emotion has during stress recovery, the neural mechanisms supporting this are still poorly understood. A novel study by Yang et al. (2018) investigated the neural mechanisms underpinning the role of positive emotions during stress recovery. The authors tested the proposal that the vmPFC acts as a hub via which positive emotion influences stress recovery through the dlPFC-dACC-amygdala pathway, and additionally whether decentering can mitigate stress recovery.

Yang et al. required participants to complete a stressful anagram task whilst neural activation was recorded with functional magnetic resonance imaging (fMRI). Prior to the main experimental data collection session, participants were trained to use emotion rating scales, and practiced an easy version of the anagram task. Subsequently, participants completed a stressful anagram task containing 15 anagrams of which 5 were easy, 5 were difficult, and 5 were unsolvable. Participants viewed the anagrams for 4 seconds followed by a 5 second period in which they were required to solve the anagram and provide their answer on a keypad. Participants were provided with immediate feedback, however this feedback included artificially inflated scores with respect to other participants' performance. The stressful anagram task lasted for 3 minutes and upon completion participants viewed their overall performance alongside a comment stating that '73% of participants performed better than them'. Subsequently, individuals rated their emotion and then immediately began a 3 minute post-stressor recovery period during which they were asked to think about the anagram task and to engage in any thoughts and feelings that come naturally, whilst simultaneously watching either a positive or neutral video. Participants rated their emotions before the anagram task (baseline), after the anagram task (post-stressor), and after emotion induction (recovery); consisting of a positive emotion question (how pleasant do you feel right now?), and a negative emotion question (how unpleasant do you feel right now?). Responses were made on a 5-point scale with 0.5 increments. Next, participants completed a 5-point decentering questionnaire providing state measures of rumination and decentering (e.g. I had the sense that I was fully aware of what was going on around me and inside me). Finally, participants completed a post-task thought content questionnaire that asked questions relating to positive, negative, or irrelevant thoughts and feelings about the stressor (anagram task) and video. All statements (e.g. I thought that the video was calming) were presented on a 5-point scale. The fMRI analytical technique adopted change-point analysis to allow the identification of brain regions responsive to the stressor and recovery tasks. Yang et al. state that this approach provides a model-free method of detecting when and for how long anatomical regions are active during a given experimental session, enabling the identification of multiple activation peaks. Such analysis is not possible using traditional general linear modelling which is not designed to detect the precise timing or duration of changes in physiological data or psychological events. Change-point analysis permits researchers to map precisely when during an experimental protocol (e.g. the exact time during a stressor) hypothesized activation occurs, and this can be mapped to corresponding behavioural measures (e.g. self-reported stress recovery).

Yang et al. demonstrated that during the stressful anagram task, increased neural activation in medial frontal cortex regions including the vmPFC, dorsomedial prefrontal cortex (dmPFC) and anterior cingulate cortex were related to higher reported positive emotion during recovery. Importantly, this relationship was only evident for individuals reporting high levels of positive emotion (compared to low levels of positive emotion) during stress recovery. Secondary mediation analysis focussing on the vmPFC was carried out on an a priori basis. This approach revealed vmPFC activation during the stressor did not directly predict negative emotional recovery. However, the indirect path between vmPFC activation and negative emotional recovery via positive emotional recovery was significant, suggesting that increased vmPFC activation during the stressor predicted increased positive emotional recovery, and this association in turn improved negative emotional recovery. Exploratory analysis investigating possible relationships between vmPFC activation and stress reactivity demonstrated that overall vmPFC activation during the stressor was not related to emotional stress reactivity. However, when neural activation of the vmPFC during the stressor was investigated temporally, two differing relationships emerged in relation to stress reactivity. During the first half of the stressful anagram task increased vmPFC activity was associated with greater negative emotional reactivity, whereas during the middle portion of the stressor vmPFC activation was related to increased positive emotional recovery. This observation may represent a normal response profile to stress with early vmPFC activation indicative of an evaluation that the stressor is negative. Sustained vmPFC activity during the middle portion of the stressor, which is correlated with positive emotion recovery, may be reflective of successful regulation of the stressor. These findings suggest temporal differences in vmPFC activation during the stressor were related to different aspects of emotional recovery and demonstrate the advantage of employing a change-point analysis framework that allows temporal neural dynamics to be investigated. In clinical populations less effective at regulating stress recovery, and less likely to demonstrate typical vmPFC recruitment during stressful tasks, longitudinal research will be able to elucidate whether changes in vmPFC structural connectivity and functional activity are related to both clinical improvements in stress regulation and increased use of decentering.

To investigate individual difference traits that may moderate biobehavioural indices during stress and subsequent emotional recovery, trait levels of decentering were recorded. Decentering was positively correlated with vmPFC activation. Further, decentering was shown to mediate the relationship between positive emotional recovery and vmPFC activity, whereas the direct relationship between vmPFC activity and positive emotional recovery was non-significant. Taken together, these results provide novel evidence that vmPFC activation during a stressor impacts positive emotion and provides benefits on stress regulation not seen until recovery. Further, decentering was shown to mediate the relationship between vmPFC activation and positive emotion during stress recovery suggesting that decentering is important for successful stress recovery.

Although not discussed by Yang et al., decentering has recently become the focus of clinical research aimed at improving therapies for anxiety and depressive disorders. Psychiatric disorders including generalised anxiety disorder (GAD) and MDD are often characterized by reduced trait levels of decentering and altered activation of the default network (DN), comprising the medial prefrontal cortex and posterior cingulate cortex. Decentering is also associated with activation of these brain regions, and altered resting state activity in the DN system is observed in GAD and MDD, whilst associations in intrinsic functional connectivity of the DN have been observed as a function of changes in decentering (Fresco et al., 2017). Further, emotion regulation therapy, a theoretically derived and mechanistic focussed treatment targeting the normalization of biobehavioural deficits, has demonstrated reductions in GAD and MDD severity alongside clinical improvements in decentering (Renna et al., 2018). Yang et al. build upon these findings showing that decentering can mediate the relationship between activation of the vmPFC during a stressor and subsequent emotional recovery and suggests that decentering should be included in biobehavioural models of stress recovery.

It has been recommended that both positive and negative emotion conditions are included within affective neuroscience study designs (Bendall et al., 2016). Such an approach permits researchers to make more precise interpretations regarding the neurocognitive mechanisms underpinning affective processing. For instance, without a negative emotion condition included within a study design, authors may suggest any observed differences in neurocognitive indices between positive and neutral conditions are specific to the positive condition. However, it is possible that in some situations such an interpretation may not be the most appropriate with results instead reflecting a more general impact of valence. For example, brain regions including the amygdala, ventral striatum, dmPFC, and vlPFC have demonstrated increased activation in relation to positive valence and negative valence (Lindquist et al., 2016). Theoretical work also supports inclusion of both positive and negative emotion conditions. Yang et al. briefly discuss the broaden-and-build theory (Fredrickson, 2001) and provide a valid theoretical rationale as to why positive emotion may facilitate stress recovery (via positive emotions broadening of attention). However, the broaden-and-build theory also makes predictions regarding the impact of negative emotion on behaviour – predicting they have the opposite effect (a narrowing of attentional focus and reduction in cognitive resources). Future studies aimed at investigating the role of emotion on stress recovery should adopt positive emotion and negative emotion conditions, as well as neutral control conditions.

Self-report questionnaires are often adopted in affective neuroscience study designs. Whilst this approach provides one method of recording affective information there known limitations in self-report data (e.g. socially desirable responding). Indeed, Yang et al. acknowledge that future research would benefit from adopting more objective physiological indices of stress response (e.g., cortisol sampling to assess hypothalamic-pituitary-adrenal axis activity). Cardiovascular recovery following a stressful task has been investigated with results indicating blood pressure recovery was impeded by both negative emotion and rumination (repetitive and intrusive negatively-focused and unconstructive thought), but was not enhanced by positive emotion (Radstaak et al., 2011). A significant correlation between rumination and negative emotion recovery is observed by Yang et al., indicating that greater rumination led to less recovery, though no further exploration of this maladaptive coping strategy appears to have been conducted. Rumination has been related to a number of psychopathologies, including MDD, as well as to negative-valence-specific biases in attentional control that are associated with impaired inhibition and cognitive control (Koster et al., 2011), reinforcing the need to consider valence-specific effects alongside both adaptive and maladaptive coping strategies.

Future research should investigate the neurocognitive mechanisms underpinning beliefs about stress. Perception of relative stress harm has been shown to influence mortality rates where individuals who report higher levels of stress and believe that stress negatively impacts health suffer from increased risk of premature death (Keller et al., 2012). Such research would benefit from adopting longitudinal anatomical and functional neuroscientific approaches that permit the investigation of changes in brain morphology, structural connectivity and neural activity with respect to stress recovery and the mediating role of individual difference traits such as decentering.

Adopting an elegant and rigorous study design Yang et al. provide novel insights relevant to biobehavioural models of stress recovery and positive emotion demonstrating that decentering can mediate the relationship between vmPFC activation during a stressor and subsequent emotional recovery. The adoption of change-point analysis allowing temporal neural dynamics to be investigated revealed multiple vmPFC activity peaks during a stressor and these predicted different aspects of stress recovery. Research building upon these correlational findings adopting experimental manipulations is required to allow causal interpretations to be made. Such research will help to reveal the neurocognitive mechanisms underpinning successful stress recovery and should provide valuable insight to those wishing to develop evidence-based translational therapeutic interventions.

7.8. Conclusion

Developments in affective science and our understanding of the neurocognitive mechanisms supporting emotion-attention interactions will benefit the health and wellbeing of both non-clinical and clinical populations. Mixed findings are evident in the literature regarding the influence of emotion and stimuli valence on visual attention. Moreover, a lack of rigorous research investigating visuospatial attention has sought to extend findings using simple stimuli arrays to more realistic real-world scenes. The main aim of the thesis was to investigate affective influences on top-down visual attention. This was accomplished using three separate approaches centring on the investigation of the influences of emotion, stimuli valence and inter-individual differences in affective traits on visual attention. The experiments presented in this thesis provide several novel and important findings. Firstly, when considered independently, emotion had no impact on visual attention. Secondly, individuals with higher levels of extraversion demonstrated improved change detection compared to individuals with lower levels of extraversion. Moreover, negative emotion was shown to interact with extraversion to guide the allocation of attention. Additionally, task-irrelevant positive and negative real-world scenes were shown to influence visual attention in different ways suggesting that the specific valence of scenes may cue differing processing styles. Increased habitual use of two ER strategies, cognitive reappraisal, and expressive suppression, were shown to improve visual attention in a visual search task. Lastly, using fNIRS, negative emotion was shown to increase dlPFC and vlPFC neural activation during visual search. In conclusion, this thesis has presented novel findings regarding the influence of emotion and stimuli valence on visual attention within real-world scenes. It has shown that the influences of emotion on attention are more complex than the broaden-and-build theory suggests and provides new insights into the effects of inter-individual differences in affective traits on top-down selective visual attention.

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Appendix

Appendix One: Supplementary figures and tables

Supplementary Table 1. Emotional valence and arousal ratings of images used during emotion induction procedure taken from the International Affective Picture System (Lang et al., 2008).

Positive images			Neutral images			Negative images		
IAPS number	Valence	Arousal	IAPS number	Valence	Arousal	IAPS number	Valence	Arousal
1610	7.82	3.98	2101	4.49	3.46	2141	2.44	5.00
2058	7.91	5.09	2210	4.54	3.32	2205	1.95	4.53
2150	7.92	5.00	2215	4.63	3.38	2375	2.20	4.88
2314	7.55	4.00	2221	4.39	3.07	2900	2.56	4.61
2360	7.70	3.66	2383	4.72	3.41	3215	2.51	5.44
2398	7.48	4.74	5130	4.45	2.51	3220	2.49	5.52
2530	7.80	3.99	7025	4.63	2.71	9000	2.55	4.06
4622	7.46	4.11	7030	4.69	2.99	9007	2.49	5.03
5480	7.53	5.48	7031	4.52	2.03	9140	2.19	5.38
5700	7.61	5.68	7040	4.69	2.69	9332	2.25	5.34
5780	7.52	3.75	7044	4.69	3.94	9340	2.41	5.16
5829	7.65	4.68	7110	4.55	2.27	9419	2.55	5.19
7270	7.53	5.76	7130	4.77	3.35	9420	2.31	5.69
7502	7.75	5.91	7150	4.72	2.61	9421	2.21	5.04
7580	7.71	4.59	7180	4.73	3.43	9435	2.27	5.00
8200	7.54	6.35	7186	4.63	3.60	9560	2.12	5.50
8370	7.77	6.73	7224	4.45	2.81	9561	2.68	4.79
8380	7.56	5.74	7590	4.77	3.80	9810	2.09	6.62
8499	7.63	6.07	7705	4.77	2.65	9830	2.54	4.86
8502	7.51	5.78	8121	4.63	4.14	9901	2.27	5.70
	M = 7.65	*M* = 5.05		*M* = 4.62	*M* = 3.11		*M* = 2.35	*M* = 5.17

Supplementary Table 2. Emotional valence and arousal ratings of positive images presented at the end of the experimental session taken from the International Affective Picture System (Lang et al., 2008).

IAPS number	Valence	Arousal
1460	8.21	4.31
1710	8.34	5.41
1750	8.28	4.10
1920	7.90	4.27
2154	8.03	4.48
2332	7.64	4.30
2340	8.03	4.90
4626	7.60	5.78
5621	7.57	5.19
5760	8.05	3.22
5825	8.03	5.46
5830	8.00	4.92
5833	8.22	5.71
5910	7.80	5.59
7330	7.69	5.14
7405	7.38	6.28
8470	7.74	6.14
8496	7.58	5.79
8501	7.91	6.44
8540	7.48	5.16
	M = 7.87	*M* = 5.13

Supplementary Table 3. NAPS ID numbers.

Positive images

Animals_161_h	Landscapes_174_h	Objects_254_h	People_196_h
Animals_173_h	Landscapes_178_h	Objects_291_h	People_154_h
Animals_219_h	Landscapes_157_h	Objects_171_h	People_185_h
Animals_158_h	Landscapes_121_h	Objects_272_h	People_043_h
Animals_179_h	Landscapes_117_h	Objects_086_h	People_116_h
Animals_131_h	Landscapes_175_h	Objects_081_h	People_055_h
Animals_183_h	Landscapes_132_h	Objects_192_h	People_026_h
Animals_163_h	Landscapes_098_h	Objects_190_h	People_103_h
Animals_172_h	Landscapes_096_h	Objects_097_h	People_096_h
Animals_186_h	Landscapes_168_h	Objects_037_h	People_052_h
Animals_156_h	Landscapes_141_h	Objects_101_h	People_187_h
Animals_187_h	Landscapes_123_h	Objects_325_h	People_115_h
Animals_201_h	Landscapes_165_h	Objects_080_h	People_051_h
Animals_184_h	Landscapes_154_h	Objects_327_h	People_113_h
Animals_220_h	Landscapes_183_h	Objects_077_h	People_110_h
Animals_177_h	Landscapes_180_h	Objects_326_h	People_190_h

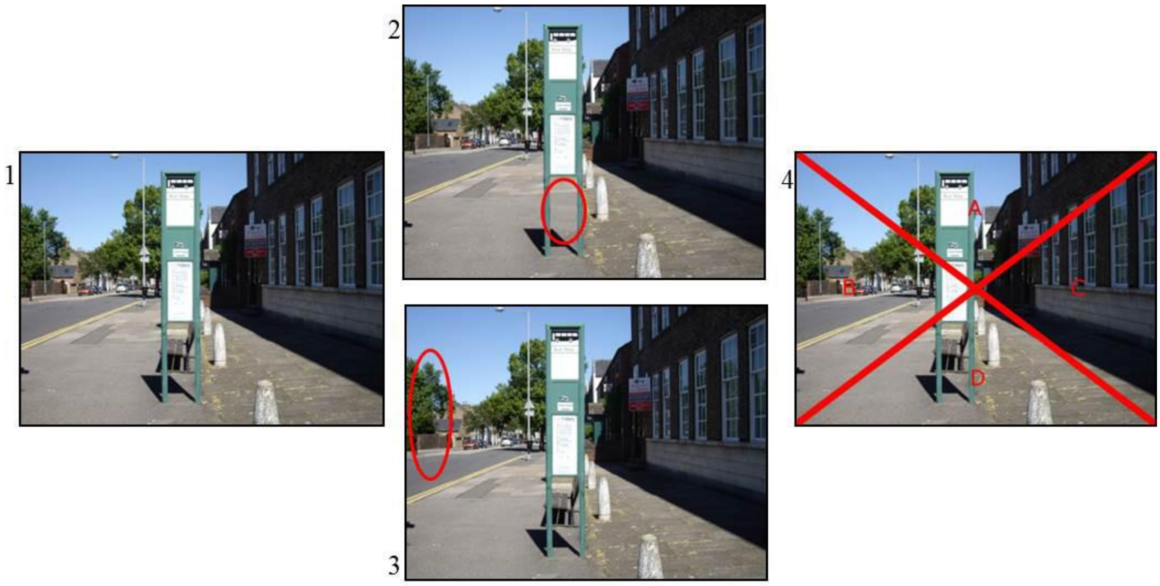
Neutral images

Animals_111_h	Landscapes_093_h	Objects_314_h	People_061_h
Animals_079_h	Landscapes_056_h	Objects_057_h	People_122_h
Animals_133_h	Landscapes_170_h	Objects_213_h	People_065_h
Animals_081_h	Landscapes_061_h	Objects_112_h	People_036_h
Animals_141_h	Landscapes_067_h	Objects_130_h	People_164_h
Animals_047_h	Landscapes_076_h	Objects_226_h	People_146_h
Animals_011_h	Landscapes_044_h	Objects_071_h	People_100_h
Animals_072_h	Landscapes_016_h	Objects_067_h	People_150_h
Animals_058_h	Landscapes_091_h	Objects_308_h	People_095_h
Animals_127_h	Landscapes_019_h	Objects_119_h	People_091_h
Animals_035_h	Landscapes_036_h	Objects_311_h	People_097_h
Animals_014_h	Landscapes_060_h	Objects_050_h	People_042_h
Animals_129_h	Landscapes_181_h	Objects_244_h	People_155_h
Animals_083_h	Landscapes_043_h	Objects_189_h	People_104_h
Animals_003_h	Landscapes_020_h	Objects_299_h	People_132_h
Animals_043_h	Landscapes_159_h	Objects_089_h	People_135_h
Animals_177_h	Landscapes_180_h	Objects_326_h	People_190_h

Negative images

Animals_016_h	Landscapes_001_h	Objects_126_h	People_127_h
Animals_074_h	Landscapes_025_h	Objects_125_h	People_222_h
Animals_056_h	Landscapes_028_h	Objects_139_h	People_128_h
Animals_077_h	Landscapes_139_h	Objects_149_h	People_200_h
Animals_078_h	Landscapes_026_h	Objects_003_h	People_238_h
Animals_071_h	Landscapes_022_h	Objects_283_h	People_198_h
Animals_033_h	Landscapes_002_h	Objects_002_h	People_237_h
Animals_024_h	Landscapes_007_h	Objects_001_h	People_038_h
Animals_039_h	Landscapes_004_h	Objects_285_h	People_226_h
Animals_063_h	Landscapes_005_h	Objects_011_h	People_240_h
Animals_062_h	Landscapes_177_h	Objects_132_h	People_208_h
Animals_027_h	Landscapes_017_h	Objects_157_h	People_227_h
Animals_068_h	Landscapes_010_h	Objects_007_h	People_221_h
Animals_001_h	Landscapes_014_h	Objects_144_h	People_246_h
Animals_054_h	Landscapes_011_h	Objects_022_h	People_220_h
Animals_025_h	Landscapes_068_h	Objects_004_h	People_022_h

Supplementary Figure 1.

