Trait anxiety, cognitive control, and visual affect

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Declaration of Authorship

I Andrew Robert du Rocher hereby declare that this thesis and the work presented in it is entirely my own. Where I have consulted the work of others, this is always clearly stated.

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Abstract

High anxiety may relate to the enhanced processing of threat-related stimuli, enhanced cognitive distraction, and/or altered conflict resolution. It was the purpose of this thesis to carry out a series of behavioural experiments designed to tap into these neuro-cognitive functions. Facial stimuli were used in computerised reaction time experiments. Personality traits were assessed using psychometric measures. The primary aim of this thesis was to determine how trait anxiety (and social anxiety) relates to the recognition of emotional facial expressions, how trait anxiety relates to distraction by other emotional faces (or emotional words) when identifying emotional facial expressions, how trait anxiety relates to differences in how emotional conflict resolution is achieved, and to determine how trait anxiety relates to other personality traits. Moreover this work aimed to develop a novel emotional face conflict resolution paradigm that is grounded in neuroscientific theory.
Results showed that high trait and social anxiety are (differentially) related to the enhanced processing of threat-related faces, but provided no evidence that trait anxiety is related to distraction caused by peripheral emotional faces (threat-related or otherwise). However, we found a very specific distracting effect of happy words that was related to trait anxiety. We found that trait anxiety was somewhat related to conflict resolution but further work is required before this relationship can be properly understood. These results are discussed in detail, in relation to established theories of anxiety.

My original contribution to knowledge is a detailed analysis of how sub-clinical levels of anxiety relate to emotional face discrimination, emotional distraction (when emotional face discrimination is required), and emotional conflict resolution (when emotional face discrimination is required). My original contribution to knowledge is also a detailed examination of how sub-clinical anxiety relates to other personality constructs, and the development of a novel but scientifically grounded emotional face flanker task.

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Chapter 1

1. Introduction

1.1 The study of emotion and cognition

The body contains complex integrated systems that interact to sustain life (LeDoux, 2012). Darwin (1872) proposed that a limited set of basic emotions are present across species and across cultures that are critical for survival. Further biological theorising led to James (1884) proposing that emotions were simply the experiential component of felt bodily changes that occur in response to affective stimuli being present in one's immediate environment. Lange (1885) proposed similar ideas at around the same time, and the two perspectives became known as the James-Lange theory of emotion. Despite some criticism from Cannon (1927, 1931), the James-Lange theory has remained influential. Most contemporary neuroscience approaches to the study of emotion adopt a modified James-Lange perspective suggesting that feedback from bodily changes modulates how emotion is experienced (see Dalgleish, 2004; for review). Rainville, Bechara, Naqvi and Damasio (2006) asked participants to recall and experience potent autobiographical emotional experiences relating to fear, anger, sadness and happiness. Each of these induced basic emotions were related to distinct recordings of cardiorespiratory activity relative to a neutral control condition. Although the study by Rainville et al. investigated biological activity and emotion, it also required participants to think, and thus required cognition.

Cognition refers to functions such as attention, memory, problem solving, language, and planning (Pessoa, 2008). These functions often require controlled processes such as inhibiting interference during the pursuit of any goal. Pre-historic humans will have required 'executive control' processes such as planning and response inhibition for tool making and agriculture (Ardila, 2008), which are the foundations of modern human society. Planning, response inhibition and response activation processes in humans are complemented by other 'executive control' processes, such as performance monitoring (Ridderinkhof et al., 2004a), dual task performance, task switching, and selective attention (Baddeley, 1996). Some of these 'executive control' process are often further delineated and described as 'cognitive control' processes. Cognitive control processes generally refer to the ability to select aspects of any situation that are goal relevant, whilst ignoring goal irrelevant stimulation (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001). Thus, this may entail micro-level adjustments in cognitive and behavioural responses in order to maintain any goal directed behaviour.

Situations requiring executive control / cognitive control will often not be emotionally neutral in nature. Everyday visual stimuli often have emotional significance which affects perception and cognitive control (Pessoa, 2009). Ardila (2008) suggests that 'executive functions' can be dichotomised into meta-cognitive functions (eg. planning, attention, etc.), and emotional/motivational functions that co-ordinate emotion and cognition. This interaction of emotion and cognition also involves inhibitory processes. For example, social situations require inhibition of basic impulses that may be selfish or unacceptable (Ardila, 2008).

Emotions are harder to define than cognition, as cognition and emotion interact (for review see Pessoa, 2008). Definitions of emotion often revolve around the concepts of drive and motivation leading to reward or punishment (e.g., Rolls, 2005), or conscious/unconscious evaluations or appraisals of events (e.g., Arnold, 1960). Some theoretical perspectives focus upon 'basic' emotions (e.g., Ekman, 1972; 1992). The most well-known list of basic emotions contains the emotions referred to as fear, anger, happiness, sadness, disgust and surprise (Ekman, 1972). The term basic emotions refers to emotions that are discrete and have evolved through adaptation to the species' surroundings (Ekman & Cordaro, 2011). It is noteworthy that the list of proposed 'basic' emotions has also grown since the initial concept, and now includes surprise and contempt (Ekman & Cordaro, 2011). Ekman and Cordaro also suggest that they expect to find evidence for several other rewarding emotions including amusement, relief, wonder, ecstasy, excitement, and sensory pleasure. Other perspectives upon emotion extend the emotions of interest to include those pertaining to morality such as envy and pride (e.g., Moll, Zahn, de Oliveira-Souza, Krueger, & Grafman, 2005; Haidt, 2003). Ekman and Cordaro suggest that any biological appraisal system and/or cognitive appraisal system for the basic emotions must function very quickly (as the stimulation to emotion onset interval can be very short). Thus, they suggest that these appraisal systems must often function either automatically, or very near automatically, although there will be exceptions when conscious appraisal and reasoning is required.

Izard (2007) suggests that the basic emotions can be considered ‘natural kinds’. Izard defines the term natural kinds as a category of related phenomena that have been provided by nature and have properties that are observably similar (i.e., they are significantly alike in some way). Izard suggests that the basic emotions of happiness, interest, sadness, disgust, anger, and fear all meet the relevant criteria for the classification of natural kinds. In contrast, Izard suggests that ‘emotional schemas’ are not natural kinds. Izard suggest that the basic emotions become entwined with their related cognitive components, and as such form emotional schemas. These schemas cannot be classed as natural kinds as they contain a person’s appraisals and higher level cognitions. Izard suggests that any emotional schemas that frequently occur could be construed as emotional traits, or at least the motivational constituents of personality traits. Izard continues by suggesting that there is never any such entity as an emotionless mind, as affect is always present. From this perspective all mental functions are in some way influenced by the always present emotion. From this perspective, research would focus upon how any ongoing emotional state is replaced by (or integrated with) a different emotional state, as opposed to focusing upon how any emotional state is activated.

It has previously been proposed that at some point during information processing, emotion and cognition eventually equally and conjointly contribute to the way a person controls their thoughts and behaviour (Gray, Braver, & Raichle, 2002). Whereas the study by Gray et al. concerned memory performance and mood state, Pessoa (2008) suggests that this merging of emotion and cognition would occur in a vast selection of situations. Pessoa thus suggests that although emotions and cognitions are partly distinct, integration of the two processes often takes place which blurs distinguishing between them. Pessoa suggests that behaviour is produced via the orchestration of activity in several brain regions. From this perspective it is the aggregated functions of these brain regions that facilitate emotion and cognition.

LeDoux (2012) adopts a different perspective on emotion from that of those who advocate the ‘basic emotions’ approach. LeDoux suggests that differentiating between the basic emotions is problematic, whereas evidence that they have separable neural mechanisms is also weak. LeDoux proposes that the study of emotion should move away from trying to understand the felt experience of emotion, and focus upon studying what he terms the survival circuits in the brain. Brain functions that are life-sustaining facilitate behavioural responses to the environment. LeDoux distinguishes between the traditional idea of basic emotion circuits and survival circuits; basic emotion circuits are supposed to explain the feelings associated with whatever each circuit is responsible for. In contrast, survival circuits are not directly related to feelings, instead they modulate behaviour-environment interactions (which can indirectly influence felt experiences). The critical point here is the function of a survival circuit is to control behaviour when opportunities and challenges are present, not simply to create feelings. LeDoux continues by suggesting that survival circuits aid an organism's survival by organising the functions of the brain. Once activated, specific categories of responses are inhibited whereas other categories of responses rise in priority. Moreover, brain and body arousal levels are increased, the focus of attention is directed to survival relevant stimuli (both external and internal), and motivational and learning systems will be activated. LeDoux summarises the function of these survival circuits as "*sensory-motor integrative devices that serve specific adaptive purposes*" (p. 655).

LeDoux (2012) also proposes that these survival circuits may be triggered by past experience, be innate, and genetically predetermined in early development. Therefore, although not discussed in any detail, this theoretical viewpoint does allow for individual differences in the reactivity of these survival circuits. The most common trigger of a survival circuit would be any stimuli that signal potential harm. This could also be a learned trigger and not be innate. Either learned or innate triggers would suffice to trigger a defence response. LeDoux draws attention to research showing that fearful and aggressive faces are a strong defence trigger (e.g., Adolphs, 2008). LeDoux also incorporates an information processing explanation, as humans are able to recognise some emotions by partial facial expression features such as the eyes (e.g., Whalen et al., 2004), which could be a learned trigger.