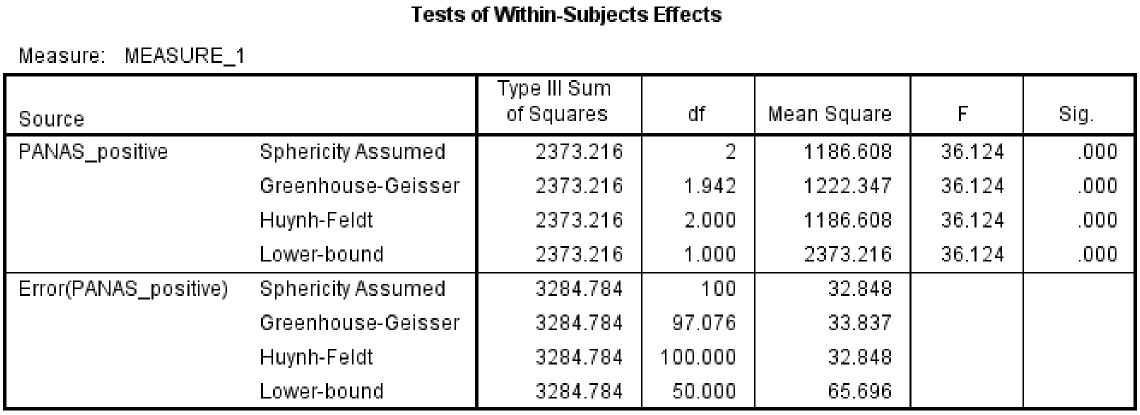


Supplementary Figure 1. Example change detection trial stimuli. In each trial participants viewed an original image (1) followed by an image with an item removed from either the centre (2) or the periphery (3). Once the change had been detected a response screen was presented for participants to indicate the location of the change (4).

Appendix Two: Statistical output

Experiment One

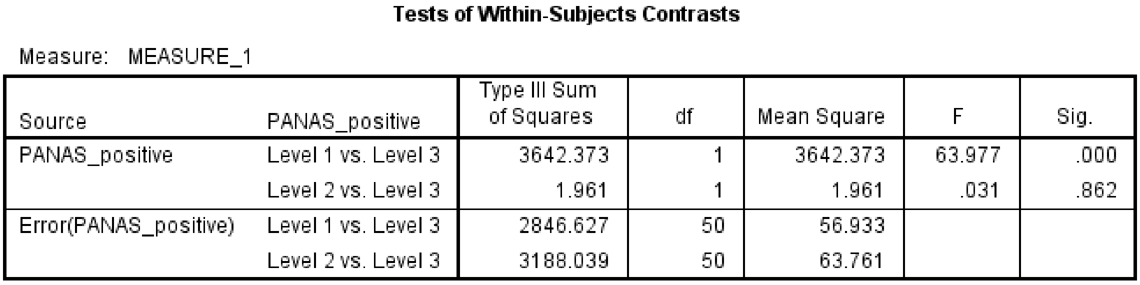
PANAS positive affect



Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PANAS_positive	Sphericity Assumed	2373.216	2	1186.608	36.124	.000
	Greenhouse-Geisser	2373.216	1.942	1222.347	36.124	.000
	Huynh-Feldt	2373.216	2.000	1186.608	36.124	.000
	Lower-bound	2373.216	1.000	2373.216	36.124	.000
Error(PANAS_positive)	Sphericity Assumed	3284.784	100	32.848		
	Greenhouse-Geisser	3284.784	97.076	33.837		
	Huynh-Feldt	3284.784	100.000	32.848		
	Lower-bound	3284.784	50.000	65.696		

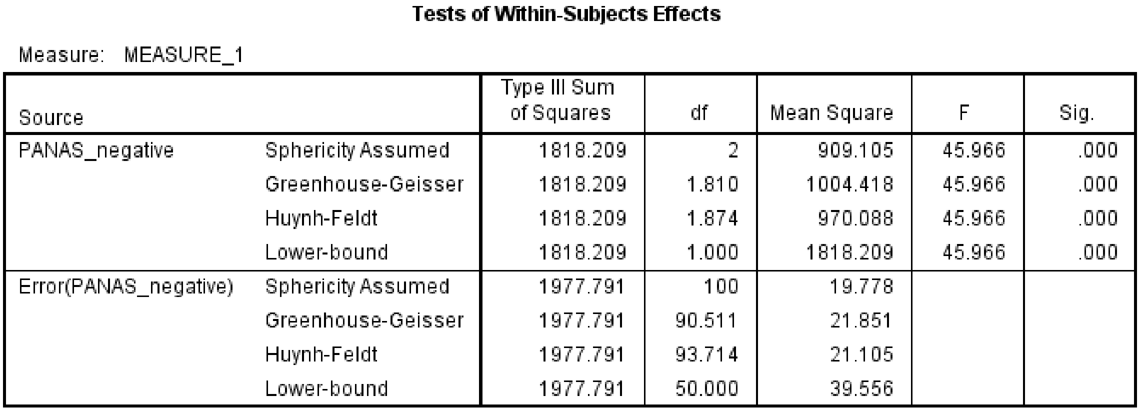


Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	PANAS_positive	Type III Sum of Squares	df	Mean Square	F	Sig.
PANAS_positive	Level 1 vs. Level 3	3642.373	1	3642.373	63.977	.000
	Level 2 vs. Level 3	1.961	1	1.961	.031	.862
Error(PANAS_positive)	Level 1 vs. Level 3	2846.627	50	56.933		
	Level 2 vs. Level 3	3188.039	50	63.761		

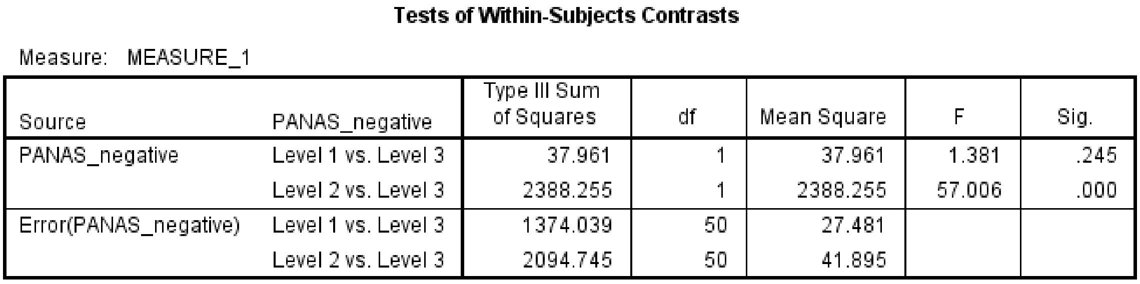
PANAS negative affect



Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PANAS_negative	Sphericity Assumed	1818.209	2	909.105	45.966	.000
	Greenhouse-Geisser	1818.209	1.810	1004.418	45.966	.000
	Huynh-Feldt	1818.209	1.874	970.088	45.966	.000
	Lower-bound	1818.209	1.000	1818.209	45.966	.000
Error(PANAS_negative)	Sphericity Assumed	1977.791	100	19.778		
	Greenhouse-Geisser	1977.791	90.511	21.851		
	Huynh-Feldt	1977.791	93.714	21.105		
	Lower-bound	1977.791	50.000	39.556		

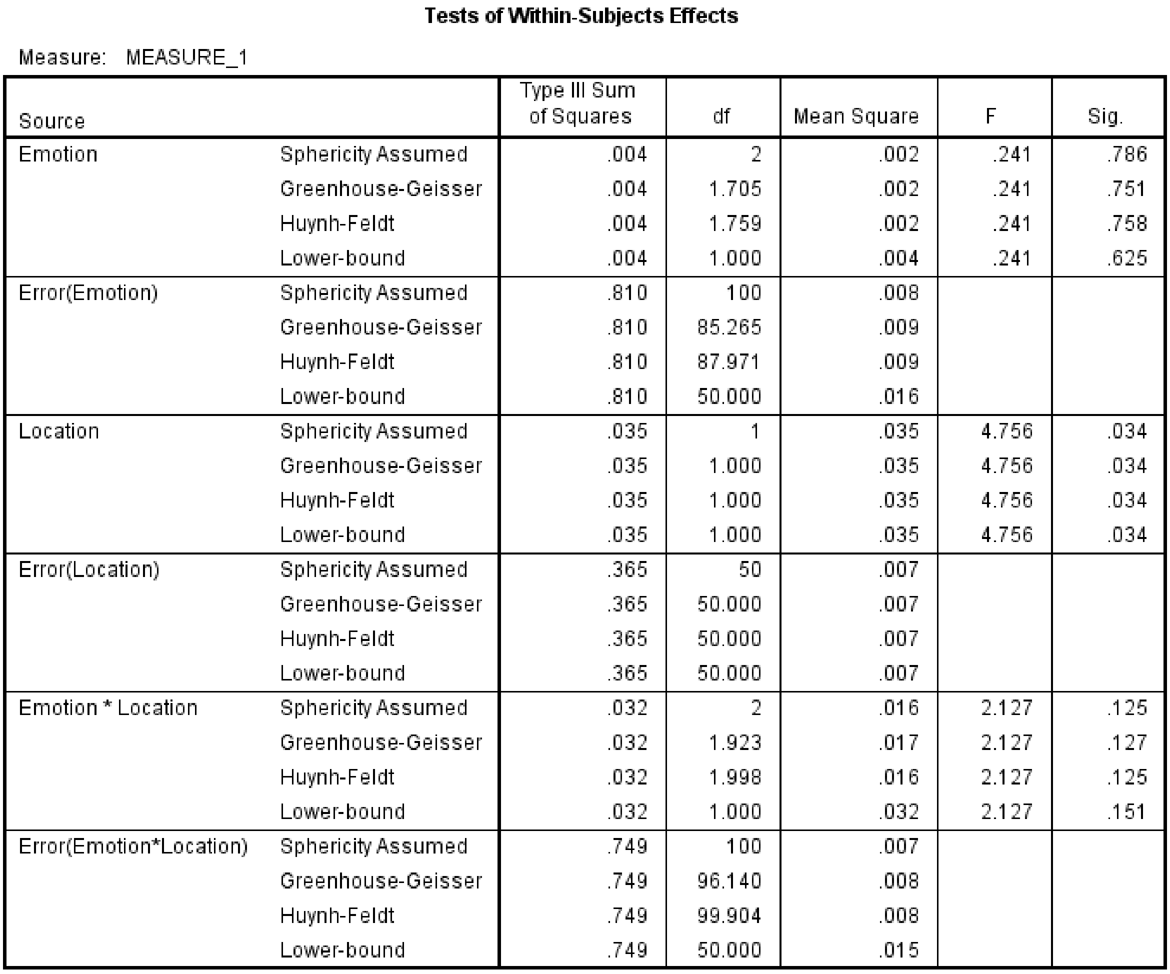


Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	PANAS_negative	Type III Sum of Squares	df	Mean Square	F	Sig.
PANAS_negative	Level 1 vs. Level 3	37.961	1	37.961	1.381	.245
	Level 2 vs. Level 3	2388.255	1	2388.255	57.006	.000
Error(PANAS_negative)	Level 1 vs. Level 3	1374.039	50	27.481		
	Level 2 vs. Level 3	2094.745	50	41.895		

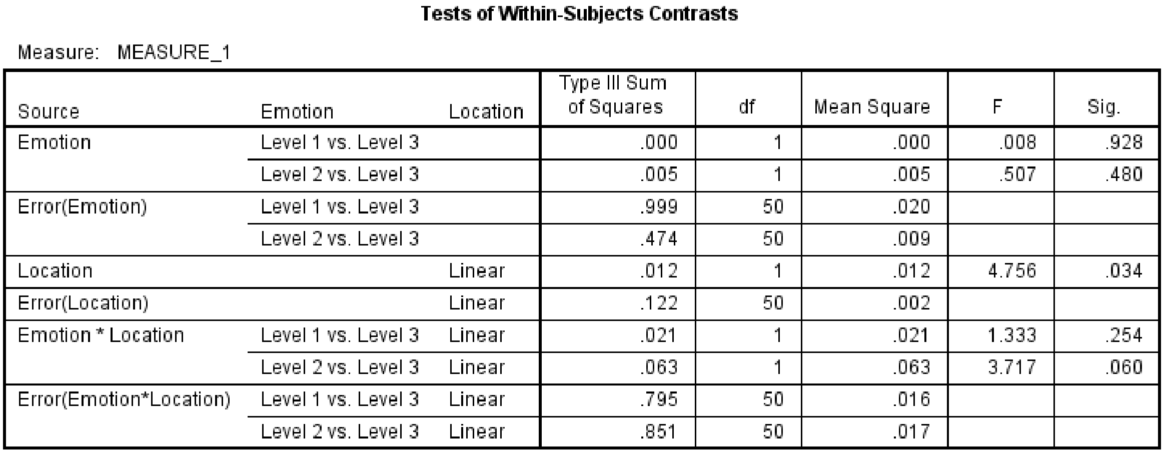
Accuracy



Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Emotion	Sphericity Assumed	.004	2	.002	.241	.786
	Greenhouse-Geisser	.004	1.705	.002	.241	.751
	Huynh-Feldt	.004	1.759	.002	.241	.758
	Lower-bound	.004	1.000	.004	.241	.625
Error(Emotion)	Sphericity Assumed	.810	100	.008		
	Greenhouse-Geisser	.810	85.265	.009		
	Huynh-Feldt	.810	87.971	.009		
	Lower-bound	.810	50.000	.016		
Location	Sphericity Assumed	.035	1	.035	4.756	.034
	Greenhouse-Geisser	.035	1.000	.035	4.756	.034
	Huynh-Feldt	.035	1.000	.035	4.756	.034
	Lower-bound	.035	1.000	.035	4.756	.034
Error(Location)	Sphericity Assumed	.365	50	.007		
	Greenhouse-Geisser	.365	50.000	.007		
	Huynh-Feldt	.365	50.000	.007		
	Lower-bound	.365	50.000	.007		
Emotion * Location	Sphericity Assumed	.032	2	.016	2.127	.125
	Greenhouse-Geisser	.032	1.923	.017	2.127	.127
	Huynh-Feldt	.032	1.998	.016	2.127	.125
	Lower-bound	.032	1.000	.032	2.127	.151
Error(Emotion*Location)	Sphericity Assumed	.749	100	.007		
	Greenhouse-Geisser	.749	96.140	.008		
	Huynh-Feldt	.749	99.904	.008		
	Lower-bound	.749	50.000	.015		

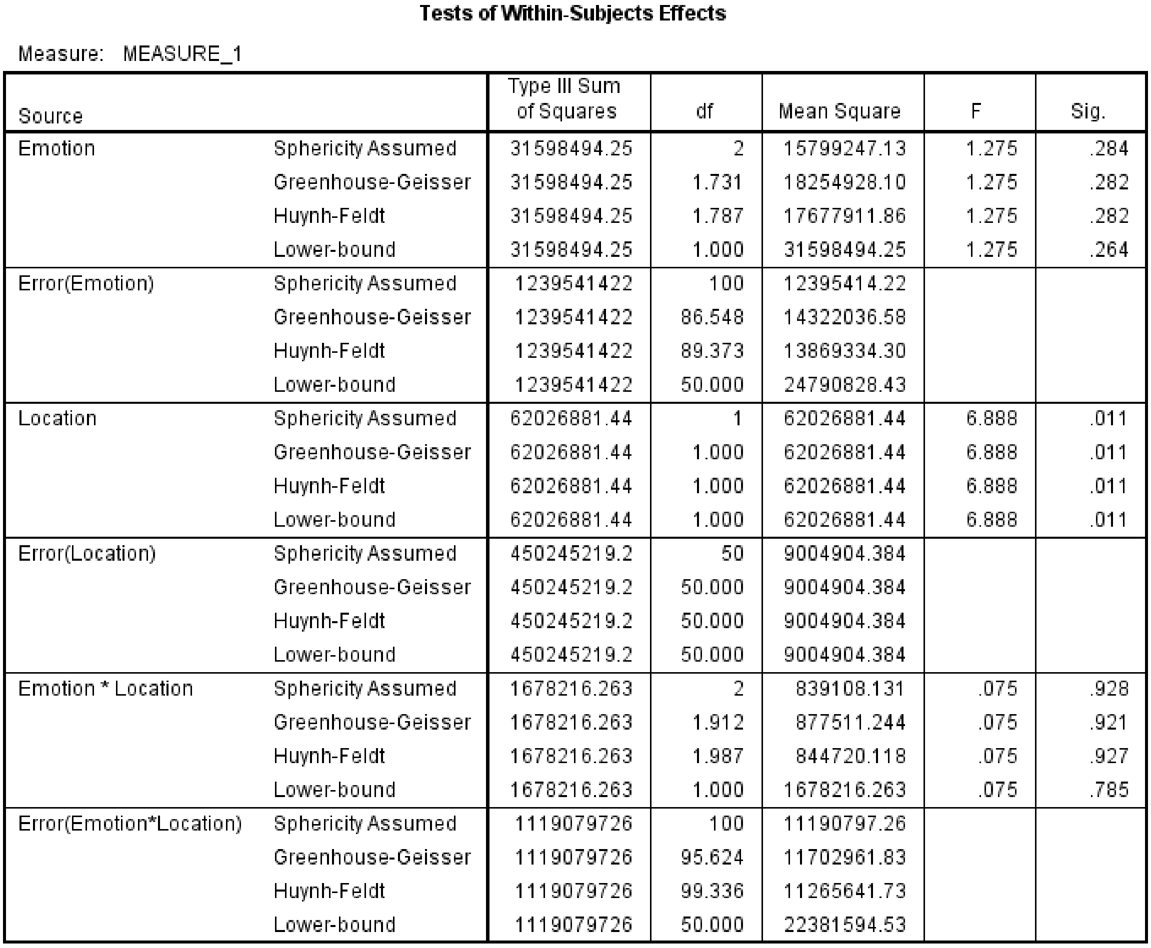


Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Emotion	Location	Type III Sum of Squares	df	Mean Square	F	Sig.
Emotion	Level 1 vs. Level 3		.000	1	.000	.008	.928
	Level 2 vs. Level 3		.005	1	.005	.507	.480
Error(Emotion)	Level 1 vs. Level 3		.999	50	.020		
	Level 2 vs. Level 3		.474	50	.009		
Location		Linear	.012	1	.012	4.756	.034
Error(Location)		Linear	.122	50	.002		
Emotion * Location	Level 1 vs. Level 3	Linear	.021	1	.021	1.333	.254
	Level 2 vs. Level 3	Linear	.063	1	.063	3.717	.060
Error(Emotion*Location)	Level 1 vs. Level 3	Linear	.795	50	.016		
	Level 2 vs. Level 3	Linear	.851	50	.017		

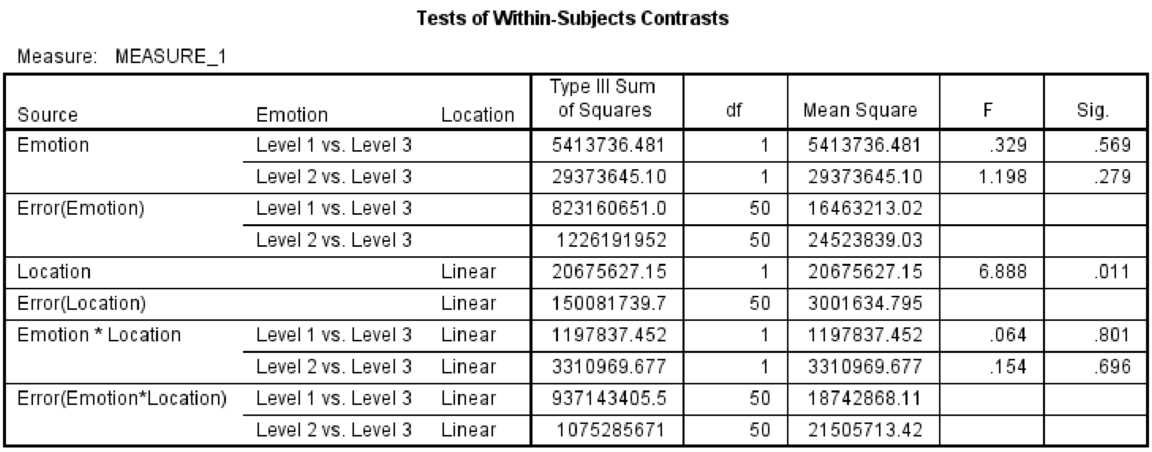
Reaction time



Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Emotion	Sphericity Assumed	31598494.25	2	15799247.13	1.275	.284
	Greenhouse-Geisser	31598494.25	1.731	18254928.10	1.275	.282
	Huynh-Feldt	31598494.25	1.787	17677911.86	1.275	.282
	Lower-bound	31598494.25	1.000	31598494.25	1.275	.264
Error(Emotion)	Sphericity Assumed	1239541422	100	12395414.22		
	Greenhouse-Geisser	1239541422	86.548	14322036.58		
	Huynh-Feldt	1239541422	89.373	13869334.30		
	Lower-bound	1239541422	50.000	24790828.43		
Location	Sphericity Assumed	62026881.44	1	62026881.44	6.888	.011
	Greenhouse-Geisser	62026881.44	1.000	62026881.44	6.888	.011
	Huynh-Feldt	62026881.44	1.000	62026881.44	6.888	.011
	Lower-bound	62026881.44	1.000	62026881.44	6.888	.011
Error(Location)	Sphericity Assumed	450245219.2	50	9004904.384		
	Greenhouse-Geisser	450245219.2	50.000	9004904.384		
	Huynh-Feldt	450245219.2	50.000	9004904.384		
	Lower-bound	450245219.2	50.000	9004904.384		
Emotion * Location	Sphericity Assumed	1678216.263	2	839108.131	.075	.928
	Greenhouse-Geisser	1678216.263	1.912	877511.244	.075	.921
	Huynh-Feldt	1678216.263	1.987	844720.118	.075	.927
	Lower-bound	1678216.263	1.000	1678216.263	.075	.785
Error(Emotion*Location)	Sphericity Assumed	1119079726	100	11190797.26		
	Greenhouse-Geisser	1119079726	95.624	11702961.83		
	Huynh-Feldt	1119079726	99.336	11265641.73		
	Lower-bound	1119079726	50.000	22381594.53		



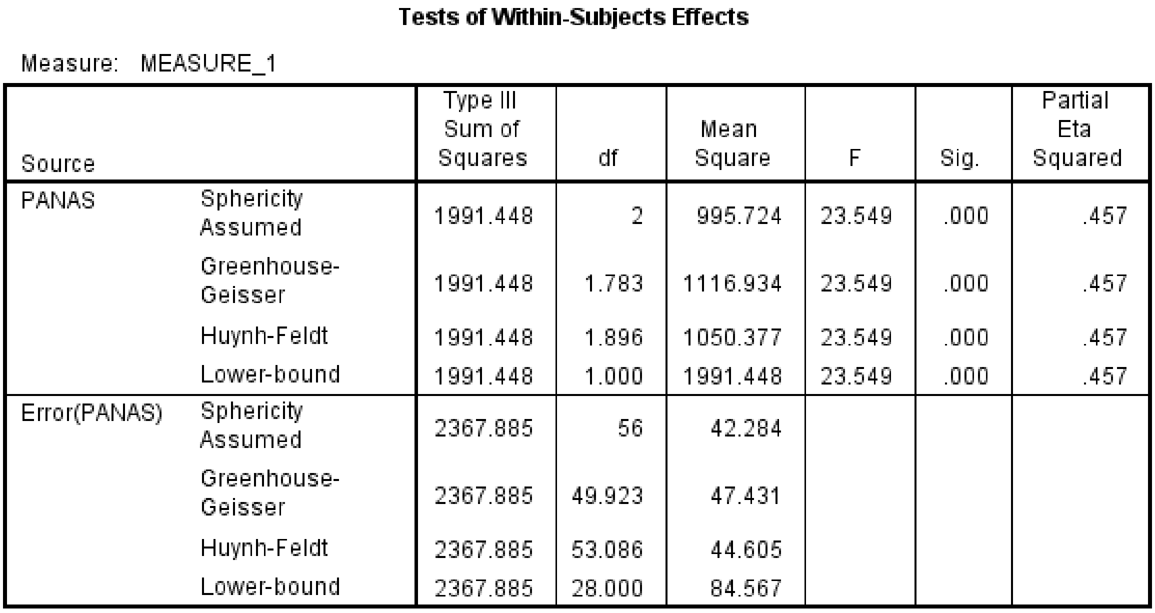
Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Emotion	Location	Type III Sum of Squares	df	Mean Square	F	Sig.
Emotion	Level 1 vs. Level 3		5413736.481	1	5413736.481	.329	.569
	Level 2 vs. Level 3		29373645.10	1	29373645.10	1.198	.279
Error(Emotion)	Level 1 vs. Level 3		823160651.0	50	16463213.02		
	Level 2 vs. Level 3		1226191952	50	24523839.03		
Location		Linear	20675627.15	1	20675627.15	6.888	.011
Error(Location)		Linear	150081739.7	50	3001634.795		
Emotion * Location	Level 1 vs. Level 3	Linear	1197837.452	1	1197837.452	.064	.801
	Level 2 vs. Level 3	Linear	3310969.677	1	3310969.677	.154	.696
Error(Emotion*Location)	Level 1 vs. Level 3	Linear	937143405.5	50	18742868.11		
	Level 2 vs. Level 3	Linear	1075285671	50	21505713.42		

Experiment Two

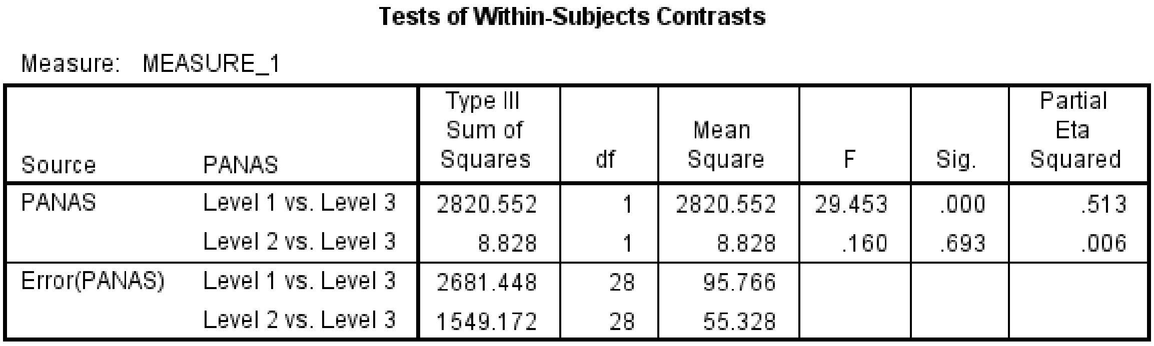
PANAS positive affect



Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
PANAS	Sphericity Assumed	1991.448	2	995.724	23.549	.000	.457
	Greenhouse-Geisser	1991.448	1.783	1116.934	23.549	.000	.457
	Huynh-Feldt	1991.448	1.896	1050.377	23.549	.000	.457
	Lower-bound	1991.448	1.000	1991.448	23.549	.000	.457
Error(PANAS)	Sphericity Assumed	2367.885	56	42.284			
	Greenhouse-Geisser	2367.885	49.923	47.431			
	Huynh-Feldt	2367.885	53.086	44.605			
	Lower-bound	2367.885	28.000	84.567			

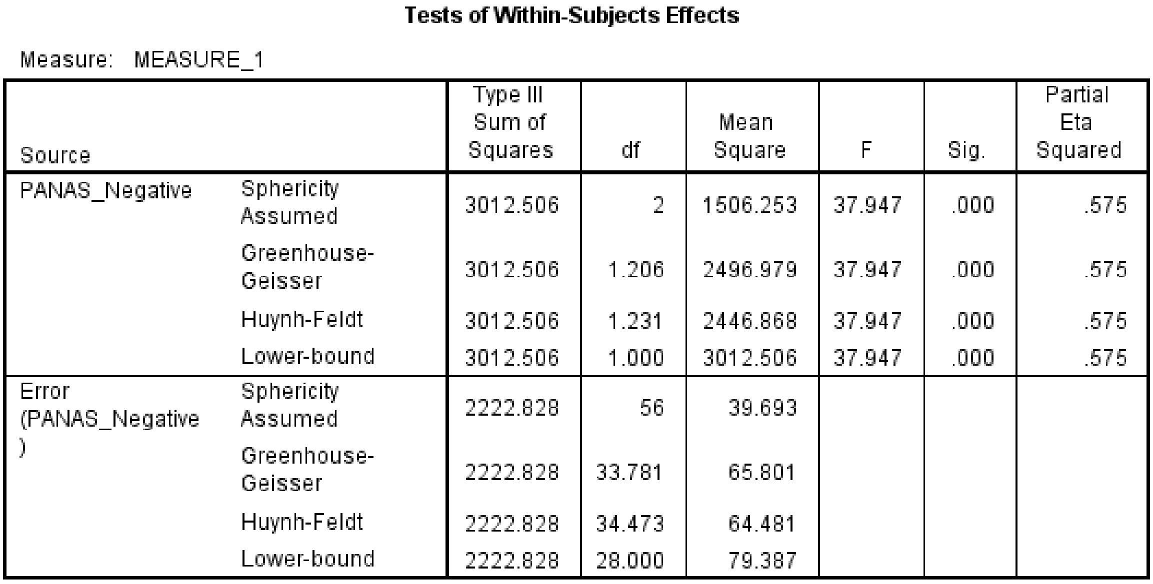


Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	PANAS	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
PANAS	Level 1 vs. Level 3	2820.552	1	2820.552	29.453	.000	.513
	Level 2 vs. Level 3	8.828	1	8.828	.160	.693	.006
Error(PANAS)	Level 1 vs. Level 3	2681.448	28	95.766			
	Level 2 vs. Level 3	1549.172	28	55.328			

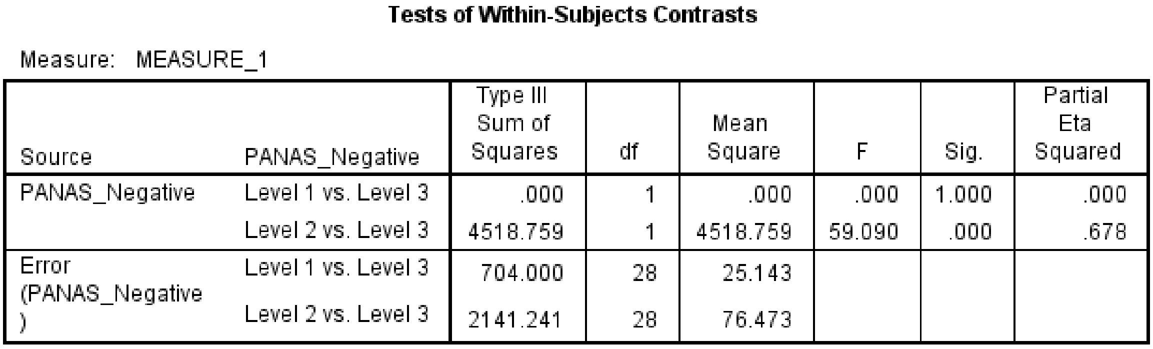
PANAS negative affect



Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
PANAS_Negative	Sphericity Assumed	3012.506	2	1506.253	37.947	.000	.575
	Greenhouse-Geisser	3012.506	1.206	2496.979	37.947	.000	.575
	Huynh-Feldt	3012.506	1.231	2446.868	37.947	.000	.575
	Lower-bound	3012.506	1.000	3012.506	37.947	.000	.575
Error (PANAS_Negative)	Sphericity Assumed	2222.828	56	39.693			
	Greenhouse-Geisser	2222.828	33.781	65.801			
	Huynh-Feldt	2222.828	34.473	64.481			
	Lower-bound	2222.828	28.000	79.387			

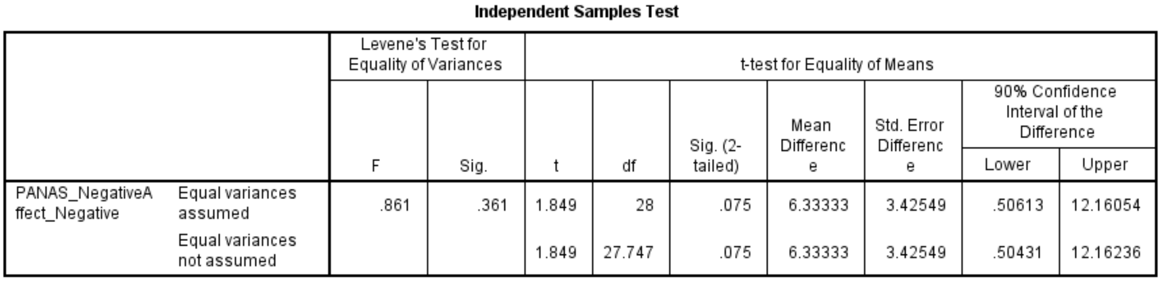


Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	PANAS_Negative	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
PANAS_Negative	Level 1 vs. Level 3	.000	1	.000	.000	1.000	.000
	Level 2 vs. Level 3	4518.759	1	4518.759	59.090	.000	.678
Error (PANAS_Negative)	Level 1 vs. Level 3	704.000	28	25.143			
	Level 2 vs. Level 3	2141.241	28	76.473			

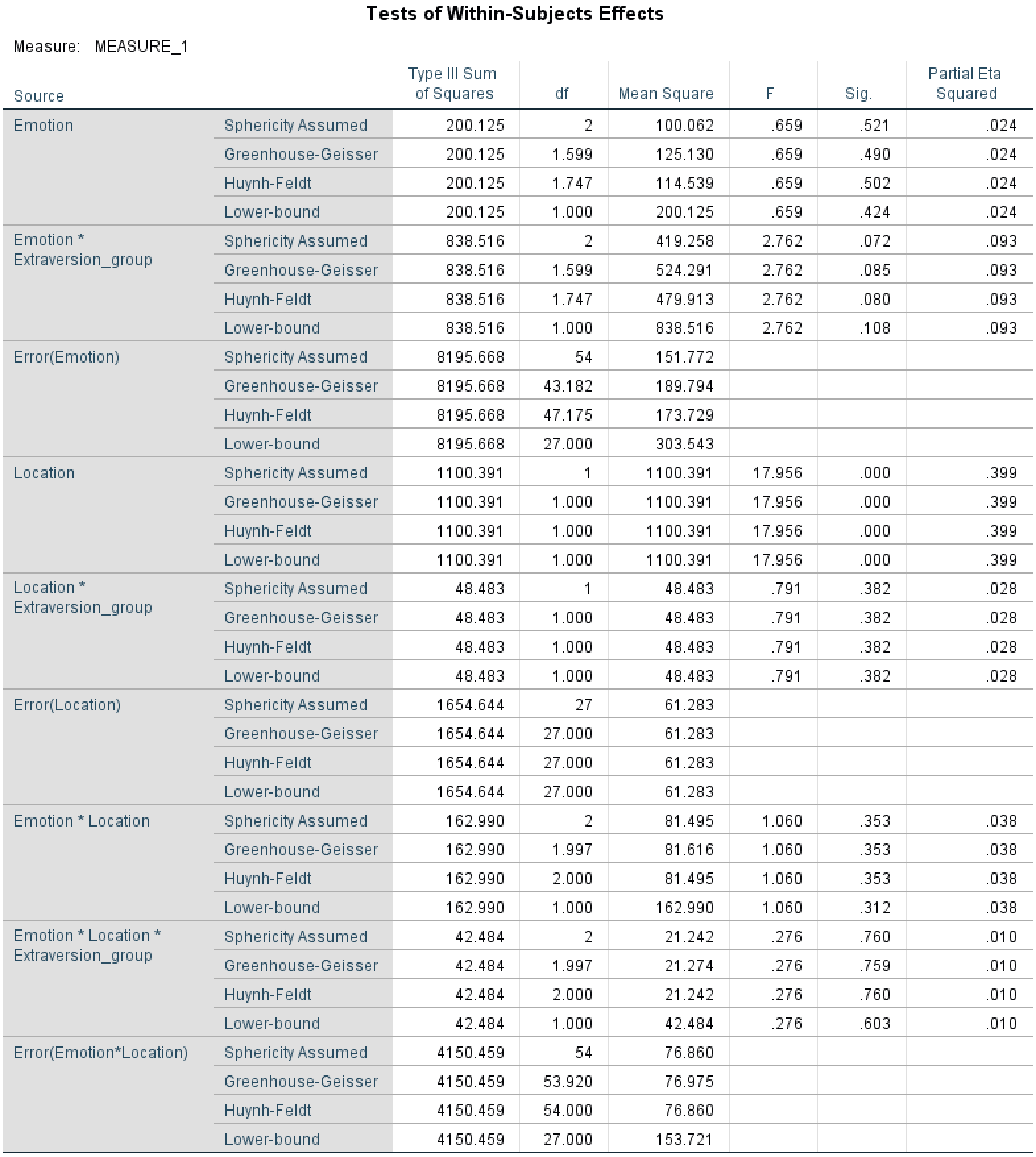
PANAS negative affect x extraversion



Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									90% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PANAS_NegativeAffect_Negative	Equal variances assumed	.861	.361	1.849	28	.075	6.33333	3.42549	.50613	12.16054
	Equal variances not assumed			1.849	27.747	.075	6.33333	3.42549	.50431	12.16236