One could attempt to amalgamate the perspective of LeDoux (2012) and the perspective of Izard (2007). For example, Izard suggests that the mind is never without emotion, and that emotional states are simply replaced with (or integrated with) other emotional states. From the perspective of LeDoux it would seem likely that any triggered survival circuit activity would replace (or be integrated with) the activity of any previously active circuit. The emotional schemas described by Izard are likely to contain memories of past experiences, the cognitions preceding the onset of the triggered survival circuit response, and any felt emotions that relate to the emotional survival circuit being triggered. LeDoux suggests that more research is required concerning how external stimuli operate as triggers for the survival circuits.

Anxiety is triggered by uncertainty and anticipation concerning possible future threat-related situations (e.g., Grupe & Nitschke, 2013**).** In healthy adults there is a lot of variability in the magnitude of a person's responses to emotional stimulation, and how a person regulates those responses (Ochsner & Gross, 2005). Moreover, many manifestations of psychopathology are also based upon deficits in the adaptive regulation of emotional responses. This can lead to personal distress and self-destructive behaviours (e.g., Gross & Munoz, 1995; Davidson, 2000). Therefore it is important that researchers and clinicians begin to understand more fully how personality and individual differences affect the cognitive control of emotion.

1.2. The study of personality - Eysenck's trait theory

Eysenck (1967) postulated two main personality super-traits. One of these super-traits was a measure of sociability which placed extraversion and introversion at either end of a continuum. Extroverts were described as impulsive, carefree, sociable, excitement/sensation seeking people who are orientated to external stimulation. Conversely, introverts were described as introspective and quiet people who are orientated towards inner stimulation. The second super-trait was a measure of neuroticism. Those high in neuroticism were suggested to exhibit excessive anxiety, fear, depression and/or shyness, whereas those low in neuroticism would display less of these emotional behaviours. It is the contemporary study of the trait anxiety component of this super-trait of neuroticism that is the primary focus of this thesis.

Eysenck's (1967) proposed that a reticulo-cortical circuit regulates levels of cortical arousal caused by the perception of incoming stimuli. Moreover, Eysenck proposed that a reticulo-limbic circuit regulates arousal levels caused by emotional stimuli. Eysenck suggested that variations in neuroticism were related to levels of arousal in the reticulo-limbic circuit. The reticulo-limbic circuit of those high in neuroticism was proposed to facilitate more arousal by emotionally relevant stimuli than that of those who fall in the low neuroticism part of the continuum. Thus, from Eysenck's perspective, those high in trait anxiety would be more physiologically aroused upon perception of emotional stimuli. Despite its biological underpinnings Eysenck's trait theory was based upon 'top down' methods that used statistics derived from personality assessments.

1.3. Personality and anxiety: Reinforcement sensitivity theory

Heavily influenced by Eysenck's (1967) trait theory, Gray (1982) proposed a similar theory now known as reinforcement sensitivity theory (RST). Gray used a bottom up approach that was based primarily on rodent studies and some human pharmacological studies. Gray suggested that the extraversion and neuroticism continuums in Eysenck's factor space should be rotated by around 30 degrees to reflect reward sensitivity/impulsivity and punishment sensitivity/anxiety, respectively (see Figure 1.1). Gray also provided a different and much more detailed neuropsychological basis for his theory.

Gray (1982) proposed a behavioural inhibition system (BIS) as the basis for anxiety. The anatomical basis of the BIS was suggested to be the septo-hippocampal system, the Papez circuit, anterior thalamus, cingulate and pre-frontal cortices. In addition, Gray specified the involvement of neocortical inputs from the prefrontal cortex (PFC) and entorhinal area, to the septo-hippocampal system. Clinical anxiety, phobias and obsessive compulsive disorders were therefore postulated to arise from too much activity of the BIS. Gray and McNaughton (2000) made some subtle revisions to RST, once again using mainly rodent studies combined with some human pharmacological evidence. It is this revised version that is the focus here.

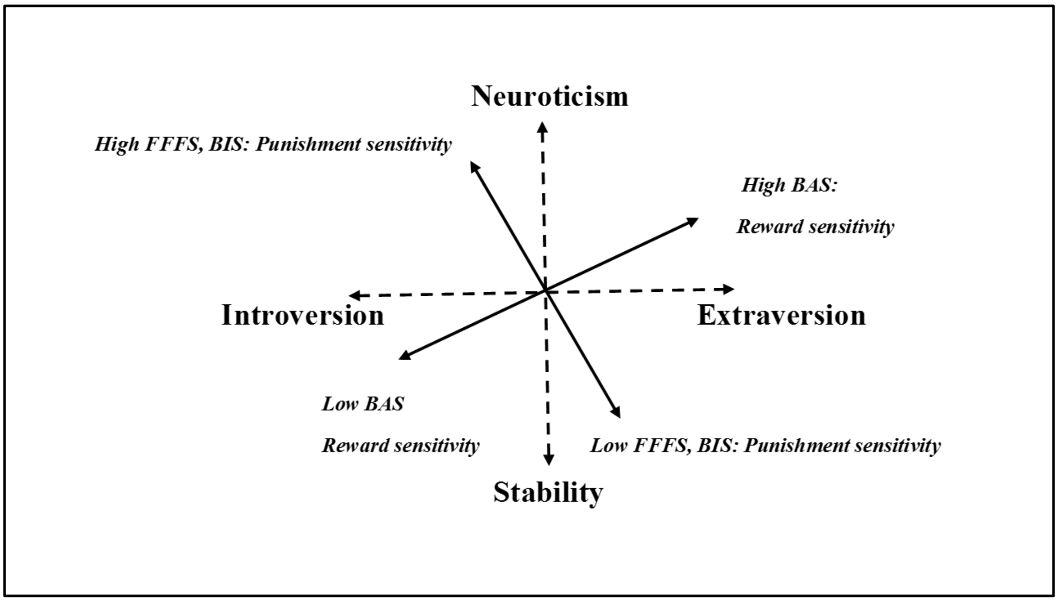

Figure 1.1: The relationship between Eysenck's (1967), Gray's (1982) and Gray and McNaughton's (2000) personality dimensions.

The revised RST (Gray & McNaughton, 2000) is still primarily concerned with the BIS which is activated by goal conflict. As with the original version, this neurobiological system is complemented by two slave systems. The flight fight freeze system (FFFS) mediates responses to all aversive stimuli. Fear is therefore mediated by the FFFS whereas the BIS mediates anxiety. Gray and McNaughton reiterate that although these emotions may be linked, they are not seen as the same conceptually. The behavioural approach system (BAS) is suggested to mediate approach behaviours and reward based behaviour. The BAS is conceptualised as a reward system or feedback loop for positive information, and is active for all appetitive stimuli. The BIS is suggested to be activated when both the BAS and the FFFS are activated simultaneously. This increases levels of anxiety, but only if the BAS and FFFS inputs are similarly weighted. If there is an imbalance, either slave system will dominate behavioural control. Thus, from this perspective the BIS is a conflict resolution system that resolves goal conflict arising from concurrent approach and avoidance behaviour/motivation. The BIS therefore inhibits behaviour and directs attention and physiological arousal towards any conflict inducing stimuli. This facilitates cautious defensive approach type behaviour and risk assessment.

To clarify, Gray and McNaughton (2000) suggest that in a situation of goal conflict where BIS activity is heightened, the BIS will either further activate the FFFS to initiate withdrawal type behaviour, or BAS related approach behaviour will continue. Thus, in a withdrawal situation, the FFFS would be activated by receiving enhanced negative emotional inputs from the BIS, and withdrawal would therefore decrease levels of anxiety. However, it is noteworthy here that in a situation where the FFFS becomes dominant, a fight response could also occur. In RST it is not really clear why this response is not dealt with by the BAS. It has been suggested that anger, which will often be present in a fight response, is in fact mediated by the BAS (e.g., Carver & Harmon-Jones, 2009).

Gray and McNaughton (2000) suggest that the perception of task relevant but goal conflicting stimuli often inhibits much of the motor activity that is being carried out at the time. They suggest that the stimulus that is perceived as inducing this goal conflict, has its neural representation changed and ‘tagged’ as ‘faulty needs checking.’ Future experiences of these tagged stimuli are suggested to be dealt with in a more inhibited manor. From this perspective, behavioural inhibition and risk assessment are putatively mediated by the posterior cingulate and septo-hippocampal system, whereas avoidance behaviours may be mediated by the anterior cingulate and amygdala.

Smillie, Pickering and Jackson (2006) draw attention to the fact that the strength of any effect upon behaviour that any stimulus may have, is dependent upon three things; the motivational strength of the stimulus itself, the level of activation of its mediating system; and the level of activation of the competing system(s). For example, BAS outputs are not only regulated by the BAS and by the strength of rewarding stimuli, but also by the level of inhibition facilitated by the BIS and FFFS. In short, whilst the FFFS controls simple escape or fight based defensive behaviours, the BIS mediates risk analysis, thus restraining BAS and FFFS outputs. Smillie et al. suggest that whilst RST is often referred to as a theory of anxiety and impulsivity, it is better described as a neuropsychological theory of motivation, emotion and learning.

In summary, RST (Gray & McNaughton, 2000) comprises three systems. The functional outputs of a reward based approach motivation system, and a threat based avoidance motivation system, are modulated by a conflict resolution system. All three systems can be said to be necessary for survival. RST therefore fits within the framework of emotional survival circuits proposed by LeDoux (2012). From this perspective, it would seem likely that Gray and McNaughton tapped into two basic survival circuit functions (i.e., FFFS and BAS), and a third more complex survival circuit (BIS) that mediates the balance of the two basic systems.

1.4. Human reinforcement sensitivity theory research

Corr (2004) reviewed RST research carried out with humans, with a particular focus upon laboratory experiments. The studies of emotion and RST reviewed by Corr do not seem to provide any conclusive evidence as to how emotion relates to the theory. Indeed Corr suggests that there is confusion about what the nature of reinforcement actually is. For example, Corr suggests that the distinction between motivational and emotional components can be confusing. Corr cites Mathews and Gilliland (1999) as suggesting that taking a strictly biological approach may be of limited utility as the literature is so confusing, and generalising from animal to human studies is difficult. Mathews and Gilliland suggested that cognitive approaches may prove to be more informative. Corr suggests that this is also difficult as making precise experimental predictions is hard. There have however been some later experimental studies that provide some insights into how RST relates to humans.

Although the majority of the biological evidence in favour of RST comes from rodent studies, there has been some human RST biological research. Mathews, Yiend and Lawrence (2004) refer to the septo-hippocampal system described by Gray and McNaughton (2000) as a hierarchical defence system. Mathews et al. showed that threat related visual stimuli activated the entire septo-hippocampal system. Differential levels of brain activity in many of the areas of this system including the hippocampus, parahippocampal cortex and amygdala were positively correlated with individual differences in behavioural inhibition, which is a construct closely related to anxiety (as measured by the BIS scale, Carver & White, 1994).

Experimental behavioural RST research with human participants can be conducted using reaction time paradigms. For example, Eriksson, Jansson, Lisspers and Sundin (2016) used a modified stop-signal task to investigate the reactivity of the BIS. Eriksson et al. reported an interaction between levels of self-reported behavioural inhibition, stop-signal reaction times, and stop-signal accuracy levels. Participants with high BIS scores (as measured by the BIS scale; Carver & White, 1994) and also long stop-signal reaction times (indicating poorer levels of inhibitory control), showed poorer accuracy levels than those with low BIS scores (and long stop-signal reaction times). Accuracy levels did not differ between high and low BIS scorers with short stop-signal reaction times (which indicate good inhibitory control). However, it is noteworthy that the correlations present were also in the direction one would expect. The correlation between BIS and stop-signal reaction time was positive and moderate, but it did not reach significance. Furthermore, the correlation between BIS and stop-signal accuracy was negative but only weak in magnitude, and also did not reach significance.

In the human neuroscience literature the anterior cingulate cortex (ACC) is suggested to be involved in monitoring environmental conflict (Botvinick, Braver, Carter, Barch, & Cohen, 2001). This functional description of the ACC resonates with Gray and McNaughton's description of BIS function, and the ACC is part of their proposed septo-hippocampal system. Amodio, Master, Yee and Taylor (2008) used EEG and a response inhibition task to investigate individual differences in BIS activity. The focus here was on brain activity as evidenced by specific event related potentials (ERP), that are proposed to originate from the ACC. Dipole models suggest that the error-related negativity (ERN), which reflects error related brain activity, and the N2, which reflects conflict related brain activity, are generated in the ACC (Mathalon, Whitfield, & Ford, 2003). The go/no-go task used by Amodio et al. showed that the frontocentral N2 ERP during no-go trials correlated with BIS scores measured by the BIS scale (Carver & White, 1994). The study by Amodio et al. therefore links variations in anxiety to variations in conflict monitoring. Moreover, in their study the ERN was related to lower error rates and lower BIS scores.

Kanske and Kotz (2012) also investigated the relationship between individual differences in anxiety and goal conflict monitoring. They used a modified flanker task in three experiments that used negative, positive and neutral words. Participants had to identify the ink colour of the central word that was either congruent or incongruent with the colour of the surrounding vertically flanked words. Anxiety was selectively related to the reaction time interference effect (incongruent minus congruent) during trials with negative words, but not positive words. Moreover, their EEG analyses showed that a conflict related negativity ERP (observed at 190-250 milliseconds) during negative trials was reduced in high anxious participants. Increases in activation of the ventral ACC during negative word incongruent trials were negatively correlated with anxiety. Moreover, amygdala activity during these trials was reportedly greater in high anxious participants. It is noteworthy that Kanske and Kotz's findings in their flanker experiments were in alignment with their findings using a modified Simon task (that delineates high and low auditory response conflict, but still requires a motor response) presented in the same paper.

There is also some evidence linking BIS/anxiety to conflict monitoring and inhibitory control that is derived from studies that used other goal conflict tasks, and focused upon the sequential effects of conflict processing. For example, Etkin and Schatzberg (2011) and Etkin, Prater, Hoeft, Menon and Schatzberg (2010) used an emotional goal conflict task to investigate how clinical anxiety is related to emotional conflict resolution. In these studies anxiety seemed to relate to an impairment in the control of emotional conflict. In a similar study Larson, Clawson, Clayson and Baldwin (2013) used a neutral goal conflict task to investigate the same question in a non-emotional situation. In this study anxiety seemed to relate to an enhanced conflict resolution ability. However, the evidence from these studies, and the type of paradigms used are discussed in detail in chapter two and thus will not be discussed further here.

1.5. Anxiety and emotional face processing

Emotional facial expressions aid communication in social situations (e.g., Darwin (1872). Recognising a person's facial expression aids the observer to identify a person's intentions and mood (e.g., Bruce & Young, 1986). Accordingly, research concerning anxiety and the processing of emotion often focuses on emotional face processing. For example, Perlman et al. (2009) reported an interesting result derived from using an eye-tracking methodology. Neuroticism (the basis for anxiety) correlated positively with the amount of time looking at the eyes of fearful faces (.6), sad faces (.4), and happy faces (.37). Further insights into the effect of anxiety upon emotional face processing comes from a study concerning emotional face detection sensitivity. Doty, Japee, Ingvar and Ungerleider (2013) showed that those high in trait anxiety had an increased ability to detect briefly presented (33 milliseconds) target fearful faces that were immediately masked by neutral faces. In this study the sensitivity of the detection of masked fearful faces also correlated positively with individual differences in neuroticism, harm avoidance, and social anxiety, in addition to trait anxiety.

In real world settings emotional faces may appear infrequently amongst neutral faces. Rossignol, Philippot, Douilliez, Crommelinck and Campanella (2005) used an emotional face detection oddball paradigm where a stream of neutral faces were presented along with intermittently appearing fearful and happy faces. Detection of fearful faces was faster than happy faces by both high and low trait anxious participants. However, high trait anxious participants were faster than low trait anxious participants at detecting both fearful and happy faces. Rossignol et al. also recorded brain activity using EEG. Their ERP analyses revealed that high anxious participants showed an earlier P3b ERP for emotional faces relative to low anxious participants, and a decreased N300 ERP amplitude (in the right hemisphere) for emotional faces relative to low anxious participants. The authors suggest that the N300 is related to processing emotional features, and the P3b may reflect a conscious speeded decision based replacement for the diminished N300 based emotion evaluation function. Rossignol et al. suggest that high anxious participants may use less neural resources when initially evaluating the emotionality of the faces (as reflected in the reduced N300), but increase the use of explicit decision making resources (as reflected in the earlier P3b). This experiment suggests that anxiety may modulate the processing of facial emotion. However, other studies have provided inconsistent results.

Holmes, Nielsen and Green (2008) used an emotional face processing task where high and low trait anxious participants were required to respond to immediate emotional facial expression repetitions. Two conditions were included. One condition required participants to respond to repeated fearful faces or repeated neutral faces. The other condition required participants to respond to repeated happy faces or repeated neutral faces. Participants were divided into high and low trait anxiety groups using a median split. There were no effects of emotional face type nor trait anxiety in the RT data. However, Holmes et al. reported differences in brain activity that related to trait anxiety. In their low trait anxious group there was a trend towards an increased P1 ERP for fearful faces compared to neutral faces. This P1 effect was located in the right occipital area and was not present in the left hemisphere. In their high trait anxious group this P1 effect was increased in magnitude relative to their low trait anxious group. Moreover, the P1 was present in the occipital area of both hemispheres. These effects were not present for happy faces compared to neutral faces. Holmes et al. suggest that the occipital P1 ERP represents an enhanced perception of threat, and fast attentional orienting towards this threat-related stimuli.