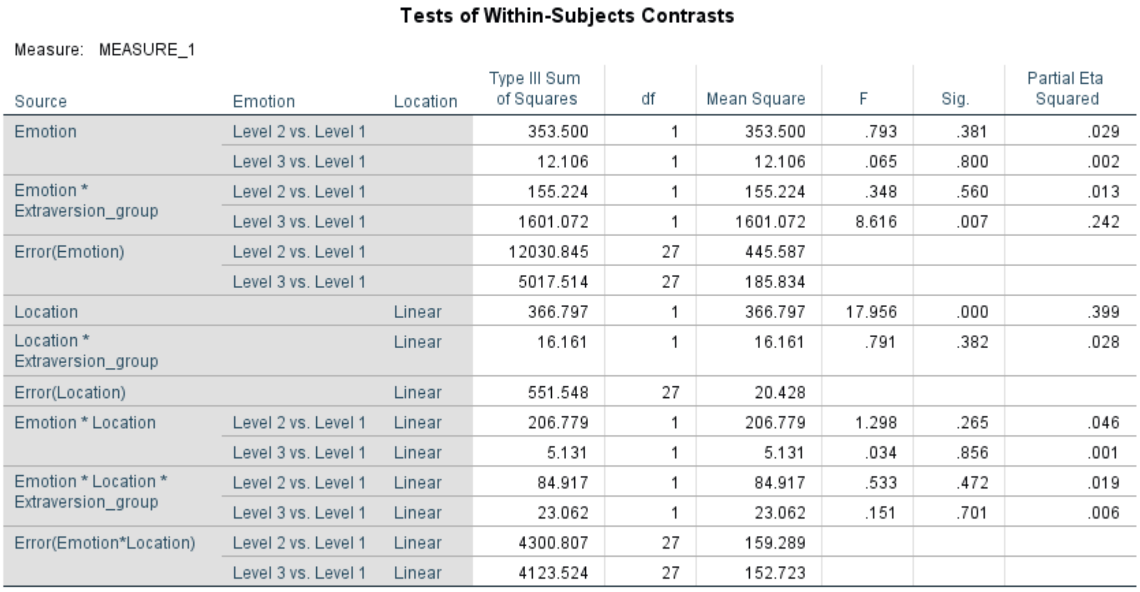
Accuracy



Tests of Within-Subjects Effects

Measure: MEASURE_1

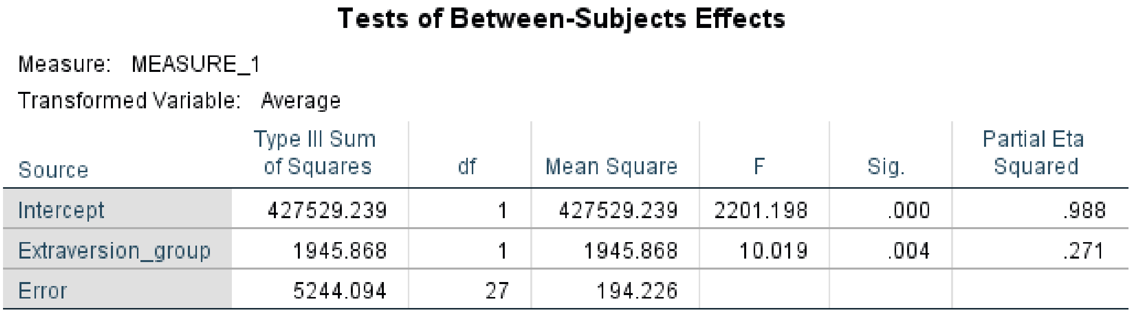
Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Emotion	Sphericity Assumed	200.125	2	100.062	.659	.521	.024
	Greenhouse-Geisser	200.125	1.599	125.130	.659	.490	.024
	Huynh-Feldt	200.125	1.747	114.539	.659	.502	.024
	Lower-bound	200.125	1.000	200.125	.659	.424	.024
Emotion * Extraversion_group	Sphericity Assumed	838.516	2	419.258	2.762	.072	.093
	Greenhouse-Geisser	838.516	1.599	524.291	2.762	.085	.093
	Huynh-Feldt	838.516	1.747	479.913	2.762	.080	.093
	Lower-bound	838.516	1.000	838.516	2.762	.108	.093
Error(Emotion)	Sphericity Assumed	8195.668	54	151.772			
	Greenhouse-Geisser	8195.668	43.182	189.794			
	Huynh-Feldt	8195.668	47.175	173.729			
	Lower-bound	8195.668	27.000	303.543			
Location	Sphericity Assumed	1100.391	1	1100.391	17.956	.000	.399
	Greenhouse-Geisser	1100.391	1.000	1100.391	17.956	.000	.399
	Huynh-Feldt	1100.391	1.000	1100.391	17.956	.000	.399
	Lower-bound	1100.391	1.000	1100.391	17.956	.000	.399
Location * Extraversion_group	Sphericity Assumed	48.483	1	48.483	.791	.382	.028
	Greenhouse-Geisser	48.483	1.000	48.483	.791	.382	.028
	Huynh-Feldt	48.483	1.000	48.483	.791	.382	.028
	Lower-bound	48.483	1.000	48.483	.791	.382	.028
Error(Location)	Sphericity Assumed	1654.644	27	61.283			
	Greenhouse-Geisser	1654.644	27.000	61.283			
	Huynh-Feldt	1654.644	27.000	61.283			
	Lower-bound	1654.644	27.000	61.283			
Emotion * Location	Sphericity Assumed	162.990	2	81.495	1.060	.353	.038
	Greenhouse-Geisser	162.990	1.997	81.616	1.060	.353	.038
	Huynh-Feldt	162.990	2.000	81.495	1.060	.353	.038
	Lower-bound	162.990	1.000	162.990	1.060	.312	.038
Emotion * Location * Extraversion_group	Sphericity Assumed	42.484	2	21.242	.276	.760	.010
	Greenhouse-Geisser	42.484	1.997	21.274	.276	.759	.010
	Huynh-Feldt	42.484	2.000	21.242	.276	.760	.010
	Lower-bound	42.484	1.000	42.484	.276	.603	.010
Error(Emotion*Location)	Sphericity Assumed	4150.459	54	76.860			
	Greenhouse-Geisser	4150.459	53.920	76.975			
	Huynh-Feldt	4150.459	54.000	76.860			
	Lower-bound	4150.459	27.000	153.721			



Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Emotion	Location	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Emotion	Level 2 vs. Level 1		353.500	1	353.500	.793	.381	.029
	Level 3 vs. Level 1		12.106	1	12.106	.065	.800	.002
Emotion * Extraversion_group	Level 2 vs. Level 1		155.224	1	155.224	.348	.560	.013
	Level 3 vs. Level 1		1601.072	1	1601.072	8.616	.007	.242
Error(Emotion)	Level 2 vs. Level 1		12030.845	27	445.587			
	Level 3 vs. Level 1		5017.514	27	185.834			
Location		Linear	366.797	1	366.797	17.956	.000	.399
Location * Extraversion_group		Linear	16.161	1	16.161	.791	.382	.028
Error(Location)		Linear	551.548	27	20.428			
Emotion * Location	Level 2 vs. Level 1	Linear	206.779	1	206.779	1.298	.265	.046
	Level 3 vs. Level 1	Linear	5.131	1	5.131	.034	.856	.001
Emotion * Location * Extraversion_group	Level 2 vs. Level 1	Linear	84.917	1	84.917	.533	.472	.019
	Level 3 vs. Level 1	Linear	23.062	1	23.062	.151	.701	.006
Error(Emotion*Location)	Level 2 vs. Level 1	Linear	4300.807	27	159.289			
	Level 3 vs. Level 1	Linear	4123.524	27	152.723			



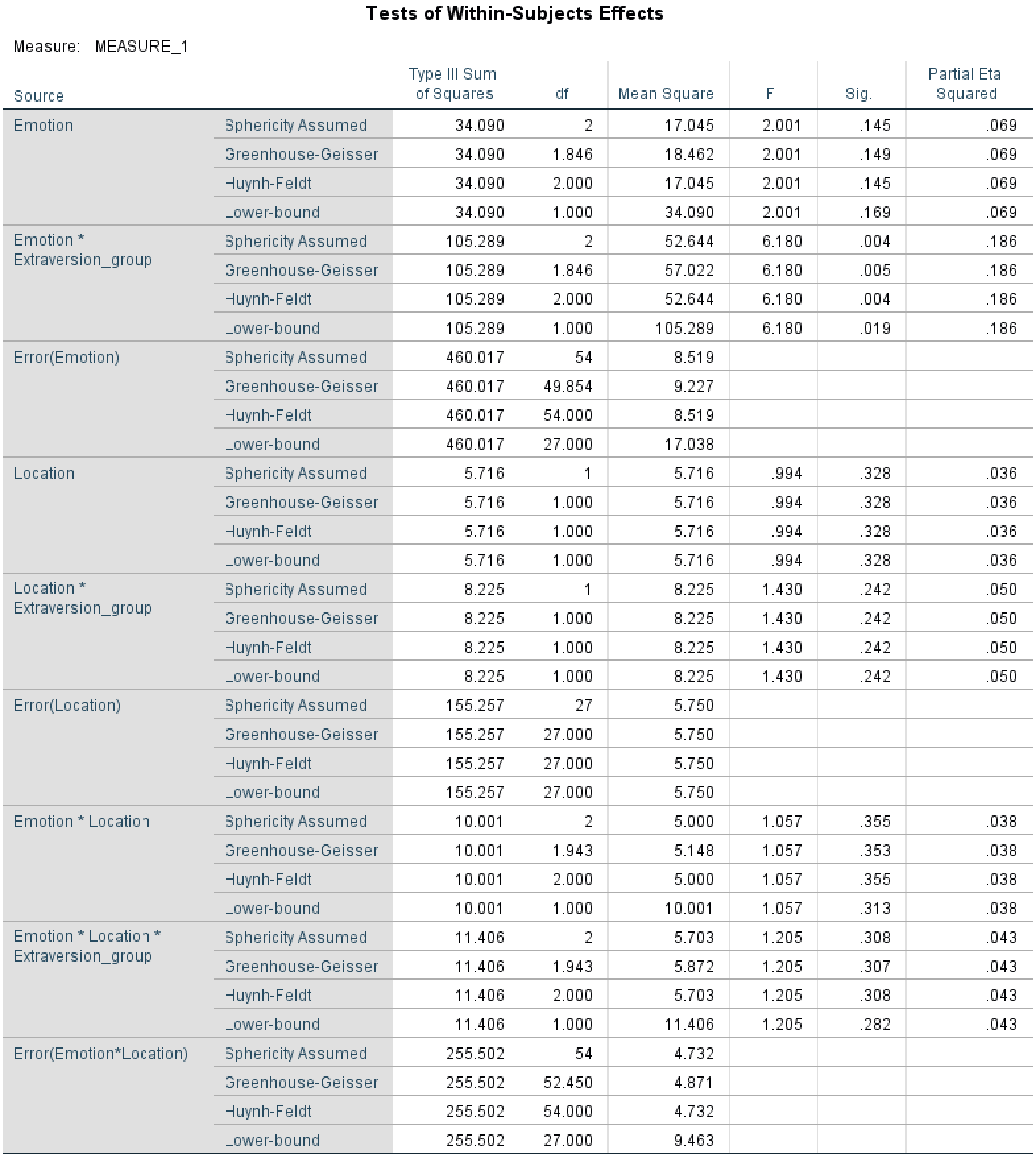
Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	427529.239	1	427529.239	2201.198	.000	.988
Extraversion_group	1945.868	1	1945.868	10.019	.004	.271
Error	5244.094	27	194.226			

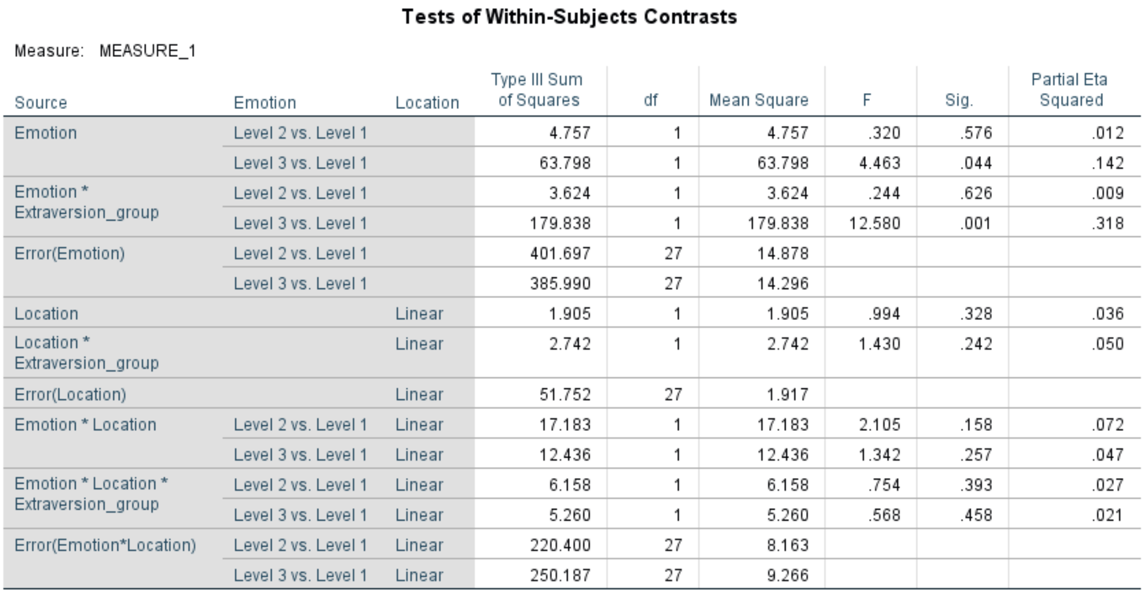
Reaction time



Tests of Within-Subjects Effects

Measure: MEASURE_1

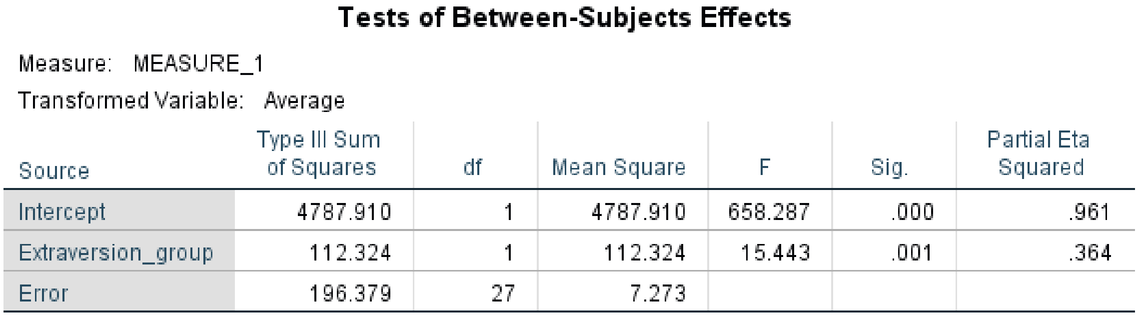
Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Emotion	Sphericity Assumed	34.090	2	17.045	2.001	.145	.069
	Greenhouse-Geisser	34.090	1.846	18.462	2.001	.149	.069
	Huynh-Feldt	34.090	2.000	17.045	2.001	.145	.069
	Lower-bound	34.090	1.000	34.090	2.001	.169	.069
Emotion * Extraversion_group	Sphericity Assumed	105.289	2	52.644	6.180	.004	.186
	Greenhouse-Geisser	105.289	1.846	57.022	6.180	.005	.186
	Huynh-Feldt	105.289	2.000	52.644	6.180	.004	.186
	Lower-bound	105.289	1.000	105.289	6.180	.019	.186
Error(Emotion)	Sphericity Assumed	460.017	54	8.519			
	Greenhouse-Geisser	460.017	49.854	9.227			
	Huynh-Feldt	460.017	54.000	8.519			
	Lower-bound	460.017	27.000	17.038			
Location	Sphericity Assumed	5.716	1	5.716	.994	.328	.036
	Greenhouse-Geisser	5.716	1.000	5.716	.994	.328	.036
	Huynh-Feldt	5.716	1.000	5.716	.994	.328	.036
	Lower-bound	5.716	1.000	5.716	.994	.328	.036
Location * Extraversion_group	Sphericity Assumed	8.225	1	8.225	1.430	.242	.050
	Greenhouse-Geisser	8.225	1.000	8.225	1.430	.242	.050
	Huynh-Feldt	8.225	1.000	8.225	1.430	.242	.050
	Lower-bound	8.225	1.000	8.225	1.430	.242	.050
Error(Location)	Sphericity Assumed	155.257	27	5.750			
	Greenhouse-Geisser	155.257	27.000	5.750			
	Huynh-Feldt	155.257	27.000	5.750			
	Lower-bound	155.257	27.000	5.750			
Emotion * Location	Sphericity Assumed	10.001	2	5.000	1.057	.355	.038
	Greenhouse-Geisser	10.001	1.943	5.148	1.057	.353	.038
	Huynh-Feldt	10.001	2.000	5.000	1.057	.355	.038
	Lower-bound	10.001	1.000	10.001	1.057	.313	.038
Emotion * Location * Extraversion_group	Sphericity Assumed	11.406	2	5.703	1.205	.308	.043
	Greenhouse-Geisser	11.406	1.943	5.872	1.205	.307	.043
	Huynh-Feldt	11.406	2.000	5.703	1.205	.308	.043
	Lower-bound	11.406	1.000	11.406	1.205	.282	.043
Error(Emotion*Location)	Sphericity Assumed	255.502	54	4.732			
	Greenhouse-Geisser	255.502	52.450	4.871			
	Huynh-Feldt	255.502	54.000	4.732			
	Lower-bound	255.502	27.000	9.463			



Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Emotion	Location	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Emotion	Level 2 vs. Level 1		4.757	1	4.757	.320	.576	.012
	Level 3 vs. Level 1		63.798	1	63.798	4.463	.044	.142
Emotion * Extraversion_group	Level 2 vs. Level 1		3.624	1	3.624	.244	.626	.009
	Level 3 vs. Level 1		179.838	1	179.838	12.580	.001	.318
Error(Emotion)	Level 2 vs. Level 1		401.697	27	14.878			
	Level 3 vs. Level 1		385.990	27	14.296			
Location		Linear	1.905	1	1.905	.994	.328	.036
Location * Extraversion_group		Linear	2.742	1	2.742	1.430	.242	.050
Error(Location)		Linear	51.752	27	1.917			
Emotion * Location	Level 2 vs. Level 1	Linear	17.183	1	17.183	2.105	.158	.072
	Level 3 vs. Level 1	Linear	12.436	1	12.436	1.342	.257	.047
Emotion * Location * Extraversion_group	Level 2 vs. Level 1	Linear	6.158	1	6.158	.754	.393	.027
	Level 3 vs. Level 1	Linear	5.260	1	5.260	.568	.458	.021
Error(Emotion*Location)	Level 2 vs. Level 1	Linear	220.400	27	8.163			
	Level 3 vs. Level 1	Linear	250.187	27	9.266			



Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	4787.910	1	4787.910	658.287	.000	.961
Extraversion_group	112.324	1	112.324	15.443	.001	.364
Error	196.379	27	7.273			

Experiment Three

Accuracy

Model Comparison

Models	P(M)	P(M|data)	BF_{M}	BF_{10}	error %
Null model (incl. subject)	0.200	0.001	0.004	1.000	
Location	0.200	2.051e -4	8.208e -4	0.190	1.327
Valence	0.200	0.821	18.391	759.763	0.610
Location + Valence	0.200	0.160	0.763	148.189	1.310
Location + Valence + Location ✻ Valence	0.200	0.017	0.070	15.869	3.087

Note. All models include subject.

Post Hoc Tests

Post Hoc Comparisons - Valence

		Prior Odds	Posterior Odds	BF $_{10, U}$	error %
Negative	Neutral	0.587	1.071	1.822	1.074e -6
	Positive	0.587	2.117	3.604	7.824e -7
Neutral	Positive	0.587	153.068	260.585	3.360e -8

Reaction time

Model Comparison

Models	P(M)	P(M|data)	BF $_M$	BF $_{10}$	error %
Null model (incl. subject)	0.200	5.645e -12	2.258e -11	1.000	
Location	0.200	0.008	0.031	1.375e +9	0.783
Valence	0.200	1.126e -10	4.505e -10	19.949	1.239
Location + Valence	0.200	0.888	31.663	1.573e +11	2.727
Location + Valence + Location ✻ Valence	0.200	0.104	0.466	1.849e +10	3.025

Post Hoc Tests

Post Hoc Comparisons - Valence

		Prior Odds	Posterior Odds	BF $_{10, U}$	error %
Negative	Neutral	0.587	295.181	502.520	1.852e -8
	Positive	0.587	1.177	2.004	1.031e -6
Neutral	Positive	0.587	0.295	0.501	1.888e -6

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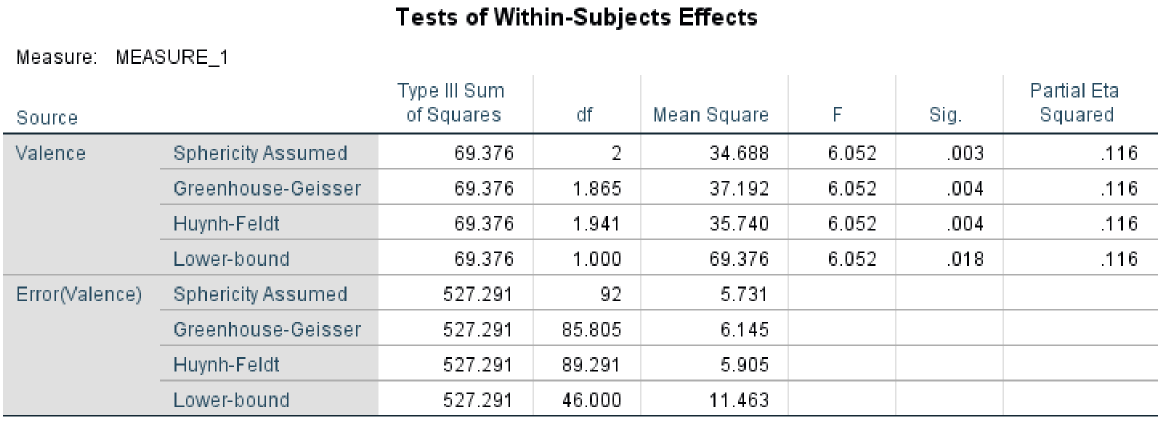
Experiment Four

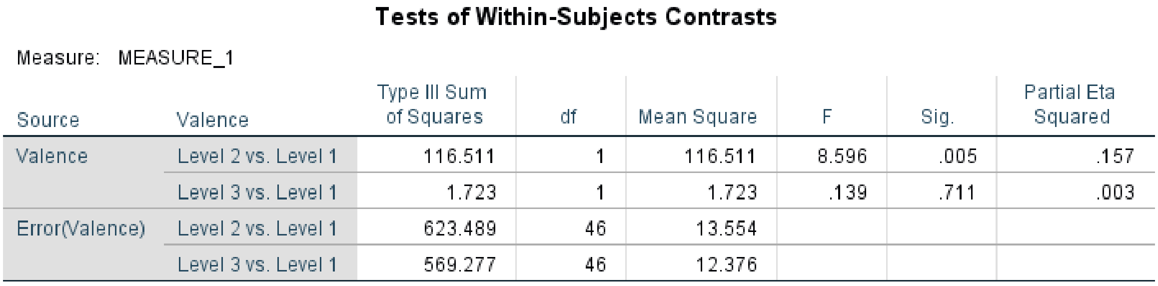
Accuracy



Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Valence	Sphericity Assumed	69.376	2	34.688	6.052	.003	.116
	Greenhouse-Geisser	69.376	1.865	37.192	6.052	.004	.116
	Huynh-Feldt	69.376	1.941	35.740	6.052	.004	.116
	Lower-bound	69.376	1.000	69.376	6.052	.018	.116
Error(Valence)	Sphericity Assumed	527.291	92	5.731			
	Greenhouse-Geisser	527.291	85.805	6.145			
	Huynh-Feldt	527.291	89.291	5.905			
	Lower-bound	527.291	46.000	11.463			

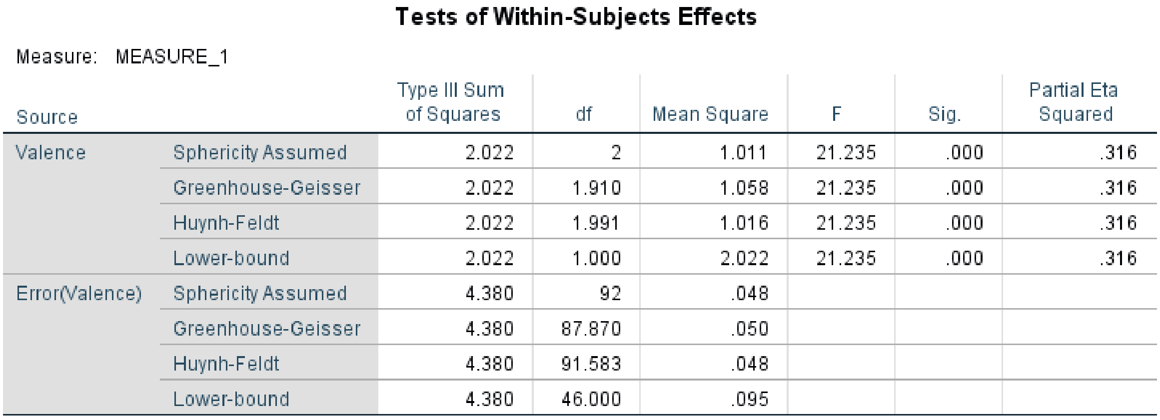


Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Valence	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Valence	Level 2 vs. Level 1	116.511	1	116.511	8.596	.005	.157
	Level 3 vs. Level 1	1.723	1	1.723	.139	.711	.003
Error(Valence)	Level 2 vs. Level 1	623.489	46	13.554			
	Level 3 vs. Level 1	569.277	46	12.376			

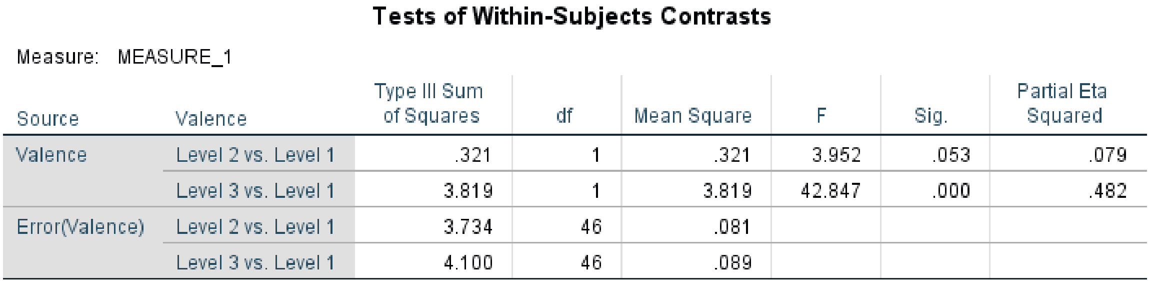
Reaction time



Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Valence	Sphericity Assumed	2.022	2	1.011	21.235	.000	.316
	Greenhouse-Geisser	2.022	1.910	1.058	21.235	.000	.316
	Huynh-Feldt	2.022	1.991	1.016	21.235	.000	.316
	Lower-bound	2.022	1.000	2.022	21.235	.000	.316
Error(Valence)	Sphericity Assumed	4.380	92	.048			
	Greenhouse-Geisser	4.380	87.870	.050			
	Huynh-Feldt	4.380	91.583	.048			
	Lower-bound	4.380	46.000	.095			

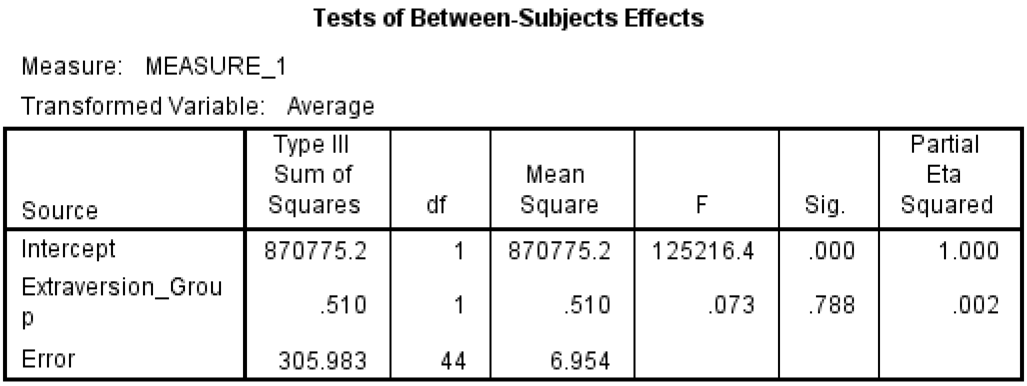


Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Valence	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Valence	Level 2 vs. Level 1	.321	1	.321	3.952	.053	.079
	Level 3 vs. Level 1	3.819	1	3.819	42.847	.000	.482
Error(Valence)	Level 2 vs. Level 1	3.734	46	.081			
	Level 3 vs. Level 1	4.100	46	.089			

Extraversion – accuracy

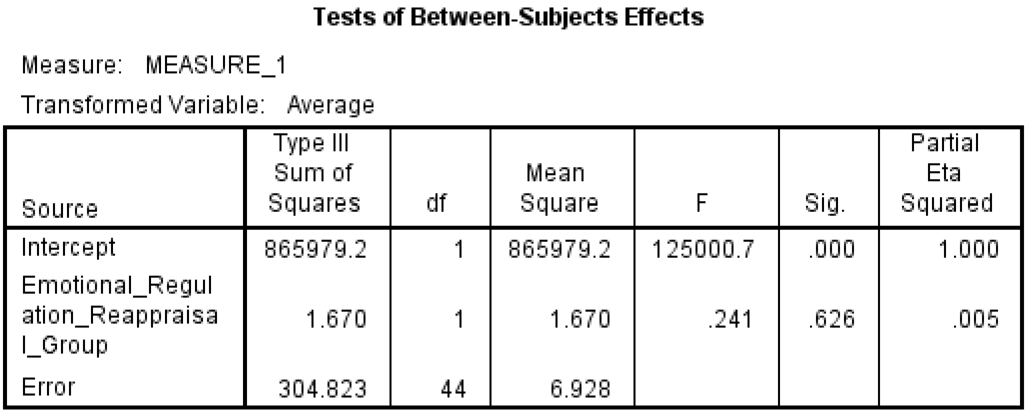

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	870775.2	1	870775.2	125216.4	.000	1.000
Extraversion_Group	.510	1	.510	.073	.788	.002
Error	305.983	44	6.954			

Cognitive reappraisal – accuracy

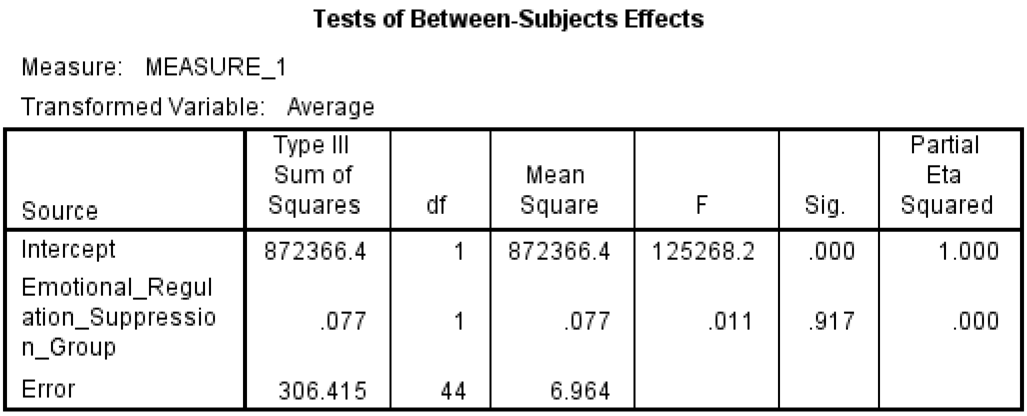

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	865979.2	1	865979.2	125000.7	.000	1.000
Emotional_Regulation_Reappraisal_Group	1.670	1	1.670	.241	.626	.005
Error	304.823	44	6.928			

Expressive suppression – accuracy



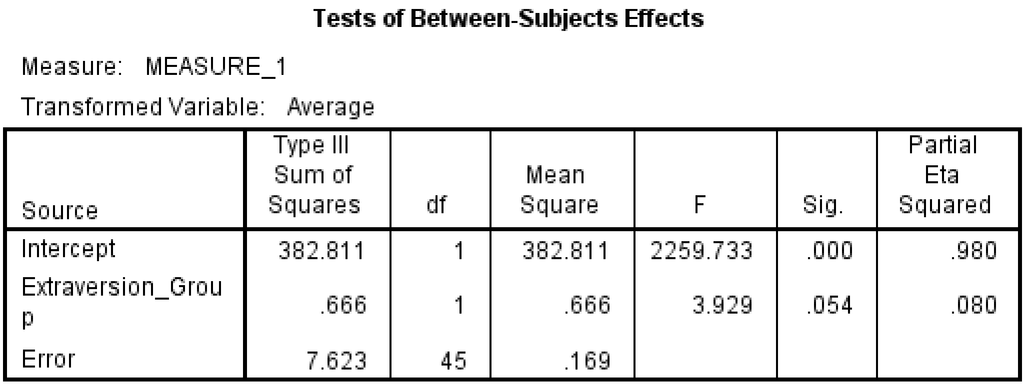
Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	872366.4	1	872366.4	125268.2	.000	1.000
Emotional_Regulation_Suppression_Group	.077	1	.077	.011	.917	.000
Error	306.415	44	6.964			

Extraversion – reaction time



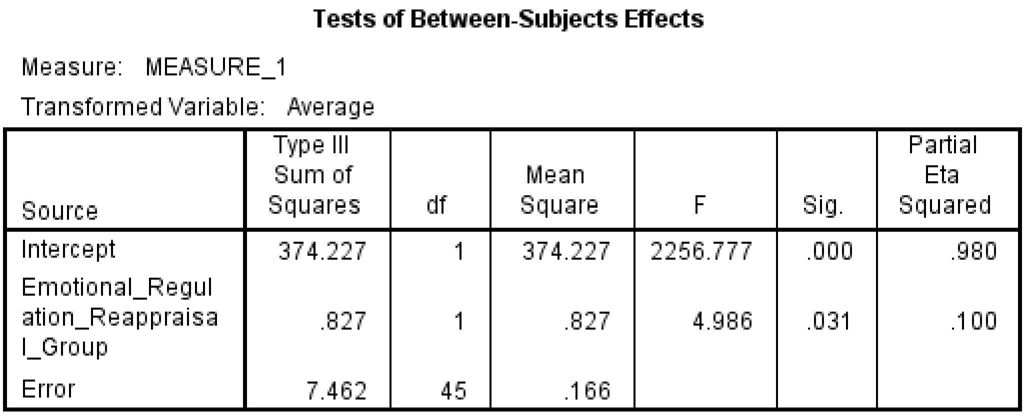
Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	382.811	1	382.811	2259.733	.000	.980
Extraversion_Group	.666	1	.666	3.929	.054	.080
Error	7.623	45	.169			

Cognitive reappraisal – reaction time



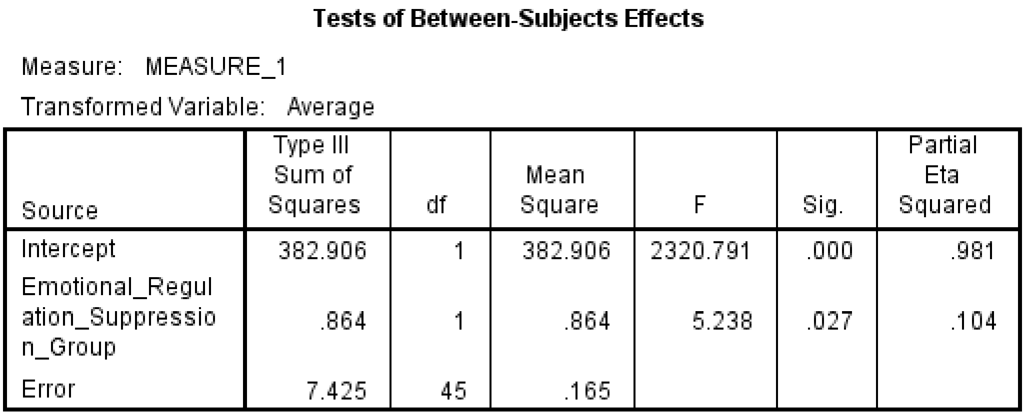
Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	374.227	1	374.227	2256.777	.000	.980
Emotional_Regulation_Reappraisal_Group	.827	1	.827	4.986	.031	.100
Error	7.462	45	.166			

Expressive suppression – reaction time



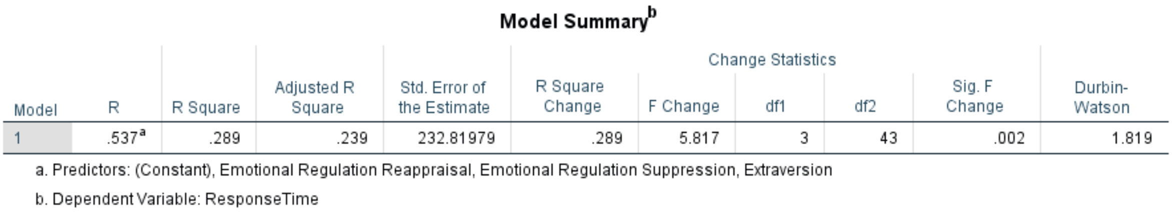
Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	382.906	1	382.906	2320.791	.000	.981
Emotional_Regulation_Suppression_Group	.864	1	.864	5.238	.027	.104
Error	7.425	45	.165			

Regression

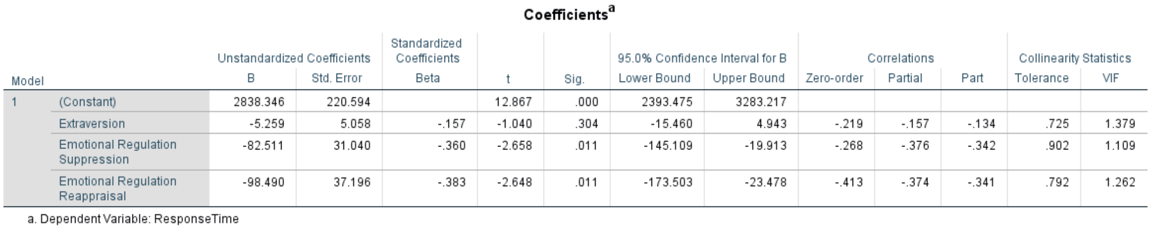


Model Summary[b]