In another experiment, Morel, George, Foucher, Chammat and Dubal (2014) required participants to decide if faces had any emotional significance or if they were neutral. Morel et al. reported that their high trait anxious group produced faster RTs in their fearful / neutral condition than their happy / neutral condition (for both emotional and neutral stimuli). Their low trait anxious group did not. They also reported that an occipital P1 ERP was larger for the emotional faces in the happy / neutral condition, but not the fearful / neutral condition. This seems somewhat in contrast to their RT findings, and opposite to the findings of Holmes et al. (2008). Moreover, this effect was specific to their high trait anxious participants, as it was not present in their low trait anxious group. Morel et al. proposed that this counterintuitive ERP effect may be due to condition effects as the entire fearful / neutral condition may have been processed as a threat related situation, whereas the entire happy / neutral condition may have been processed as a positive situation. Thus the neutral faces in the fearful / neutral condition may be processed as more threat relevant than those in the happy / neutral condition, which may have masked any possible trait anxiety related P1 ERP effects for fearful faces. Alternatively, Morel et al. suggest that the enhanced P1 ERP for happy faces in present in high trait anxious participants could reflect enhanced sensibility to the individual facial features, such as a smile. This effect suggesting that the entire fearful / neutral condition was processed as a threat-related situation was not present in the study by Holmes et al. (2008), but the task instructions differed considerably between these studies.

Task instructions differed even more in the study by Cooper, Rowe and Penton-Voak (2008). This task involved participants responding with a different key press to seven different facial expressions randomly presented in the same experiment (anger, sadness, happiness, fear, surprise, disgust and neutral). There were no effects of trait anxiety upon the RTs for any of these emotional faces. Cooper et al. suggest that anxiety does not affect RTs to fearful faces (or any of the other emotional faces). However, it is plausible that the seven emotional faces (and seven response keys) used in one experiment may have rendered any anxiety-related effect weaker and thus much harder to detect.

A recent neuroimaging study provides further insights into these issues. Fonzo et al. (2015) used an emotional face-matching task to investigate emotional face processing in generalised anxiety, social anxiety, and panic disorder patients. In this task participants are shown a target face at the top of the computer screen. They are then required to match the emotional expression of this face to one of the expressions depicted by two faces that are presented below. Rapid responses were not a requirement of this task, and thus no reaction time (RT) differences between patient groups and normal controls were observed. Trait anxiety scores were analysed for 44 of the 59 participants. In their happy face versus fearful face matching task there was a positive relationship between trait anxiety and the difference between right amygdala activation during happy face processing and right amygdala activation during fearful face processing. No trait anxiety related differences in amygdala activation related specifically to either happy face or fearful face processing versus oval control stimuli. In their happy face versus angry face matching task there was also a positive relationship between trait anxiety and the difference between anterior cingulate activity during happy face processing and anterior cingulate activity during angry face processing. Fonzo et al. report that this was due to a negative relationship between anterior cingulate activity to happy faces (versus oval control stimuli) and trait anxiety.

Further neuroimaging data was provided by Ball et al. (2012), who also used the emotional face-matching task as used by Fonzo et al. (2015). Ball et al. reported that trait anxiety was related to increased amygdala, insula and dorsal ACC activity to negative faces relative to positive faces. In a different type of experiment Etkin et al. (2004) used a backward masking paradigm. In this task participants had to identify the colour tint of fearful and neutral faces (red, yellow, or blue). Their non-masked condition involved a 200 millisecond presentation of either the fearful face or neutral face. Their backward masked condition involved a 33 millisecond presentation of either the fearful face or neutral face followed by a 167 millisecond presentation of a neutral face (of the same colour, but a different person). Etkin et al. found that trait anxiety correlated negatively with the speed of colour identification during masked fear trials but not unmasked fear trials. However, it is noteworthy that their sample was small, and as such the correlations should be treated with caution. Etkin et al. also found that masked fearful faces that were thus unconsciously perceived produced a strong positive correlation between basolateral amygdala activity (neutral minus fearful) and trait anxiety. However, in this study unmasked consciously perceived fearful faces produced only a very weak relationship.

In summary, it seems as if the behavioural effects of anxiety upon facial emotion recognition and/or discrimination are inconsistent. However, it is noteworthy that several studies have provided some complementary neuroimaging evidence that suggests that anxiety may related to altered emotional face processing. It is possible that the behavioural results are being obscured by the different task instructions used in the paradigms. It would make intuitive sense that emotional faces would trigger a survival circuit similar to that described by LeDoux (2012), and that the effects of triggering this circuit (such as faster responses to fearful faces) would be increased in high anxiety.

1.6. Social anxiety

Social anxiety can be defined as a persistent fear of social interaction, or fear of being observed and evaluated by other people (Leary & Kowalski, 1995; Clark & Wells, 1995). Indeed, highly socially anxious people perceive other people as being threatening and/or critical (Rapee & Heimberg, 1997; Turk et al., 2001; Clark & wells, 1995). McNeil (2001) and Rapee, and Heimberg (1997) proposed that social anxiety can be considered a continuum that ranges from people having no social fear at all, through to people experiencing subclinical levels of social anxiety, and in extreme cases manifesting as clinical social phobia. There are several cognitive theorists who propose that social anxiety is related to information processing biases (e.g., Clark et al., 2003; Foa, Franklin, & Kozak, 2001; Turk, Lerner, Heimberg, & Rapee, 2001; Rapee & Heimberg, 1997; Clark & Wells, 1995). It is also noteworthy here that those who score highly in social anxiety also tend to score highly on trait anxiety (e.g., Ball et al., 2012; Mattick & Clarke, 1998).

Both positive and negative emotional facial expressions deliver social information (e.g., feelings and intentions) from one person to another (Keltner & Ekman, 2000). Emotional information processing biases, and the way they relate to social anxiety levels, have been researched in experimental settings. For example, Mogg and Bradley (2002) and Mogg, Philippot and Bradley (2004) showed that socially anxious participants display an attentional bias towards angry/threatening faces instead of happy or neutral faces. Moreover, Gilboa-Schechtman, Foa and Amir (1999) showed that socially anxious participants detect threatening faces faster than happy faces using a visual search paradigm.

Bantin, Stevens, Gerlach and Hermann (2016) conducted a systematic review of social anxiety and facial dot-probe studies. In these experiments participants must respond quickly to a probe stimulus that is presented in the location of one of two previously presented faces. Those high in social anxiety seemed to preferentially direct attention towards faces that are threat-related, relative to non-socially anxious controls. Reeb-Sutherland et al. (2015) reported that behaviourally inhibited adolescents with lifetime histories of social anxiety disorder displayed a lower threshold for the identification of fearful facial expressions relative to angry facial expressions. Silvia, Allan, Beauchamp, Maschauer and Workman (2006) used a simple facial expression recognition paradigm which showed how social anxiety modulates emotional face recognition. Silvia et al. found that happy faces were responded to faster than sad faces. Silvia et al. found that those high in social anxiety were slower to recognise happy faces relative to those low in social anxiety. Silvia et al. also reported that overall happy faces were responded to faster than angry faces. They also showed that although those low in social anxiety responded to happy faces faster than angry faces, those high in social anxiety showed only a borderline trend to respond to happy faces faster than angry faces.

Further insights into social anxiety and any related emotional processing biases, are provided by complementary neuroimaging studies. For example, Ball et al. (2012) reported that social anxiety was related to variations in amygdala, insula and rostral and dorsal ACC activity when viewing emotional faces in general. Phan, Fitzgerald, Nathan and Tancer, (2006) reported that amygdala responses to fearful and angry faces were greater in patients with generalised social phobia relative to normal controls. The extent of these responses was positively related to their symptom severity. From the perspective of LeDoux (2012) the evidence discussed thus far does suggest that higher social anxiety might relate to a hyper-reactive survival circuit that is triggered by social situations and the processing of emotional faces.

1.7. Anxiety and fear

In the human and animal neuroscience literature the terms anxiety and fear are considered broad categories of survival responses (Mobbs & Kim, 2015). In the psychology literature fear is traditionally suggested to be aroused when a situation is perceived as being a threat to a person's physiological or psychological self, and is out of the control of the person (e.g., Frijda, 1986; Lazarus, 1991; Scherer, 1984). Situations perceived as threat related can be either learned or innate. A person's fear thresholds are determined by biological influences, sociocultural influences, individual differences, and previous experiences (Izard, 1997). From a psychological perspective, the desired activity when experiencing fear is to escape from any fear causing situation, as the desire for protection is high. Therefore, in any situations involving any perception of threat, avoidance behaviours are activated (Frijda, 1986; Lazarus, 1991; Roseman, Wiest, & Swartz, 1994).

From a biological perspective fear can also be described as an activated emotional state that is aversive, and motivates any organism to deal with any threatening occurrences. The resulting coping behaviours have been proposed to be focused upon defensive behaviours such as immobility, escaping or attacking (Ohman &

Weins, 2003). Ohman (2005) suggested that the data obtained from behavioural studies shows that fear stimuli automatically capture attentional resources and thus activate fear. Ohman suggested that this effect is mediated by a subcortical network of brain regions including the amygdala. The suggestions of Ohman, and Ohman and Weins are clearly in alignment with the propositions of Gray and McNaughton (2000), as their perspective on fear clearly resonates with description of the function of the FFFS.

McNaughton and Corr (2004) suggested that fear and anxiety can be distinguished by a factor they term as defensive direction. From this perspective fear would be active when leaving a threatening situation and as such can be considered part of an active avoidance response. In contrast, anxiety would be activated when entering a potentially threat related situation or withholding the entry to a potentially threat related situation. These two scenarios were also described as reflecting cautious risk assessment approach behaviour, and passive avoidance behaviour, respectively. However, McNaughton and Corr also proposed that the functions that generate fear and anxiety would overlap substantially. For example, they suggested that anxiety involves the controlling of fears or frustrations that pre-exist any current situation.

Perkins, Kemp and Corr (2007) tested Gray and McNaughton’s (2000), and McNaughton and Corr’s (2004) proposition that anxiety and fear are separate emotional constructs. Trait anxiety and trait neuroticism are suggested to be somewhat psychometrically interchangeable (e.g., Hagopian & Ollendick, 1996; Diaz & Pickering, 1993). Perkins et al. showed that the magnitude of the correlations between trait anxiety and fear as well as the correlations between trait neuroticism and fear were significantly smaller than the magnitude of the correlation between trait anxiety and self-reported neuroticism. Perkins et al. suggest their findings support Gray and McNaughton’s claim. A second study carried out by Perkins et al. showed that these self-reported levels of fear measured by the fear survey schedule (FSS; Wolpe & Lang, 1969) modulated variations in behavioural performance (in a military training setting) that was not additionally modulated by trait anxiety.

The symptoms of anxiety and fear can be similar, but they can also differ. Anxiety has been described as a feeling of long lasting apprehension (or sustained fear) concerning unpredictable and possibly unspecific threat. In contrast, fear has been described as an adaptive feeling of apprehension that dissipates quickly. This phasic type of fear would disappear as soon as any threat is removed (Davis, Walker, Miles, & Grillon, 2010).

Perkins, Cooper, Abdelall, Smillie and Corr (2010) used a threat scenario paradigm to investigate how individual differences in anxiety (measured by the STAI; Spielberger et al., 1983) and fear (measured by the FSS; Wolpe & Lang, 1969) differentially modulate responses to different hypothetical threat situations. In their first study fear scores were positively correlated with the reported tendency of a participant to orient away from threat, whereas trait anxiety scores were not. Their second study replicated the findings of their first study, and also extended the findings by modifying the threat scenario paradigm. Scores on the fear questionnaire positively correlated with self-reported intensity ratings of participants' reported defensive responses, and participants' self-reported intensity of the types of threat. Participants' fear scores also negatively correlated with their perceived distance to the hypothetical threat, escapability of the hypothetical threat, and the availability of concealment from the hypothetical threat. Perkins et al. suggest that the direction of the correlations between participants' fear scores and the ratings is consistent with the notion that those high in fear proneness perceive threats as being closer and more intense. In short, Perkins et al. suggest that those who score highly on fear questionnaires may have a magnified perception of threat. It is noteworthy that trait anxiety scores correlated negatively with self-reported perceived escapability of hypothetical threat. Scores on the neuroticism questionnaire were also positively correlated with self-reported perceived intensity of hypothetical threat. Perkins et al. reported that the lower magnitude of these other questionnaire correlations with the threat scenario ratings relative to the higher magnitude of the fear correlations with the threat scenario ratings suggests that the fear questionnaire may measure defensive responses more efficiently than the other questionnaires. Perkins et al.'s results supported Gray and McNaughton's (2000) proposition that anxiety and fear responses should not be equally predicted at all distances from any perceived threat. In short, fear related escape responses should replace anxious approach related responses if any perceived threat is particularly close or intense. Moreover, the main impact of this study is that the fear and anxiety personality questionnaires measured separable constructs.

In alignment with the suggestions of Gray and McNaughton (2000), and McNaughton and Corr (2004), Rigoli, Ewbank, Dalgleish and Calder (2016) also suggested that evolution has resulted in two defensive responses that can be described as fear and anxiety. In order to investigate if fear and anxiety are mediated by distinct brain regions they used fMRI and a computerised task where a predator pursues an agent (the agent represents the participant). In a condition that was associated with fear the predator was visible, whereas in a condition that was associated with anxiety the predator was invisible. Rigoli et al. showed that the amount of visually perceived information pertaining to threat modulates activity in defensive brain circuits. More specifically they showed that a lack of information pertaining to threat, activated brain areas relating to anxiety, such as the hippocampus and ventral medial prefrontal cortex and amygdala. In contrast, the presence of information relating to threat, activated brain areas relating to fear, such as the periaqueductal grey. Participants high in trait anxiety showed anticipatory hippocampal activation when visual information was absent. These findings suggest that the two different defence related emotions may have different neural mechanisms, even if they both contribute to increased anxiety.

Thus far it can be seen that in the psychological and neuroscientific literatures anxiety and fear are considered to be somewhat separate constructs. However, it is noteworthy that they are often somewhat entwined in evolutionary theories of emotion, as both behaviours aid escaping from threat. From an evolutionary perspective, both anxiety and fear are considered specialised states that have been designed by natural selection. In specific situations both anxiety and fear can increase Darwinian fitness. Fitness, from this perspective, means inclusive reproductive success. Survival and health relate to Darwinian fitness only in so far as they increase the likelihood of reproduction (Nesse, 1990). General anxiety has most likely evolved to help an individual cope with threats that are not clearly defined. Subtypes of anxiety and fear probably evolved to provide a more specific type of protection against a specific type of threat (Marks & Nesse, 1994).

1.8. Anxiety and anger

In the psychology literature anger is traditionally suggested to be elicited in situations where obstacles are perceived to be interfering with goal directed behaviour, or when demeaning offenses are perceived to have occurred against oneself or loved ones (Averill, 1982; Hampton, 1978; Izard, 1977; Lazarus, 1991). Anger is suggested to activate and sustain increased amounts of energy in order to aid defence of oneself, defence of loved ones, or to correct an appraised wrong doing (Averill, 1982; Izard, 1977, 1993). When a person experiences anger their attention is focused, and a desire to strike out, attack, or get back at the source of the goal obstruction is activated (Arnold, 1960; Averill, 1982; Frijda, 1986; Izard, 1977; Lazarus, 1991; Roseman et al., 1994). The activation of these aggressive desires facilitate behaviours that aid the removal of any social or environmental barrier to a person's goals (Frijda, 1986; Lazarus, 1991). Intense forms of anger are often related to aggression and/or impulsiveness, but less intense forms of anger can be reconceptualised as a form of problem solving. The latter form of anger can therefore result in beneficial consequences as opposed to harmful consequences (Averill, 1982). Trait anger is proposed to be mediated by the BAS (Carver & Harmon-Jones, 2009), and is therefore a behaviour closely related to approach motivation (Harmon-Jones, 2003). Moreover, trait anger is also suggested to reliably predict reactive aggression (Bettencourt, Talley, Benjamin, & Valentine, 2006).

Shields, Moons, Tewell and Yonelinas (2016) showed that experimentally induced anxious mood but not experimentally induced angry mood impaired participants executive function. They additionally showed that individual differences in post induction anxiety ratings, but not post induction anger ratings, predicted these executive function deficits. The results of these studies provide some support for the suggestion that different negative affective states may differentially modulate cognition (Nabi, 1999), although this paper refers specifically to persuasion. Anger and anxiety are two different emotional states that have been suggested to be related to unique autonomic nervous system responses (Kreibig, 2010), and patterns of brain activity (Phan, Wager, Taylor, & Liberzon, 2002). Trait anger has been shown to relate to an enhanced attentional bias towards angry faces (van Honk, Tuiten, de

Haan, van den Hout, & Stam, 2001; Putman, Hermans, & van Honk, 2004). This makes logical sense as approach motivation has also been shown to modulate brain activity to angry faces (Beaver, Lawrence, Passamonti, & Calder, 2008). In short, using fMRI, Beaver et al. showed that increased BAS scores (as assessed with the BAS drive subscale of the BIS BAS scales; Carver & White, 1994) were related to increases in amygdala activity and decreased ventral anterior cingulate and ventral striatal activation to angry facial expressions, relative to neutral and sad facial expressions. However, it is noteworthy that their sample was very small (n=22), so these results should be treated with caution. Moreover, it is noteworthy that the activated areas (amygdala, anterior cingulate) have previously been suggested to be part of the BIS and/or FFFS brain circuitry (Gray & McNaughton, 2000).

The study by Beaver et al. (2008) also showed that increased BIS scores were related to increases in dorsal anterior cingulate activity for angry facial expressions relative to neutral and sad facial expressions. The modulating effect of BIS upon brain activity is in alignment with research that suggests that this region is implicated in the anticipation of the occurrence of aversive events (Nitschke, Sarinopoulos, Mackiewicz, Schaefer, & Davidson, 2006), fear conditioning (Phelps, Delgado, Nearing, & LeDoux, 2004), and urgent response inhibition (Garavan, Ross, Murphy, Roche, & Stein, 2002). Beaver et al. suggest that the differential effects of BAS and BIS upon brain activity are in accordance with the suggestion that threat related stimuli can be interpreted as either provocative which induces aggressive behaviour, or dangerous, which induces anxious behaviour. From this perspective this would depend upon a person’s temperament or an environmental context (Dimberg & Ohman, 1996; van Honk et al., 2001).