					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.537[a]	.289	.239	232.81979	.289	5.817	3	43	.002	1.819

a. Predictors: (Constant), Emotional Regulation Reappraisal, Emotional Regulation Suppression, Extraversion

b. Dependent Variable: ResponseTime



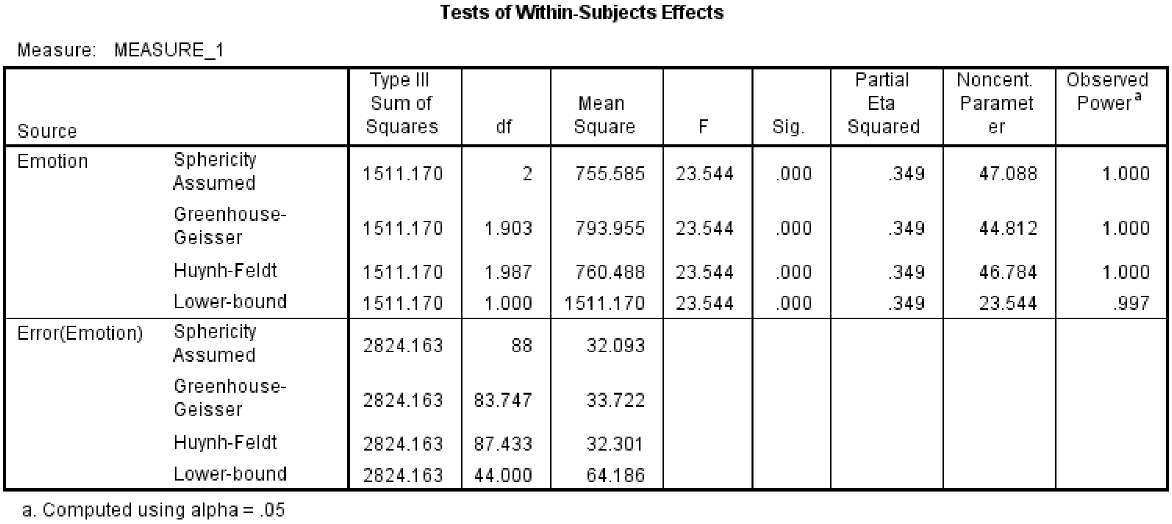
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	2838.346	220.594		12.867	.000	2393.475	3283.217					
	Extraversion	-5.259	5.058	-.157	-1.040	.304	-15.460	4.943	-.219	-.157	-.134	.725	1.379
	Emotional Regulation Suppression	-82.511	31.040	-.360	-2.658	.011	-145.109	-19.913	-.268	-.376	-.342	.902	1.109
	Emotional Regulation Reappraisal	-98.490	37.196	-.383	-2.648	.011	-173.503	-23.478	-.413	-.374	-.341	.792	1.262

a. Dependent Variable: ResponseTime

Experiment Five

PANAS positive affect

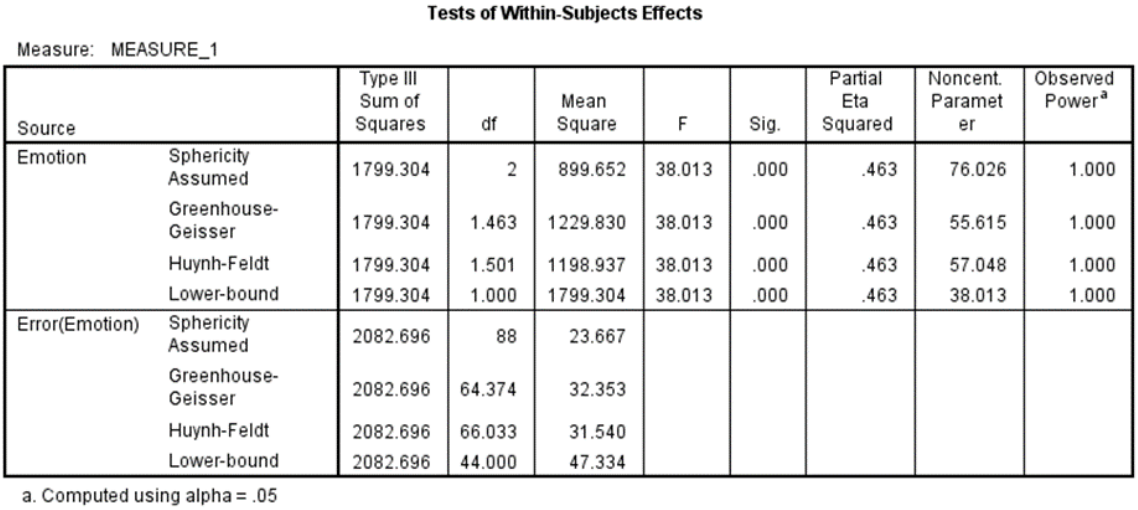


Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Emotion	Sphericity Assumed	1511.170	2	755.585	23.544	.000	.349	47.088	1.000
	Greenhouse-Geisser	1511.170	1.903	793.955	23.544	.000	.349	44.812	1.000
	Huynh-Feldt	1511.170	1.987	760.488	23.544	.000	.349	46.784	1.000
	Lower-bound	1511.170	1.000	1511.170	23.544	.000	.349	23.544	.997
Error(Emotion)	Sphericity Assumed	2824.163	88	32.093					
	Greenhouse-Geisser	2824.163	83.747	33.722					
	Huynh-Feldt	2824.163	87.433	32.301					
	Lower-bound	2824.163	44.000	64.186					

a. Computed using alpha = .05



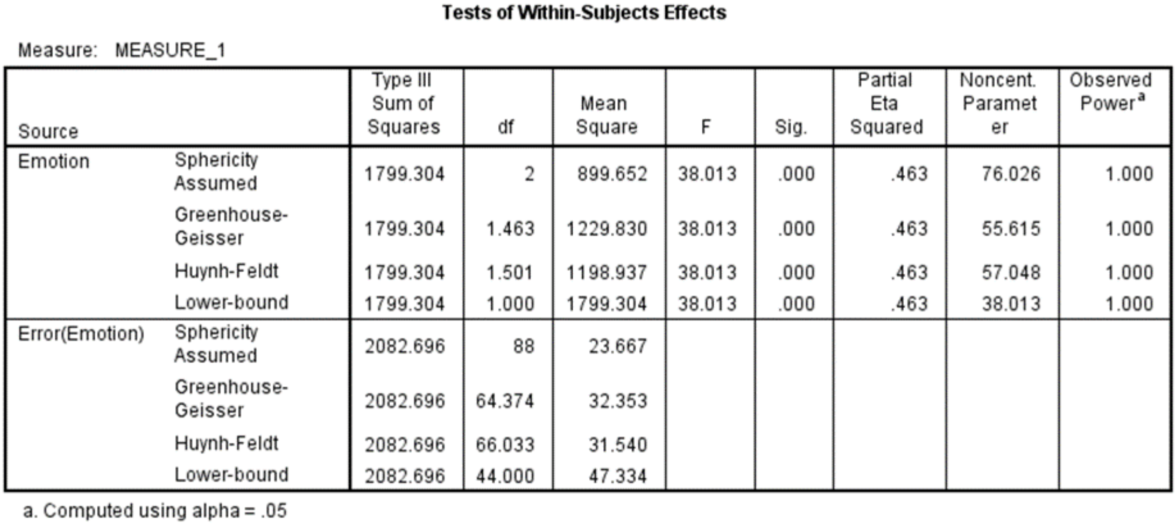
Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Emotion	Sphericity Assumed	1799.304	2	899.652	38.013	.000	.463	76.026	1.000
	Greenhouse-Geisser	1799.304	1.463	1229.830	38.013	.000	.463	55.615	1.000
	Huynh-Feldt	1799.304	1.501	1198.937	38.013	.000	.463	57.048	1.000
	Lower-bound	1799.304	1.000	1799.304	38.013	.000	.463	38.013	1.000
Error(Emotion)	Sphericity Assumed	2082.696	88	23.667					
	Greenhouse-Geisser	2082.696	64.374	32.353					
	Huynh-Feldt	2082.696	66.033	31.540					
	Lower-bound	2082.696	44.000	47.334					

a. Computed using alpha = .05

PANAS negative affect

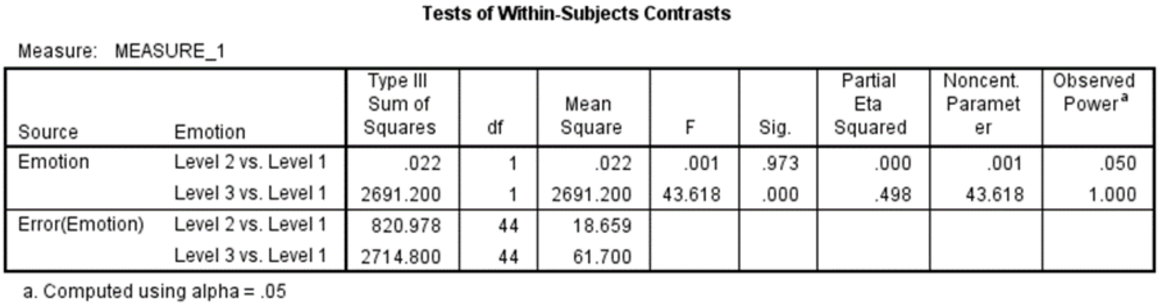


Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Emotion	Sphericity Assumed	1799.304	2	899.652	38.013	.000	.463	76.026	1.000
	Greenhouse-Geisser	1799.304	1.463	1229.830	38.013	.000	.463	55.615	1.000
	Huynh-Feldt	1799.304	1.501	1198.937	38.013	.000	.463	57.048	1.000
	Lower-bound	1799.304	1.000	1799.304	38.013	.000	.463	38.013	1.000
Error(Emotion)	Sphericity Assumed	2082.696	88	23.667					
	Greenhouse-Geisser	2082.696	64.374	32.353					
	Huynh-Feldt	2082.696	66.033	31.540					
	Lower-bound	2082.696	44.000	47.334					

a. Computed using alpha = .05



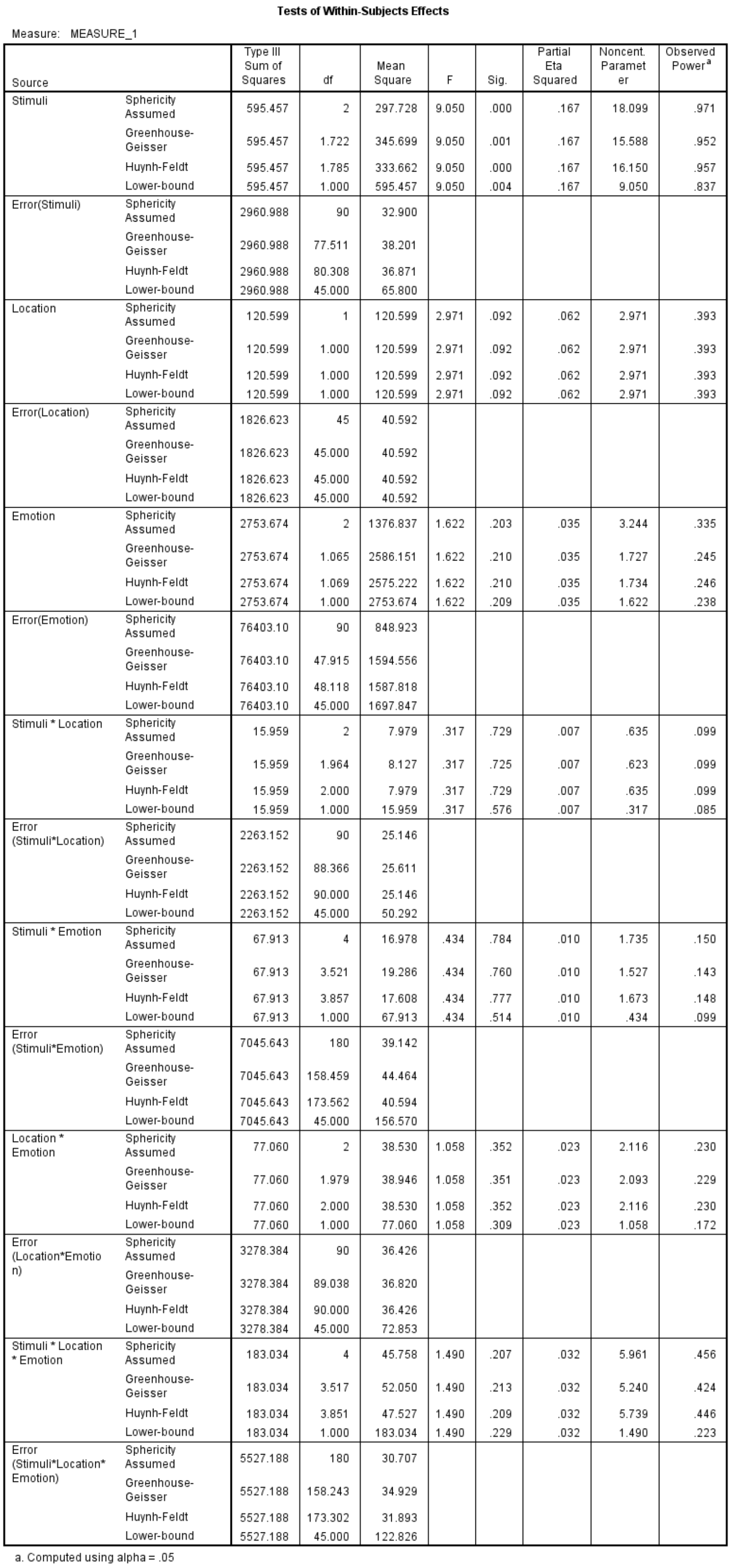
Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Emotion	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Emotion	Level 2 vs. Level 1	.022	1	.022	.001	.973	.000	.001	.050
	Level 3 vs. Level 1	2691.200	1	2691.200	43.618	.000	.498	43.618	1.000
Error(Emotion)	Level 2 vs. Level 1	820.978	44	18.659					
	Level 3 vs. Level 1	2714.800	44	61.700					

a. Computed using alpha = .05

Accuracy

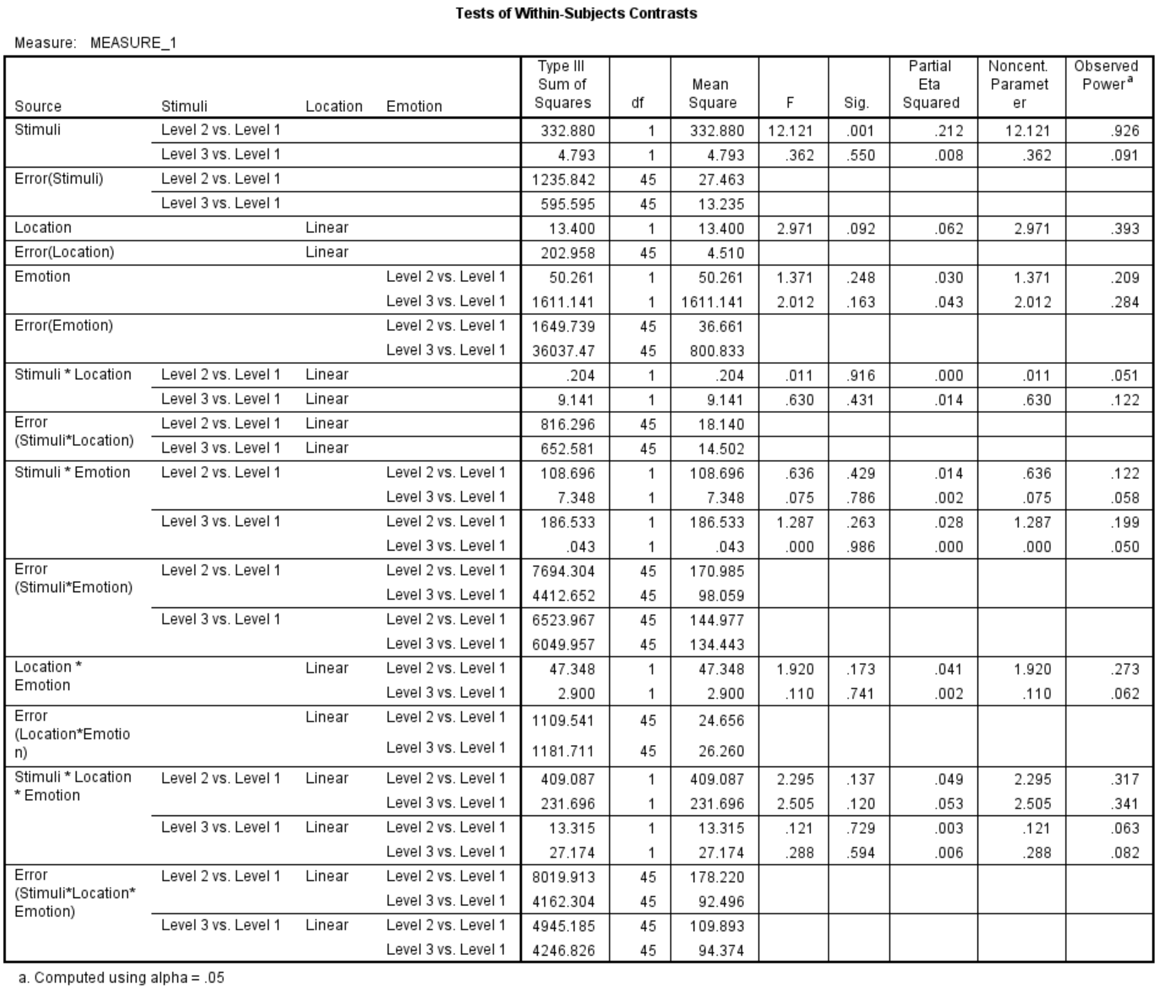


Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Stimuli	Sphericity Assumed	595.457	2	297.728	9.050	.000	.167	18.099	.971
	Greenhouse-Geisser	595.457	1.722	345.699	9.050	.001	.167	15.588	.952
	Huynh-Feldt	595.457	1.785	333.662	9.050	.000	.167	16.150	.957
	Lower-bound	595.457	1.000	595.457	9.050	.004	.167	9.050	.837
Error(Stimuli)	Sphericity Assumed	2960.988	90	32.900					
	Greenhouse-Geisser	2960.988	77.511	38.201					
	Huynh-Feldt	2960.988	80.308	36.871					
	Lower-bound	2960.988	45.000	65.800					
Location	Sphericity Assumed	120.599	1	120.599	2.971	.092	.062	2.971	.393
	Greenhouse-Geisser	120.599	1.000	120.599	2.971	.092	.062	2.971	.393
	Huynh-Feldt	120.599	1.000	120.599	2.971	.092	.062	2.971	.393
	Lower-bound	120.599	1.000	120.599	2.971	.092	.062	2.971	.393
Error(Location)	Sphericity Assumed	1826.623	45	40.592					
	Greenhouse-Geisser	1826.623	45.000	40.592					
	Huynh-Feldt	1826.623	45.000	40.592					
	Lower-bound	1826.623	45.000	40.592					
Emotion	Sphericity Assumed	2753.674	2	1376.837	1.622	.203	.035	3.244	.335
	Greenhouse-Geisser	2753.674	1.065	2586.151	1.622	.210	.035	1.727	.245
	Huynh-Feldt	2753.674	1.069	2575.222	1.622	.210	.035	1.734	.246
	Lower-bound	2753.674	1.000	2753.674	1.622	.209	.035	1.622	.238
Error(Emotion)	Sphericity Assumed	76403.10	90	848.923					
	Greenhouse-Geisser	76403.10	47.915	1594.556					
	Huynh-Feldt	76403.10	48.118	1587.818					
	Lower-bound	76403.10	45.000	1697.847					
Stimuli * Location	Sphericity Assumed	15.959	2	7.979	.317	.729	.007	.635	.099
	Greenhouse-Geisser	15.959	1.964	8.127	.317	.725	.007	.623	.099
	Huynh-Feldt	15.959	2.000	7.979	.317	.729	.007	.635	.099
	Lower-bound	15.959	1.000	15.959	.317	.576	.007	.317	.085
Error (Stimuli*Location)	Sphericity Assumed	2263.152	90	25.146					
	Greenhouse-Geisser	2263.152	88.366	25.611					
	Huynh-Feldt	2263.152	90.000	25.146					
	Lower-bound	2263.152	45.000	50.292					
Stimuli * Emotion	Sphericity Assumed	67.913	4	16.978	.434	.784	.010	1.735	.150
	Greenhouse-Geisser	67.913	3.521	19.286	.434	.760	.010	1.527	.143
	Huynh-Feldt	67.913	3.857	17.608	.434	.777	.010	1.673	.148
	Lower-bound	67.913	1.000	67.913	.434	.514	.010	.434	.099
Error (Stimuli*Emotion)	Sphericity Assumed	7045.643	180	39.142					
	Greenhouse-Geisser	7045.643	158.459	44.464					
	Huynh-Feldt	7045.643	173.562	40.594					
	Lower-bound	7045.643	45.000	156.570					
Location * Emotion	Sphericity Assumed	77.060	2	38.530	1.058	.352	.023	2.116	.230
	Greenhouse-Geisser	77.060	1.979	38.946	1.058	.351	.023	2.093	.229
	Huynh-Feldt	77.060	2.000	38.530	1.058	.352	.023	2.116	.230
	Lower-bound	77.060	1.000	77.060	1.058	.309	.023	1.058	.172
Error (Location*Emotion)	Sphericity Assumed	3278.384	90	36.426					
	Greenhouse-Geisser	3278.384	89.038	36.820					
	Huynh-Feldt	3278.384	90.000	36.426					
	Lower-bound	3278.384	45.000	72.853					
Stimuli * Location * Emotion	Sphericity Assumed	183.034	4	45.758	1.490	.207	.032	5.961	.456
	Greenhouse-Geisser	183.034	3.517	52.050	1.490	.213	.032	5.240	.424
	Huynh-Feldt	183.034	3.851	47.527	1.490	.209	.032	5.739	.446
	Lower-bound	183.034	1.000	183.034	1.490	.229	.032	1.490	.223
Error (Stimuli*Location*Emotion)	Sphericity Assumed	5527.188	180	30.707					
	Greenhouse-Geisser	5527.188	158.243	34.929					
	Huynh-Feldt	5527.188	173.302	31.893					
	Lower-bound	5527.188	45.000	122.826					