Even though trait anger and trait anxiety are separable constructs, trait anger has been shown to correlate positively with trait anxiety (Carre, Fisher, Manuck, & Hariri, 2012; van Honk et al., 2001). Carre et al. also showed that trait anger positively correlated with amygdala activity to angry faces only in male participants who scored highly in trait anxiety. Oddly, these effects were not significant for female participants. Further evidence is provided by Coccaro, McCloskey, Fitzgerald and Phan (2007) who also showed that individuals who are prone to reactive aggression and excessive bursts of anger display enhanced amygdala reactivity to angry faces.

Veenstra, Schneider, Bushman and Koole (2016) used a computerised approach-avoid task where participants were required to make approach and avoid movements with a joystick to angry and happy faces. The face stimuli had either a direct eye gaze or an averted eye gaze. Trait anger (as measured by the trait anger subscale of the State-Trait Anger Expression Inventory (STAXI, Spielberger, 1988) was related to faster approach joystick movements relative to avoid joystick movements to angry faces. Moreover, this effect was only present when the angry faces displayed a direct gaze as opposed to an averted gaze. No such effects were present for happy faces. The effects of trait anger upon task performance were therefore specific to hostile stimuli. Veenstra et al. suggest that people with elevated trait anger might approach hostile social interactions automatically. They propose that their results support an influential account of anger which suggests that high trait anger relates to a cognitive processing bias that leads people to interpret social interactions with increased hostility (Wilkowski & Robinson, 2008). Veenstra et al. suggest that in their study the trait anger related enhanced approach motivated responses (relative to avoid responses) to angry faces may reflect this processing bias. Veenstra et al. also suggest that their findings are in alignment with the model of trait anger proposed by Koole and Veenstra (2015). This model suggests that trait anger is modulated by increases in approach motivation in situations that are anger relevant. Veenstra et al. suggest that this perspective is in contrast to previous motivation research that proposed that trait anger was linked to a general multi-situational increase in approach motivation (Carver & Harmon-Jones, 2009). Veenstra et al. suggest that their data support the former explanation, and not the latter, as the effects of trait anger upon performance were only present with approach responses to stimuli with direct gaze. Veenstra et al. suggest that the latter explanation would predict these effects to be present with both approach and avoid responses. However, it is noteworthy that they did not administer trait anxiety measures which would have illustrated if just trait anger was implicated, or if trait anger plus trait anxiety was involved.

Both anxiety and anger can be differentially explained from an evolutionary perspective. For example, anger may aid Darwinian fitness by protecting against exploitation. Moreover, anger may be adaptive by signalling that any undesirable change in a previously mutually beneficial relationship will not be tolerated (Nesse, 1990). The evolutionary benefit of anger is thus suggested to function in quite the opposite way to anxiety. For example, Nesse suggests that anxiety can motivate cooperation with others when it is inconvenient or perhaps somewhat undesirable, but also in a person's best interests. Anger on the other hand, may be intended to stop a currently cooperative situation from ending.

1.9. *Cognitive perspectives on anxiety: Attentional control theory*

Whereas RST (Gray & McNaughton, 2000) was primarily derived from biological animal studies, attentional control theory (ACT, Eysenck, Derakshan, Santos, & Calvo, 2007) was derived from the study of human cognitive psychology. ACT is also influenced by the work of Derryberry and Reed (2002) who report a negative correlation between self-reported attentional control and trait anxiety. A major assumption of ACT is that anxiety is manifested when one's desired goal is under threat. Here it shares some common ground with RST, which also concerns the maintenance of goal directed behaviour. However, ACT makes more specific predictions about attentional processes and the effect of threat related stimuli in high anxiety. For example, unless the task being performed by a high anxious participant involves stimuli that are threat related, the perception of threatening peripheral goal irrelevant stimuli will reduce the focus of attention to the task in hand. Moreover, if the task being performed does involve goal relevant threat related stimuli, the threat related stimuli will enhance the goal directed behaviour of those high in anxiety.

Eysenck et al. (2007) conceptualise attentional control as a function of the central executive, as described by Baddeley (1986). They also suggest that attentional control theory resonates with Easterbrook's (1959) suggestion that anxiety narrows one's scope of attention. Inhibition and attentional shifting are the main functions implicated in attentional control theory. Impairments of these functions are proposed to be due to the reduced effectiveness of attentional control processes in high anxiety. Of particular relevance to the current project and RST are the inhibitory functions. Inhibitory processes are usually described as those facilitating the withholding of automatic or habitual responses.

The notion that anxiety relates to variations in attentional control is integral to ACT (Eysenck et al., 2007). Corbetta and Shulman (2002) suggested that a goal directed system modulated by knowledge, goals and expectation is distinct from a stimulus driven system that responds to stimuli that are salient and/or conspicuous. The goal directed system is postulated to regulate top down attention and be mediated by the PFC. This explanation resonates with the explanations of attention and cognitive control proposed by Posner and Petersen (1990) and Miller and Cohen (2001). The stimulus driven system is proposed to facilitate bottom up attentional control and detect relevant but possibly previously salient yet unattended sensory events. This system is suggested to be mediated by the ventral-frontal and temporo-parietal cortices. However, it is suggested that the two systems often functionally interact (Pashler, Johnston, & Ruthroff, 2001). ACT suggests that anxiety is disrupting to the balance between the goal directed attentional system and stimulus driven attentional system. Eysenck et al. propose that anxiety is linked to a magnified influence of the stimulus driven system coupled with a decrease in the influence of the goal directed system. Thus each system has reciprocal influences upon each other.

1.10. Attention and Corbetta & Shulman

To understand ACT (Eysenck et al., 2007) it is necessary to understand the inspiration behind the theory of attention proposed by Corbetta and Shulman (2002). From their perspective, human visual attention is modulated by 'top-down' cognitive factors including goals, knowledge and expectations in addition to 'bottom-up' factors resulting from stimulation of the senses. Whereas top-down processing is influenced by previous experience, bottom-up processing is predicated upon perceptual analyses which lead to simple motor output. However, attention can be influenced by an interaction between these processing styles during situations where stimuli are novel or unexpected. This interactive process therefore modulates what is attended to in the environment and how it is attended to. Corbetta and Shulman propose that the human visual attention system is mediated by two partly distinct brain systems. A dorsal posterior parietal and frontal cortex is implicated during top-down processing, whereas a temporoparietal and ventral frontal cortex (that is mainly right hemisphere based) mediates bottom-up processing. This latter system is particularly implicated when stimuli are unattended and salient.

Corbetta and Shulman (2002) suggest that top-down attentional control mechanisms allow humans to detect stimuli amongst a stimulus array or visual scene more efficiently as they are previously aware of perceptual information such as colour, motion or location. However, this process requires the ability to represent this 'perceptual set' cognitively, and the ability to employ it when biasing the processing of incoming information. In addition, responses to stimuli are faster if the required motor response is previously known (i.e., a 'motor set'). Corbetta and Shulman refer to the combination of perceptual and motor sets as the 'attentional set' which defines all neural representations implicated in selecting and responding to a goal-relevant stimulus.

Corbetta and Shulman (2002) also suggest that attention to sensory information can be modulated by both bottom-up and top-down processing. For example, top-down expectations may modulate perceived salience of sensory stimuli. Sensory stimuli may attract attention if they have unexpected goal directed significance, which may increase the activity of bottom-up attentional processes. For example, when cycling an unexpected vehicle or environmental signal on the periphery may increase bottom-up attentional processing. Moreover, sensory stimuli may also attract bottom-up attentional resources if they share some perceptual characteristics with stimuli that are goal relevant. Accordingly stimulus driven attention is modulated by the interaction of these two attentional systems.

From the perspective of Corbetta and Shulman (2002) the dorsal frontoparietal system that mediates top-down processing is also modulated by bottom-up stimulus salience in a stimuli array or visual scene. Neuroimaging studies suggest that this dorsal frontoparietal system is implicated during searching and detecting and thus mediates a stimulus 'salience map' that can help people direct behaviour. The ventral frontoparietal system is implicated in sensory bottom-up processing, which can disrupt goal directed top-down attention and behaviour (that is mediated by the dorsal system). Corbetta and Shulman refer to this attentional disrupting sub-function as a 'circuit breaker' (that is mainly housed in the right hemisphere). The role of this system is to attract attention to goal-relevant sensory stimuli lying outside the current focus of attention. This system may reflect an orienting system involved in directing attention towards the location of distinct stimuli. Alternatively, this system may function interactively with the dorsal system when stimulus driven orienting is required.

Corbetta and Shulman (2002) postulate two explanations for how the systems may interact. The ventral system may be an alerting system that mediates the detection of goal-relevant environmental stimuli but is unequipped to process high resolution spatial information. From this perspective, once a stimulus is attended to its exact localization is processed by the dorsal system. Alternatively, the circuit breaker function interrupts cognition when a goal-relevant stimulus is attended to. This involves abandoning the present attentional set, and adopting a new one, relevant to the new stimulus.

Corbetta, Patel and Shulman (2008) suggest that reorienting responses in humans are necessary in survival situations (e.g., changing behaviour in response to threatening or appetitive stimuli). As proposed by Corbetta and Shulman (2002), they suggest that the reorienting response is reliant upon the right hemisphere dominant ventral system (interrupting and redirecting activity) and the dorsal system (selection and linkage of stimuli and responses). When they are resting the activity of these systems is at the same level yet they remain functionally distinct. However, when attentional focus is required, the ventral system is inhibited to avoid attending to distracting stimuli. Corbetta, Patel, and Shulman (2008) postulate that the differing types of attentional activity may be mediated by inputs to the ventral system from the locus coeruleus. Corbetta et al. (2008) proposed that this reorienting system has a general role in switching between dorsal and ventral systems, as opposed to the earlier suggestion by Corbetta and Shulman (2002) that it redirects attention between objects where necessary. Corbetta et al. (2008) suggest that this explains evidence of its role in social cognition.

In summary, ACT (Eysenck et al., 2007) is a cognitive account of anxiety that is predicated upon the imbalance of two attentional systems. The two attentional systems are based upon the neuroscientific account of attention proposed by Corbetta and Shulman (2002). High anxiety is proposed to relate to an increase in the reactivity of a stimulus driven attentional system, and/or a decrease in the reactivity of a goal directed attentional system. This leads to increased cognitive interference and /or distraction. It is quite easy to see how a hyper-reactive stimulus driven attentional system (particularly in situations containing peripheral threat) could represent an (over-)enhanced survival circuit function (as described by LeDoux, 2012).

1.11. Anxiety and self-reported attentional control

The attentional control scale (Derryberry & Reed, 2001, 2002) measures individual differences in the ability to focus one's attention, shift one's attention from one task to another, and flexibly control thought processes. Derryberry and Reed (2002) also suggest that self-reported attentional control modulated a threat-related attentional bias using a spatial orienting task. High trait anxious participants, who reported low attentional control scores, displayed an attentional bias towards threatening locations. However, high trait anxious participants, who reported high attentional control scores, were more efficient at shifting attention away from the threat-related location. Derryberry and Reed suggest that some anxious participants may be able to inhibit the impact of incoming threat-related stimuli by recruiting voluntary attentional control processes. Moreover, Mathews, Yiend and Lawrence (2004) employed functional magnetic resonance imaging (fMRI) and showed that behavioural inhibition (BIS scale) scores negatively correlated, and attentional control scores positively correlated, with rostral anterior cingulate cortex activity during the processing of fear-related pictures.

Reinholdt-Dunne et al. (2009) and Walsh, Balint, Smolira SJ, Fredericksen and Madsen (2009) also showed that scores on the attentional control scale correlated negatively with trait anxiety. Moreover, Walsh et al. showed that scores on both attentional control and trait anxiety scales correlated with individual differences in mindfulness. Attentional control positively predicted mindfulness whereas trait anxiety negatively predicted mindfulness. Mindfulness is a state of increased awareness and attention to what is occurring in the present moment (Brown & Ryan, 2003). Moreover, Teper, and Inzlicht (2013) showed that individual differences in a mindfulness sub-facet (referred to as mindful acceptance) were related to increased performance during a task requiring goal conflict resolution. This was evidenced as increases in accuracy during a conventional word-colour Stroop goal conflict task. Therefore, individual differences in attentional control, as reflected in aspects of mindfulness, may also modulate goal conflict resolution.

The attentional control scale was originally presented as two scales described as attentional focusing and attentional shifting (Derryberry & Rothbart, 1988). Attentional focusing was described as the ability to intentionally maintain one's attentional focus towards desired stimuli. In addition, this ability also involves resisting the unintentional shifting of one's attentional focus towards distracting stimuli. Attentional shifting was described as the ability to intentionally shift ones attentional focus towards desired stimuli, whilst avoiding any unintentional focussing towards any other stimuli. Olafsson et al. (2011) investigated the factor structure of the attentional control scale and its relationship with anxiety and depression, using a sample of 728 students. An initial exploratory factor analysis using 361 participants revealed two factors they labelled focusing and shifting. A follow up confirmatory analysis using 367 participants indicated that the two factor model was a reasonable fit to the data. Unsurprisingly, Olafsson et al. reported that the two focussing and shifting factors correlated quite strongly (r=0.73). However, the two factors clearly do not explain all of the variance in each other. Olafsson et al. showed that the predictive validity was different for the focussing and shifting sub scales. Focusing significantly predicted anxiety (after controlling for depression), whereas shifting significantly predicted depression (after controlling for anxiety).

A later study by Judah, Grant, Mills and Lechner (2013) also supports the two factor structure of the attentional control scale, and that the focusing and shifting components have different predictive validity. They used a variety of psychometric and behavioural measures. Focusing and shifting shared only a small to medium correlation, which is somewhat in contrast to the larger correlation reported by Olafsson et al. Judah et al. also reported that focusing was much more reliably negatively correlated with anxiety than depression, whereas shifting was much more reliably negatively correlated with depression than anxiety. However, it is noteworthy that the anxiety and depression scores were obtained using the STAI (Spielberger et al., 1983) subscales proposed by Bieling, Antony and Swinson (1998). This division of the STAI does not appear to have been widely adopted in the anxiety literature. However, we return to this issue later in chapters 6 and 7. It is even more noteworthy that in the study by Judah et al. depression measured by the Beck Depression Inventory-II (BDI-II; Beck, Steer & Brown, 1996) did negatively correlate with focusing but not shifting. This contradicts their findings using the supposed subscales of the STAI. Additionally, the BDI-II correlated positively at identical magnitudes with both the supposed anxiety and depression subscales of the STAI. However, Reinholdt-Dunne, Mogg and Bradley (2013) also reported that lower focusing scores predicted increased anxiety, whereas lower shifting scores predicted increased depression (using the same subscales as Judah et al.).

Judah et al. (2013) showed that attentional focusing (but not shifting) related to enhanced antisaccade performance in an eye tracking experiment. In contrast, attentional shifting but not focusing was related to enhanced switching ability in a letter-number sequencing experiment. Previously, overall scores on the attentional control scale have been shown to relate only weakly to behavioural measures of attentional control (e.g., Muris, van der Pennen, Sigmond & Mayer, 2008), or even be unrelated to behavioural measures of attentional control (e.g., Reinholdt-Dunne et al., 2009). Olafsson et al. suggest that this discrepancy may be due to self-report measures having a broader frame of reference relative to behavioural measures that focus upon specific stimuli. They suggested that more studies that assess the relationship between scores on the attentional control scale and behavioural measures of executive function are required. More specifically, they suggested that no studies using adult samples have been conducted that assess how the focusing and shifting sub-factors of attentional control relate to behavioural measures of executive function.

1.12. Anxiety and attention to threat

Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg and van Ijzendoorn (2007) conducted a large meta-analysis of computerised emotional Stroop, emotional dot-probe, and emotional spatial cuing experiments. In the emotional Stroop task participants are required to name the ink colour of a word, but the words are either threat-related or neutral. If it takes participants longer to name a colour when the word is threat-related as opposed to neutral, a threat-related bias in attention is inferred. The emotional dot-probe task requires participants to respond as fast as possible to a probe stimulus that is presented in the location of one of two previously (briefly) shown stimuli. The briefly shown stimuli are either threat-related or neutral. If participants are faster at responding to the probes in the threat location than the neutral location a threat-related attentional bias is again inferred. The emotional spatial cuing task necessitates participants responding to stimuli whose locations are previously cued either validly in the majority of trials or invalidly in the minority of trials. As one would expect, participants are faster at responding to validly cued stimuli than the invalidly cued stimuli. A threat-related attentional bias can be inferred if participants display a larger reaction time difference between validly and invalidly cued stimuli for threat-related cues relative to neutral cues. The threat-related attentional bias observed in these experiments was meta-analytically related to high anxious participants, and was not observable in low anxious participants.

Bar-Haim et al. (2007) suggest that two separate operational definitions of attentional biases in anxious participants exist in the psychology literature. A within-subjects bias refers to anxious participants attending preferentially to threat-related experimental stimuli relative to experimental stimuli that are neutral. A between-subjects bias refers to increases in attention to threat-related stimuli by high anxious participants relative to low anxious participants. Bar-Haim et al. suggest that confusion can arise as studies sometimes report only one of these biases. For example, anxious participants may exhibit a within-subjects but no significant between-subjects bias. This may imply the bias is not anxiety related. In addition, anxious relative to non-participants may exhibit a between-subjects bias, but no within-subjects bias. To investigate this issue in detail Bar-Haim et al. included 172 studies in their meta-analysis. Overall these studies included 2263 anxious and 1768 non-anxious participants. Bar-Haim et al. reported that overall there was a robust threat-related bias in anxious participants that does not exist in non-anxious participants. They report that the effect size can be considered in the low to medium range (d = 0.45), and suggest that the meta-analytic result cannot be rendered insignificant by another 11,339 studies. Accordingly, the file drawer problem is of no concern in this area.