a. Computed using alpha = .05



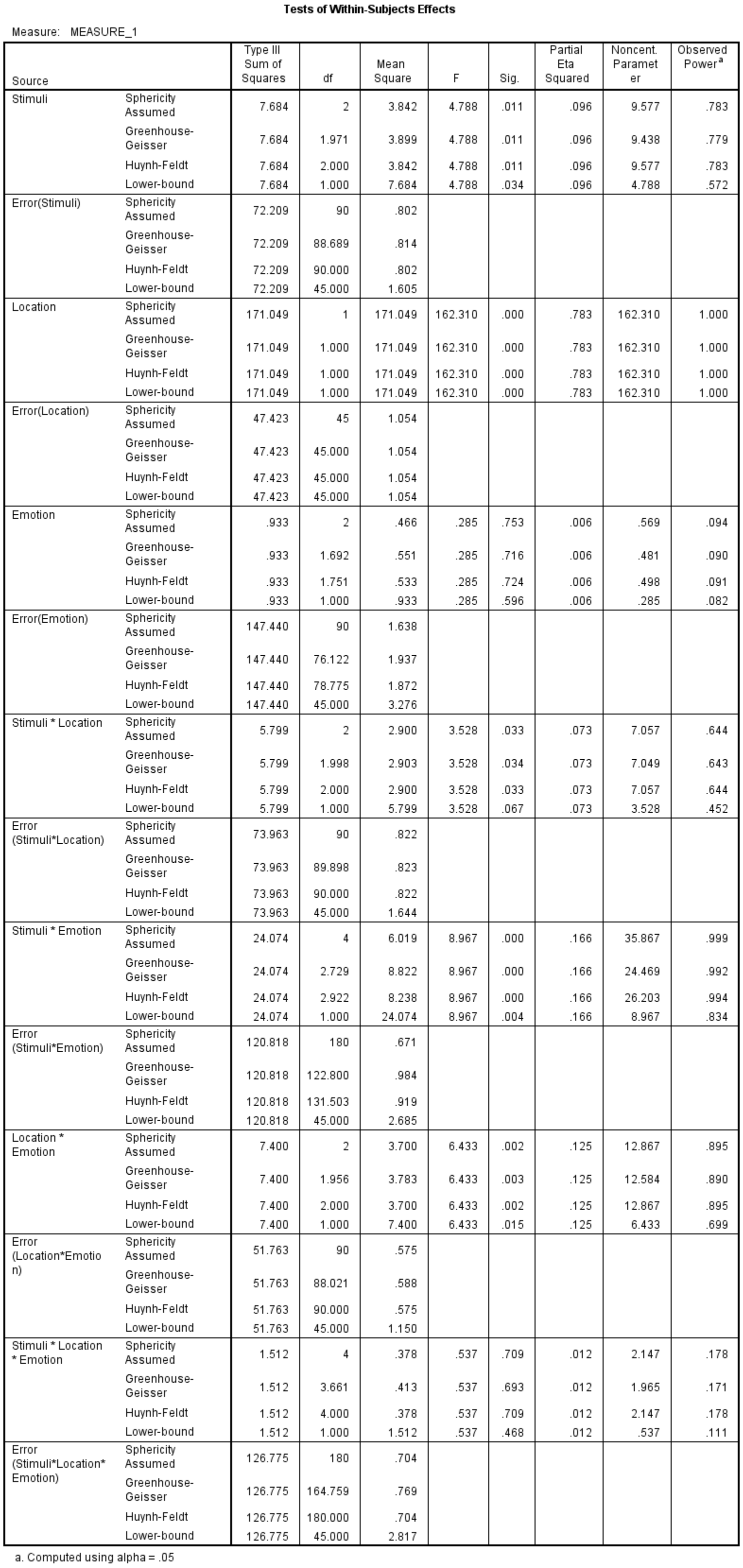
Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Stimuli	Location	Emotion	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Stimuli	Level 2 vs. Level 1			332.880	1	332.880	12.121	.001	.212	12.121	.926
	Level 3 vs. Level 1			4.793	1	4.793	.362	.550	.008	.362	.091
Error(Stimuli)	Level 2 vs. Level 1			1235.842	45	27.463					
	Level 3 vs. Level 1			595.595	45	13.235					
Location		Linear		13.400	1	13.400	2.971	.092	.062	2.971	.393
Error(Location)		Linear		202.958	45	4.510					
Emotion			Level 2 vs. Level 1	50.261	1	50.261	1.371	.248	.030	1.371	.209
			Level 3 vs. Level 1	1611.141	1	1611.141	2.012	.163	.043	2.012	.284
Error(Emotion)			Level 2 vs. Level 1	1649.739	45	36.661					
			Level 3 vs. Level 1	36037.47	45	800.833					
Stimuli * Location	Level 2 vs. Level 1	Linear		.204	1	.204	.011	.916	.000	.011	.051
	Level 3 vs. Level 1	Linear		9.141	1	9.141	.630	.431	.014	.630	.122
Error (Stimuli*Location)	Level 2 vs. Level 1	Linear		816.296	45	18.140					
	Level 3 vs. Level 1	Linear		652.581	45	14.502					
Stimuli * Emotion	Level 2 vs. Level 1		Level 2 vs. Level 1	108.696	1	108.696	.636	.429	.014	.636	.122
			Level 3 vs. Level 1	7.348	1	7.348	.075	.786	.002	.075	.058
	Level 3 vs. Level 1		Level 2 vs. Level 1	186.533	1	186.533	1.287	.263	.028	1.287	.199
			Level 3 vs. Level 1	.043	1	.043	.000	.986	.000	.000	.050
Error (Stimuli*Emotion)	Level 2 vs. Level 1		Level 2 vs. Level 1	7694.304	45	170.985					
			Level 3 vs. Level 1	4412.652	45	98.059					
	Level 3 vs. Level 1		Level 2 vs. Level 1	6523.967	45	144.977					
			Level 3 vs. Level 1	6049.957	45	134.443					
Location * Emotion		Linear	Level 2 vs. Level 1	47.348	1	47.348	1.920	.173	.041	1.920	.273
			Level 3 vs. Level 1	2.900	1	2.900	.110	.741	.002	.110	.062
Error (Location*Emotion)		Linear	Level 2 vs. Level 1	1109.541	45	24.656					
			Level 3 vs. Level 1	1181.711	45	26.260					
Stimuli * Location * Emotion	Level 2 vs. Level 1	Linear	Level 2 vs. Level 1	409.087	1	409.087	2.295	.137	.049	2.295	.317
			Level 3 vs. Level 1	231.696	1	231.696	2.505	.120	.053	2.505	.341
	Level 3 vs. Level 1	Linear	Level 2 vs. Level 1	13.315	1	13.315	.121	.729	.003	.121	.063
			Level 3 vs. Level 1	27.174	1	27.174	.288	.594	.006	.288	.082
Error (Stimuli*Location* Emotion)	Level 2 vs. Level 1	Linear	Level 2 vs. Level 1	8019.913	45	178.220					
			Level 3 vs. Level 1	4162.304	45	92.496					
	Level 3 vs. Level 1	Linear	Level 2 vs. Level 1	4945.185	45	109.893					
			Level 3 vs. Level 1	4246.826	45	94.374					

a. Computed using alpha = .05

Reaction time

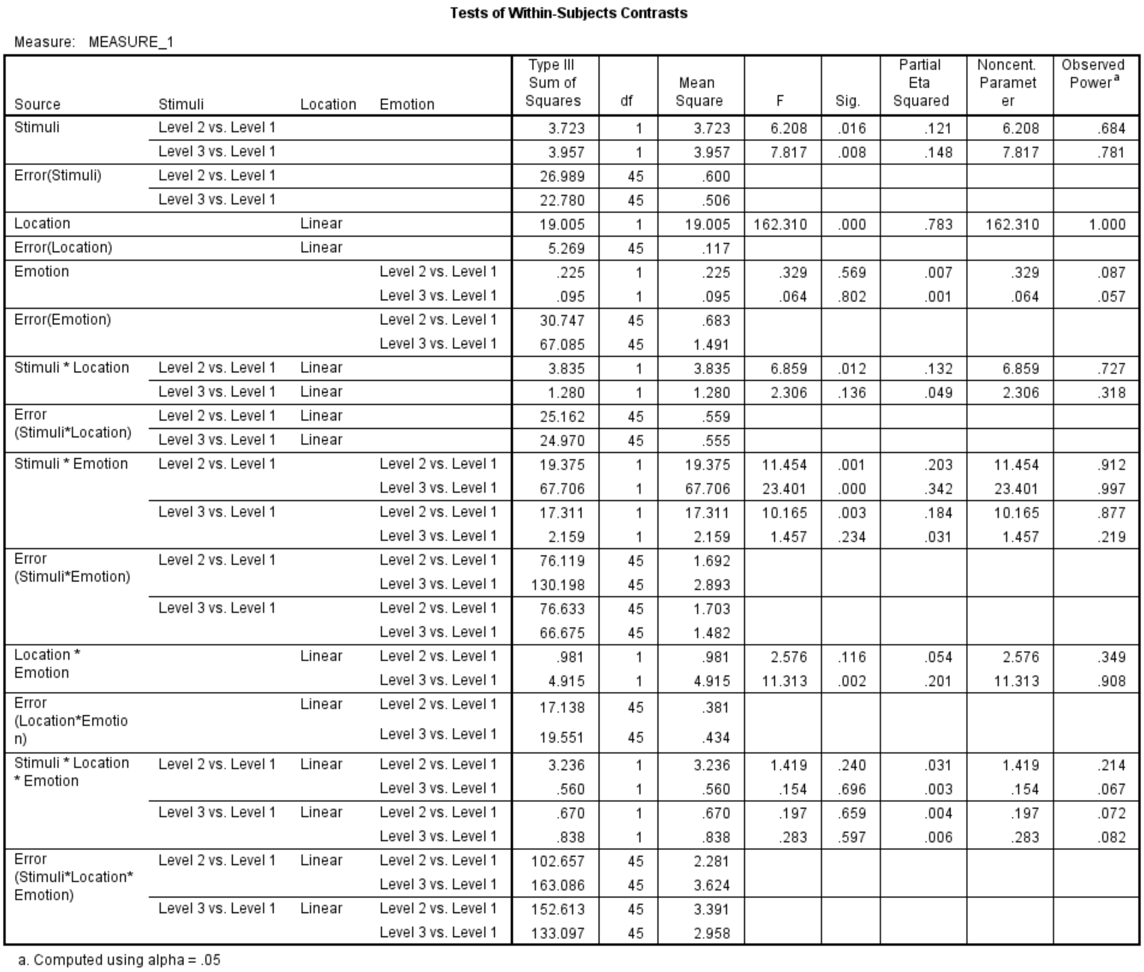


Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Stimuli	Sphericity Assumed	7.684	2	3.842	4.788	.011	.096	9.577	.783
	Greenhouse-Geisser	7.684	1.971	3.899	4.788	.011	.096	9.438	.779
	Huynh-Feldt	7.684	2.000	3.842	4.788	.011	.096	9.577	.783
	Lower-bound	7.684	1.000	7.684	4.788	.034	.096	4.788	.572
Error(Stimuli)	Sphericity Assumed	72.209	90	.802					
	Greenhouse-Geisser	72.209	88.689	.814					
	Huynh-Feldt	72.209	90.000	.802					
	Lower-bound	72.209	45.000	1.605					
Location	Sphericity Assumed	171.049	1	171.049	162.310	.000	.783	162.310	1.000
	Greenhouse-Geisser	171.049	1.000	171.049	162.310	.000	.783	162.310	1.000
	Huynh-Feldt	171.049	1.000	171.049	162.310	.000	.783	162.310	1.000
	Lower-bound	171.049	1.000	171.049	162.310	.000	.783	162.310	1.000
Error(Location)	Sphericity Assumed	47.423	45	1.054					
	Greenhouse-Geisser	47.423	45.000	1.054					
	Huynh-Feldt	47.423	45.000	1.054					
	Lower-bound	47.423	45.000	1.054					
Emotion	Sphericity Assumed	.933	2	.466	.285	.753	.006	.569	.094
	Greenhouse-Geisser	.933	1.692	.551	.285	.716	.006	.481	.090
	Huynh-Feldt	.933	1.751	.533	.285	.724	.006	.498	.091
	Lower-bound	.933	1.000	.933	.285	.596	.006	.285	.082
Error(Emotion)	Sphericity Assumed	147.440	90	1.638					
	Greenhouse-Geisser	147.440	76.122	1.937					
	Huynh-Feldt	147.440	78.775	1.872					
	Lower-bound	147.440	45.000	3.276					
Stimuli * Location	Sphericity Assumed	5.799	2	2.900	3.528	.033	.073	7.057	.644
	Greenhouse-Geisser	5.799	1.998	2.903	3.528	.034	.073	7.049	.643
	Huynh-Feldt	5.799	2.000	2.900	3.528	.033	.073	7.057	.644
	Lower-bound	5.799	1.000	5.799	3.528	.067	.073	3.528	.452
Error (Stimuli*Location)	Sphericity Assumed	73.963	90	.822					
	Greenhouse-Geisser	73.963	89.898	.823					
	Huynh-Feldt	73.963	90.000	.822					
	Lower-bound	73.963	45.000	1.644					
Stimuli * Emotion	Sphericity Assumed	24.074	4	6.019	8.967	.000	.166	35.867	.999
	Greenhouse-Geisser	24.074	2.729	8.822	8.967	.000	.166	24.469	.992
	Huynh-Feldt	24.074	2.922	8.238	8.967	.000	.166	26.203	.994
	Lower-bound	24.074	1.000	24.074	8.967	.004	.166	8.967	.834
Error (Stimuli*Emotion)	Sphericity Assumed	120.818	180	.671					
	Greenhouse-Geisser	120.818	122.800	.984					
	Huynh-Feldt	120.818	131.503	.919					
	Lower-bound	120.818	45.000	2.685					
Location * Emotion	Sphericity Assumed	7.400	2	3.700	6.433	.002	.125	12.867	.895
	Greenhouse-Geisser	7.400	1.956	3.783	6.433	.003	.125	12.584	.890
	Huynh-Feldt	7.400	2.000	3.700	6.433	.002	.125	12.867	.895
	Lower-bound	7.400	1.000	7.400	6.433	.015	.125	6.433	.699
Error (Location*Emotion)	Sphericity Assumed	51.763	90	.575					
	Greenhouse-Geisser	51.763	88.021	.588					
	Huynh-Feldt	51.763	90.000	.575					
	Lower-bound	51.763	45.000	1.150					
Stimuli * Location * Emotion	Sphericity Assumed	1.512	4	.378	.537	.709	.012	2.147	.178
	Greenhouse-Geisser	1.512	3.661	.413	.537	.693	.012	1.965	.171
	Huynh-Feldt	1.512	4.000	.378	.537	.709	.012	2.147	.178
	Lower-bound	1.512	1.000	1.512	.537	.468	.012	.537	.111
Error (Stimuli*Location*Emotion)	Sphericity Assumed	126.775	180	.704					
	Greenhouse-Geisser	126.775	164.759	.769					
	Huynh-Feldt	126.775	180.000	.704					
	Lower-bound	126.775	45.000	2.817					

a. Computed using alpha = .05



Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Stimuli	Location	Emotion	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Stimuli	Level 2 vs. Level 1			3.723	1	3.723	6.208	.016	.121	6.208	.684
	Level 3 vs. Level 1			3.957	1	3.957	7.817	.008	.148	7.817	.781
Error(Stimuli)	Level 2 vs. Level 1			26.989	45	.600					
	Level 3 vs. Level 1			22.780	45	.506					
Location		Linear		19.005	1	19.005	162.310	.000	.783	162.310	1.000
Error(Location)		Linear		5.269	45	.117					
Emotion			Level 2 vs. Level 1	.225	1	.225	.329	.569	.007	.329	.087
			Level 3 vs. Level 1	.095	1	.095	.064	.802	.001	.064	.057
Error(Emotion)			Level 2 vs. Level 1	30.747	45	.683					
			Level 3 vs. Level 1	67.085	45	1.491					
Stimuli * Location	Level 2 vs. Level 1	Linear		3.835	1	3.835	6.859	.012	.132	6.859	.727
	Level 3 vs. Level 1	Linear		1.280	1	1.280	2.306	.136	.049	2.306	.318
Error (Stimuli*Location)	Level 2 vs. Level 1	Linear		25.162	45	.559					
	Level 3 vs. Level 1	Linear		24.970	45	.555					
Stimuli * Emotion	Level 2 vs. Level 1		Level 2 vs. Level 1	19.375	1	19.375	11.454	.001	.203	11.454	.912
			Level 3 vs. Level 1	67.706	1	67.706	23.401	.000	.342	23.401	.997
	Level 3 vs. Level 1		Level 2 vs. Level 1	17.311	1	17.311	10.165	.003	.184	10.165	.877
			Level 3 vs. Level 1	2.159	1	2.159	1.457	.234	.031	1.457	.219
Error (Stimuli*Emotion)	Level 2 vs. Level 1		Level 2 vs. Level 1	76.119	45	1.692					
			Level 3 vs. Level 1	130.198	45	2.893					
	Level 3 vs. Level 1		Level 2 vs. Level 1	76.633	45	1.703					
			Level 3 vs. Level 1	66.675	45	1.482					
Location * Emotion		Linear	Level 2 vs. Level 1	.981	1	.981	2.576	.116	.054	2.576	.349
			Level 3 vs. Level 1	4.915	1	4.915	11.313	.002	.201	11.313	.908
Error (Location*Emotion)		Linear	Level 2 vs. Level 1	17.138	45	.381					
			Level 3 vs. Level 1	19.551	45	.434					
Stimuli * Location * Emotion	Level 2 vs. Level 1	Linear	Level 2 vs. Level 1	3.236	1	3.236	1.419	.240	.031	1.419	.214
			Level 3 vs. Level 1	.560	1	.560	.154	.696	.003	.154	.067
	Level 3 vs. Level 1	Linear	Level 2 vs. Level 1	.670	1	.670	.197	.659	.004	.197	.072
			Level 3 vs. Level 1	.838	1	.838	.283	.597	.006	.283	.082
Error (Stimuli*Location*Emotion)	Level 2 vs. Level 1	Linear	Level 2 vs. Level 1	102.657	45	2.281					
			Level 3 vs. Level 1	163.086	45	3.624					
	Level 3 vs. Level 1	Linear	Level 2 vs. Level 1	152.613	45	3.391					
			Level 3 vs. Level 1	133.097	45	2.958					

a. Computed using alpha = .05

Appendix Three: Participant Information Sheets

Participant Information Sheet – The influence of emotion on change blindness

I would like to invite you to take part in a research study. Before you decide whether you would like to take part you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or you would like more information. Please take at least 24 hours to decide whether or not to take part.

What is the purpose of this study?

Researchers in the Directorate of Psychology and Public Health are interested in the benefits that emotion may have on cognitive processing. Whenever you complete a task you are using cognitive skills (thinking, memory, attention, decision-making) and to perform well in the task it is important to ensure a high level of processing. With the present research we are investigating whether emotion can influence processing. For example, do we perform differently in happy moods, compared to less-positive moods?

Why have I been invited?

You have been invited to take part because you are studying on one of the Psychology programmes at the University of Salford. A large amount of Psychology research is conducted using Psychology students and for this study we hope to recruit a total of 36 participants.

Do I have to take part?

It is up to you to decide whether you would like to take part. If you do decide to take part you will be asked to sign a consent form to show that you have agreed to participate. You are free to withdraw from the study at any time, without having to provide a reason. Please also be aware that your participation or non-participation has no reflection on your course and in no way will it count towards or against your academic studies.

What will happen to me if I take part?

The research will consist of three tasks. First you will be presented with a series of photographs and you simply need to look at these images (some of the images will be positive and some will be negative, but you will have the opportunity to see an example of the images before you consent to taking part in the study). You will then be shown some more photographs but you will be asked to spot changes made to these photographs. Finally you will be asked to complete a short questionnaire that asks you to rate how you are feeling at the present time. We will do all three tasks 3 times, but the photographs you see each time will be different. During the experiment we will be recording brain activity via a rubber band that sits around your forehead (similar to a headband that athletes may wear). This is a non-invasive piece of equipment that will record blood flow in the brain while you complete the task. The whole experiment will take a maximum of 60 minutes and the experimenter will remain in the testing room with you if you have any queries.

Expenses and payments?

You will receive an inconvenience allowance of £10 for taking part in this study.

What are the possible disadvantages and risks of taking part?

Some of the images used in the experiment will be negative (e.g. photographs of violence or illness); you will be shown examples of the images before the experiment begins so that you know what to expect and you can decide if you wish to continue with the experiment. The second stage of the experiment (the change detection task) involves images being presented quickly on the computer screen. This will result in a pronounced flicker effect; if you suffer from epilepsy, or you think this flicker may cause you any discomfort you will not be able to take part. If you do decide to take part and find that the flicker is a problem, you are free to stop the experiment at any time.

What are the possible benefits of taking part?

We cannot promise that the experiment will help you, however taking part may give you a greater understanding of the research process. The results obtained from the study will help to show how emotion can affect cognitive processing.

What if there is a problem?

If you have a concern about any aspect of this study, you should speak to the researchers who will do their best to answer your questions:
Catherine Thompson – c.thompson@salford.ac.uk (0161 2953486)
Robert Bendall – r.c.a.bendall@salford.ac.uk (0161 2952159)
If you remain unhappy and wish to complain formally you can do this by contacting the Research and Innovation Manager in the College of Health and Social Care at the University of Salford:
Anish Kurien - a.kurien@salford.ac.uk (0161 2955276)

Will my taking part in the study be kept confidential?

All results will remain confidential and you will be given a participant number. All data will only be referred to by number and any document that includes your name will not be associated with your participant number. Data collected from this study will be stored on a password-protected computer, and all paperwork used in the experiment will be stored in a locked filing cabinet in the researcher's office. The data will be stored for a period of 3 years.

What will happen if I don't carry on with the study?

I you choose to withdraw from the study, or if you wish to remove your data from the study at any point, you can contact the researcher with your participant number and all data collected from you, to date, will be destroyed, and your name will be removed from all study files.

What will happen to the results of the research study?

This study will be submitted to the Journal of Cognitive Psychology for potential publication, and the results may also be used in research presentations. You will not be identified in any publications.

Further information and contact details:

If you would like further information about the study or you would like to volunteer and want to arrange a suitable time to take part please contact:
Robert Bendall – r.c.a.bendall@salford.ac.uk
Room L820, Allerton Building, School of Health Sciences, University of Salford

Participant Information Sheet

Study title: **The effects of mood, neuroticism and extraversion on visual attention.**

I would like to invite you to take part in a research study. First of all, I would like to inform you about why I've chosen to carry out this study and what your contribution would consist of if you did chose to take part. Please take time to read the information sheet carefully and if you have any questions about the research study free to contact me via my contact details presented at the bottom of this form.

What is the purpose of this research study?

To investigate if mood and/or personality traits may have any influence on our visual attention performance.

Why have I been invited?

You have been invited to participate in this study as you are a student at the university where the research will be carried out (Salford University). There are no restrictions on who can volunteer for this study.

Do I have to take part?

It is not compulsory for you to take part in this research. You will participate on your own accord, it is voluntary and you have the right to withdraw from the experiment at any time. You will be presented with a consent form, which I urge you to read carefully before agreeing to anything. Once you have signed your consent form or taken part in the experiment you can still withdraw your data from this study without giving reason.

What will happen to me if I take part?

If you chose to participate the experiment will consist of both self-report questionnaire's and a visual attention task on a computer screen. The experiment as a whole should run for approximately 45 minutes. You will be asked to complete three questionnaires and a visual attention task. The questionnaires will assess mood, personality and depressive symptoms (evident in a healthy population). The visual attention task will assess your accuracy and response times for 24 visual attention trials. After data collection the research study will last a further 2 months. No personal information will be taken from you. Everything will be kept confidential and only the researchers will have access to the data. The visual attention task will have flashing images reoccurring and so if you suffer from epilepsy or feel uncomfortable about this please avoid participation.

What will I have to do?

You will be expected to fill out three questionnaires prior to the visual attention task. One assessing your current mood, the other assessing your personality traits and another assessing depressive symptoms (in a healthy population). Once you have completed these questionnaires you will be seated in front of a computer screen and given a set of instructions to guide you through the process. You will be asked to establish a change in the centre or periphery of the image. Your accuracy score and response times will be recorded. You will do this for 24 trials. Once you have completed the task you will be free to go. You will also be given the opportunity to ask any questions and of course at this point you are still able to withdraw without having to give a reason.

What are the possible disadvantages and risk of taking part?

As we have a series of images which will vary in emotional valence, this may upset some people. To help you make your decision, before the experiment begins I will show you the best positive image, most neutral and worse negative image you will see. If you see these example images and wish to withdraw, you can do. Experiments using these exact stimuli have previously been conducted at Salford University with full ethical approval. If you chose to stay and take part in the experiment and feel slightly uneasy or upset at the end, please visit the link provided below to our team of counsellors here at the University of Salford. They will be able to provide help and advice in such situations.

University of Salford Well-Being and Counselling Services

Phone: 0161 295 0023

Email: wellbeing@salford.ac.uk

What are the possible benefits of taking part?

We cannot say that you will benefit from taking part in this research. Your participation will help research investigating if mood and personality traits influence visual attention.

What if there is a problem?

If you have a concern about any aspect of this study, you should ask to speak to the researchers by email (Robert Bendall – r.c.a.bendall@salford.ac.uk or Dr Catherine Thompson – c.thompson@salford.ac.uk) who will do their best to answer your questions.

If the matter is still not resolved, please forward your concerns to Dr Linda Dubrow-Marshall, Co-Chair of the Health Taught Ethics Panel, Room C809, Allerton Building, Frederick Road Campus, University of Salford, Salford, M6 6PU. Tel: 0161 296 6988. l.dubrow-marshall@salford.ac.uk, or Dr Anna Cooper-Ryan, Co-Chair of the Health Taught Ethics Panel, Room L812a, Allerton Building, Frederick Road Campus, University of Salford, Salford, M6 6PU. Tel: 0161 295 5094. a.m.cooper-ryan@salford.ac.uk.

Will my taking part be kept confidential?

Yes. Under the Data Protection Act (1998) all your data will be kept confidential throughout the entire duration of the research study. No personal information will be obtained. The researchers are the only individuals to have access to your data and it will be stored in a locked cabinet. Your computerized experiment will be saved anonymously on a password protected computer. Once the research study is complete the data will be destroyed and nobody will have any way of retaining the data.

What will happen if I don’t carry on with the study?

If you wish to withdraw from the study all information and data collected from you will be destroyed and there will be no evidence that you ever gave consent to take part.

What will happen to the results of the research study?

If you wish to find out what the research study will unfold when it is complete, then please feel free to contact me and I will make great efforts to keep you informed and send you a copy of the finished project once it has been assessed and returned back to me. You will not be identifiable in any published reports of the study findings.

Contact details of the researcher

Name:

Email address:

Thank you for taking the time to read this information sheet. Please think about it for at least 24 hours before making any decision.

Participant Information Sheet – The influence of emotion and individual differences on visual attention

I would like to invite you to take part in a research study. Before you decide whether you would like to take part you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or you would like more information. Please take at least 24 hours to decide whether or not to take part.

What is the purpose of this study?
Researchers in the Directorate of Psychology and Public Health are interested in the benefits that emotion and individual differences may have on cognitive processing. Whenever you complete a task you are using cognitive skills (thinking, memory, attention, decision-making) and to perform well in the task it is important to ensure a high level of processing. With the present research we are investigating whether emotion and certain traits can influence processing. For example, do we perform differently in happy moods, compared to less-positive moods?

Why have I been invited?
You may have been invited to take part because you are studying on one of the Psychology programmes at the University of Salford. A large amount of Psychology research is conducted using Psychology students and for this study we hope to recruit a total of 52 participants.

Do I have to take part?
It is up to you to decide whether you would like to take part. If you do decide to take part you will be asked to sign a consent form to show that you have agreed to participate. You are free to withdraw from the study at any time, without having to provide a reason. Please also be aware that your participation or non-participation has no reflection on your course and in no way will it count towards or against your academic studies.

What will happen to me if I take part?
The research will consist of two parts. First you will be shown some photographs and you will be asked to find a letter (either a T or L) in these photographs as quickly as possible. Then you will then be asked to complete a series of questionnaires relating to various personality traits. During the experiment we will be recording eye-movements with an eye-tracker. This is a non-invasive piece of equipment that will record eye-movements while you complete the first task. The whole experiment will take a maximum of 60 minutes and the experimenter will remain in the testing room with you if you have any queries.

Expenses and payments?
You will receive an inconvenience allowance of £10 for taking part in this study.

What are the possible disadvantages and risks of taking part?
Some of the images used in the experiment will be negative (e.g. photographs of violence or illness); you will be shown examples of the images before the experiment begins so that you know what to expect and you can decide if you wish to continue with the experiment. If you do decide to take part and find that either the visual search task or the negative images are a problem, you are free to stop the experiment at any time.

What are the possible benefits of taking part?

We cannot promise that the experiment will help you, however taking part may give you a greater understanding of the research process. The results obtained from the study will help to show how emotion can affect cognitive processing.

What if there is a problem?

If you have a concern about any aspect of this study, you should speak to the researcher who will do their best to answer your questions:

Robert Bendall – r.c.a.bendall@salford.ac.uk (0161 2952159)
Supervisor - Catherine Thompson – c.thompson@salford.ac.uk (0161 2953486)

If you remain unhappy and wish to complain formally you can do this by contacting the Research and Innovation Manager in the College of Health and Social Care at the University of Salford:

Anish Kurien - a.kurien@salford.ac.uk (0161 2955276)

Will my taking part in the study be kept confidential?

All results will remain confidential and you will be given a participant number. All data will only be referred to by number and any document that includes your name will not be associated with your participant number. Data collected from this study will be stored on a password-protected computer, and all paperwork used in the experiment will be stored in a locked filing cabinet in the researcher's office. The data will be stored for a period of 3 years.

What will happen if I don't carry on with the study?

If you choose to withdraw from the study, or if you wish to remove your data from the study at any point, you can contact the researcher with your participant number and all data collected from you, to date, will be destroyed, and your name will be removed from all study files.

What will happen to the results of the research study?

This study will be submitted to the Journal of Cognitive Psychology for potential publication, and the results may also be used in research presentations. You will not be identified in any publications.

Further information and contact details:

If you would like further information about the study or you would like to volunteer and want to arrange a suitable time to take part please contact:

Robert Bendall – r.c.a.bendall@salford.ac.uk
Room L827, Allerton Building, School of Health Sciences, University of Salford

PARTICIPANT INFORMATION SHEET

Title of study: The influence of emotion and individual differences on visual attention: A combined eye-tracking and functional near-infrared spectroscopy study

Name of Researcher: Robert Bendall

Invitation paragraph

I would like to invite you to take part in a research study. Before you decide whether you would like to take part you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or you would like more information. Please take at least 24 hours to decide whether or not to take part.

What is the purpose of the study?

Researchers in the Directorate of Psychology and Public Health are interested in the benefits that emotion and individual differences may have on cognitive processing. Whenever you complete a task you are using cognitive skills (thinking, memory, attention, decision-making) and to perform well in the task it is important to ensure a high level of processing. With the present research we are investigating whether emotion and certain traits can influence processing. For example, do we perform differently in happy moods, compared to less-positive moods? We are also interested in recording eye-movements and brain activation during cognitive processing.

Why have I been invited to take part?

You may have been invited to take part because you are a student or employee at the University of Salford. A large amount of Psychology research is conducted using students and for this study we hope to recruit a total of 50 participants.

Do I have to take part?

It is up to you to decide whether you would like to take part. If you do decide to take part you will be asked to sign a Consent Form to show that you have agreed to participate. You are free to withdraw from the study at any time, without having to provide a reason. Please also be aware that your participation or non-participation has no reflection on your course (if applicable) and in no way will it count towards or against your academic studies.

What will happen to me if I take part?

The research will consist of two parts. First you will be asked to complete five questionnaires relating to various individual difference traits. You will then be shown some photographs and you will be asked to find a letter (either a T or L) in these photographs as quickly as possible. Some of the images used in the experiment will be negative (e.g. photographs of violence or illness). During the experiment we will be recording eye-movements with an eye-tracker. This is a non-invasive piece of equipment that will record eye-movements while you complete the first task. Brain activity will also be recorded with a non-invasive piece of equipment including a rubber band which will be placed on your forehead. The whole experiment will take a maximum of 60 minutes and the experimenter will remain in the testing room with you if you have any queries.

Expenses and payments?

After completion of the study tasks detailed above you will receive an inconvenience allowance of £10 for taking part.

What are the possible disadvantages and risks of taking part?

Some of the images used in the experiment will be negative (e.g. photographs of violence or illness); you will be shown examples of the images before the experiment begins so that you know what to expect and you can decide if you wish to continue with the experiment. If you do decide to take part and find that either the visual search task or the negative images are a problem, you are free to stop the experiment at any time. If you feel the need to contact the university Counselling and Wellbeing Service their details are provided below.

What are the possible benefits of taking part?

We cannot promise that the experiment will help you. However, taking part may give you a greater understanding of the research process. The results obtained from the study will help to show how emotion and individual difference traits can affect cognitive processing.

What if there is a problem?

If you have a concern about any aspect of this study, you should speak to the researcher who will do their best to answer your questions:

Researcher – Robert Bendall r.c.a.bendall@salford.ac.uk

Supervisor – Dr Catherine Thompson c.thompson@salford.ac.uk

Alternatively, you can also contact the Counselling and Wellbeing Service at the university via email or telephone.

wellbeing@salford.ac.uk 0161 295 0023

Will my taking part in the study be kept confidential?

All results will remain confidential and you will be given a participant number. All data will only be referred to by number and any document that includes your name will not be associated with your participant number. Data collected from this study will be stored on a password-protected computer, and all paperwork used in the experiment will be stored in a locked filing cabinet in the researcher's office. The data will be stored for a period of 3 years.

What will happen if I don't carry on with the study?

If you choose to withdraw from the study, or if you wish to remove your data from the study at any point, you can contact the researcher with your participant number and all data collected from you, to date, will be destroyed, and your name will be removed from all study files. If you decide to withdraw, your anonymised information will not be able to be removed from any reports or publications already published.

What will happen to the results of the research study?

This study will be submitted to the journal Cognition and Emotion for potential publication, and the results may also be used in research presentations. You will not be identified in any publications.

Who is organising or sponsoring the research?

University of Salford.

Further information and contact details:

If you would like further information about the study or you would like to volunteer and want to arrange a suitable time to take part please contact:

Researcher – Robert Bendall r.c.a.bendall@salford.ac.uk

University Counselling and Wellbeing Service.

wellbeing@salford.ac.uk

0161 295 0023

Appendix Four: Sample size calculations

All sample size calculations/power analyses were conducted using G*Power 3.1 (Faul et al., 2007).

The experiment presented in Chapter Three was the first to investigate the impact of affective traits on change detection. Consequently, no data had thus far been collected relating to effect sizes of affective trait influences on visual attention, and so a medium effect size (.25) was deemed to be an appropriate initial reference criterion.

The experiment presented in Chapter Five was a partial replication of the previous experiment presented in Chapter Four. Therefore, the effect sizes from this earlier experiment were used to guide the sample size calculation. Given previous effect sizes of .21 and .35, a medium effect size of .25 was considered appropriate.

The sample size calculation for the experiment presented in Chapter Six was informed by observed effect sizes reported in the experiments presented in Chapter Four and Chapter Five. These experiments provided effect scores of .12, .21, .29, .32 and .35, and again a medium effect size of .25 was considered appropriate.

Appendix Five: Affective trait descriptive statistics

Affective trait descriptive statistics – Experiment Two

		Mdn	*M*	*SD*
Extraversion	Total	114.00	116.97	20.37
	Higher group	125.00	131.80	16.28
	Lower group	99.00	100.13	6.74
Neuroticism	Total	100.50	103.63	23.67
	Higher group	115.00	121.87	19.30
	Lower group	88.00	85.40	8.70

Correlations between affective traits – Experiment Two

		Extraversion	Neuroticism
Extraversion	Pearson's r	—	
	p-value	—	
Neuroticism	Pearson's r	-0.281	—
	p-value	.133	—

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

Affective trait descriptive statistics – Experiment Four

		Mdn	*M*	*SD*
Extraversion	Total	28.00	27.32	7.89
	Higher group	33.00	33.65	3.52
	Lower group	22.50	21.25	5.84
Cognitive reappraisal	Total	30.00	29.34	6.31
	Higher group	34.00	34.23	2.62
	Lower group	27.00	25.04	5.40
Expressive suppression	Total	13.00	13.45	4.81
	Higher group	17.00	17.29	3.01
	Lower group	10.00	9.43	2.45

Correlations between affective traits – Experiment Four

		Extraversion	Cognitive reappraisal	Expressive suppression
Extraversion	Pearson's r	—		
	p-value	—		
Cognitive reappraisal	Pearson's r	0.466 ***	—	
	p-value	< .001	—	
Expressive suppression	Pearson's r	-0.303 *	-0.097	—
	p-value	0.038	0.518	—

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

Affective trait descriptive statistics – Experiment Five

		Mdn	*M*	*SD*
Extraversion	Total	29.00	28.11	7.02
	Higher group	34.50	34.60	3.69
	Lower group	24.00	23.30	4.56
Cognitive reappraisal	Total	29.00	29.62	5.72
	Higher group	33.00	33.88	3.92
	Lower group	25.50	24.77	2.83
Expressive suppression	Total	15.00	14.23	5.49
	Higher group	18.50	18.79	2.95
	Lower group	11.00	9.48	2.74
State anxiety	Total	33.00	34.87	8.86
	Higher group	39.00	41.17	8.12
	Lower group	28.00	28.30	2.64

Correlations between affective traits – Experiment Five

		Extraversion	Cognitive reappraisal	Expressive suppression	State anxiety
Extraversion	Pearson's r	—			
	p-value	—			
Cognitive reappraisal	Pearson's r	0.347 *	—		
	p-value	0.017	—		
Expressive suppression	Pearson's r	-0.455 **	-0.173	—	
	p-value	0.001	0.245	—	
State anxiety	Pearson's r	-0.146	-0.373 **	0.047	—
	p-value	0.328	0.010	0.755	—

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