Bar-Haim et al. (2007) suggest that their finding of a lack of an overall threat-related attentional bias in low-anxious participants is inconsistent with the literature (e.g., LeDoux, 1995) that proposes that people in general automatically and preferentially attend to threat. However, Bar-Haim et al., state that when a study used strongly perceived threat it was evident. They draw attention to Mogg and Bradley's (1996) and Wilson and MacLeod's (2003) suggestions that anxious participants show a bias to mildly and highly threat-related stimuli, whereas low-anxious participants show the bias only to highly threat-related stimuli. Overall studies using pictures did not produce a larger effect than words. However, with subliminal stimuli pictures produced a much larger effect size than words. Bar-Haim et al. propose that this may be due to semantic processing requiring longer than sensory processing.

1.13. Cognitive perspectives on anxiety and the threat-related attentional bias

There have been several cognitive theories concerning anxiety and the threat-related attentional bias, but they all contain slightly different functional mechanisms. They are broadly in alignment with, and can as such broadly be accommodated within, the emotional survival circuit framework proposed by LeDoux (2012). These models and their differential mechanisms were reviewed concisely by Cisler and Koster (2010), but due to their theoretical relevance and for clarity they are each briefly described below.

An early and influential cognitive model proposed by Williams, Watts, MacLeod and Mathews (1988) placed the bias at a preconscious level. From this perspective the level of threat pertaining to any incoming stimulus is ascertained by an affective decision mechanism. Although the term 'decision mechanism' sounds like a conscious function, Williams et al. conceptualise this function as an implicit function. The affective decision mechanism decides if the incoming stimulus represents high or low threat. If a stimulus is appraised as representing high threat, a resource allocation mechanism would be activated. In this situation the resource allocation mechanism would direct attentional resources towards threat-related stimuli. In contrast, if the incoming stimulus was appraised as representing low threat, attentional resources would be directed towards the task in hand, thus the new stimulus would not be attended to. Williams et al. suggested that the resource allocation mechanism is modulated by trait anxiety. According to Williams et al. those high in trait anxiety will direct attention towards threat, whereas those low in trait anxiety ignore this threat. However, the suggestion concerning low trait anxiety has been suggested to be problematic (Mogg & Bradley, 1998). Indeed, Wilson and MacLeod (2003) showed that those low in trait anxiety show a threat related attentional bias for severely threatening stimuli, but not moderately threatening stimuli. In contrast, those high in trait anxiety showed the bias towards both moderate and severe threat related stimuli.

An alternative model also focuses upon preconscious processing of threat related stimuli. Ohman (1996) conceptualises the threat-related attentional bias in anxiety as being evolutionarily adaptive. From this perspective, incoming stimuli are analysed by a feature detection system. The feature detection model proposes that biologically relevant stimuli directly modulate physiological arousal (via the feature detection system) without conscious awareness, resulting in increases in attention towards threat. Once information pertaining to any stimulus has passed the feature detection system it enters a significance evaluation system. Threat-related or relevant information is then suggested to enter a conscious perception system which mediates a slow cognitive appraisal of meaning influenced by emotional memories stored in an expectancy system. From this perspective the slow conscious processing system can also modulate the arousal system if information is appraised as being threat-related. Feedback loops between the autonomic arousal system and the significance evaluation system enable arousal to increase the sensitivity of the significance evaluation system. The expectancy system may also increase the sensitivity of the significance evaluation system to specific stimuli that have been learnt about previously.

Wells and Mathews (1994) proposed a very different explanation of the anxiety related attentional bias for threat-related stimuli. They view the bias as relating to top down self-regulatory executive control processes. Wells and Mathews suggest that self-knowledge, beliefs and voluntary goals direct an individual’s attention towards threat. They argue that those high in anxiety consciously perceive threat to self-perseverance. They suggest that this type of motivational disposition would be associated with threat monitoring, and that the bias observed in experimental settings is mediated by the belief that monitoring threat is important.

The cognitive model proposed by Beck and Clark (1997), involves three stages of information processing. An initial attentional bias or orienting effect at the point of registration of any threatening stimulus was suggested to be predominantly stimulus driven. This was suggested to lead to the activation of a primal threat mode, which involves innate cognitive and affective psychophysiological and behavioural responses to any personally relevant threat related stimuli. The function of this primal threat response was proposed to be the reduction of environmental threat. The third and final stage was proposed to be based upon the secondary activation of slower reflective and elaborative cognitions that are schema based.

Mogg and Bradley (1998) proposed a cognitive-motivational model of anxiety. From this perspective, attention towards threatening stimuli is conceptualised as a normal adaptive function. Mogg and Bradley were influenced heavily by the work of LeDoux (1996). LeDoux showed that threat related material can be processed via two neural routes. One neural route involves fast but crude analyses of features of any stimulus that relate to any previously encountered threat situation. The second neural route involves a slower and more detailed analysis of any incoming stimulus based upon memories and contextual information. Similarly, Mogg and Bradley suggested that attention involves two systems. A valence evaluation system was proposed to be responsible for preconscious initial appraisal of any incoming stimulus. Output from the valence evaluation system was proposed to be modulated by previous learning and contextual information. Trait anxiety was suggested to modulate the reactivity of the valence evaluation system’s response to threat. Thus, from this perspective, those high in trait anxiety would show an increased sensitivity to threat relative to those low in trait anxiety. Mogg and Bradley suggested that output from the valence evaluation system is then fed into a goal engagement system which determines how processing resources are allocated. If any incoming stimulus is tagged as being highly threat-related then any current behavioural activity will be interrupted as attentional resources will be reallocated to the incoming stimulus. In contrast, if the incoming stimulus was tagged as having a low level of threat relevance then current behavioural activity will not be interrupted as further processing of the incoming stimulus will be stopped. From this perspective stimuli with mild levels of threat relevance would be more likely to be appraised as a high level of threat relevance by those high in trait anxiety relative to those low in trait anxiety. In short, Mogg and Bradley suggested that high trait anxious participants have an oversensitive valence evaluation system.

Mathews and Mackintosh (1998), and Mathews, Mackintosh and Fulcher (1997), developed another cognitive model that is somewhat similar to the cognitive-motivational model proposed by Mogg and Bradley (1998). However, from this perspective the attentional bias would occur only when threat needs to compete with other task demands or other stimuli. A threat evaluation system was proposed to automatically evaluate any incoming stimulus. Output from this system was proposed to be fed into a distractor/threat representation system. Any interference/distraction was proposed to be countered by voluntary effort and goal directed behaviour. From this perspective the strength of any stimulus input would need to exceed a certain threshold before any output from the threat evaluation system can feed into the distractor/threat representation system. Those high in anxiety would have a reduced threshold level enabling increased output of the threat evaluation system into the distractor/threat representation system. From this perspective, strong threat cues would attract attention at all levels of anxiety, but weak threat cues would only attract attention in those high in anxiety.

Bar-Haim et al. (2007) proposed an integrative model of attentional biases (incorporating components from the models of Williams et al., 1988, and Mogg and Bradley, 1998) that comprised four systems. Bar-Haim et al. (2007) suggested that a preattentive threat evaluation system evaluates any stimuli present in the environment. If threat is perceived as high, a resource allocation system is activated which results in increased physiological alertness. Any ongoing activities will be interrupted, and attention will be oriented towards the threat relevant stimulus. The output of this resource allocation system is also the input of a guided threat evaluation system. In this system the current stimulus is compared with previously learnt experiences and memories. At this point contextual information and possible coping mechanisms are evaluated. The output of this guided threat evaluation system is a conscious evaluation of the level of threat posed by any incoming stimulus. If the threat level of the stimulus is consciously appraised as high, then a goal engagement system would interrupt current goal directed behaviour. The goal of the individual would then be to alleviate their current increase in anxiety. From this perspective the threat-related attentional bias is mediated by the resource allocation system. In short, Bar-Haim et al suggest that a hyper-sensitive resource allocation system will even direct attentional resources to stimuli that appraised as only mildly threatening by the preattentive threat evaluation system. They suggest that this is the cause of anxiety related problems.

Cisler and Koster (2010) extensively reviewed the literature on anxiety and the threat-related attentional bias, and assessed the evidence for the aforementioned models of this effect that were proposed by Beck and Clark (1997); Williams et al. (1988); Ohman (1996, 2005); Wells and Mathews (1994); Mogg and Bradley, (1998); Mathews and Mackintosh, (1998); Eysenck et al. (2007); and Bar-Haim et al. (2007). Cisler and Koster drew attention to the fact that the only consistent feature across these models is a threat detection system that operates automatically, and mediates enhanced attention to threat-related stimuli. When reviewing the empirical evidence for these models they predominantly focused upon studies using spatial cueing tasks, visual search tasks and dot probe tasks. Cisler and Koster also drew attention to the fact that the attentional bias has three components. These components were defined as facilitated attention towards threat related stimuli; difficulty in disengaging attention away from threat related stimuli; and attentional avoidance of threat related stimuli. In summary of their findings, the evidence suggest that the threat related attentional bias consists of facilitated attention to threat when stimuli are presented for a short duration and have a high threat intensity, but also delayed disengagement and avoidance of threat at later stages of information processing. Cisler and Koster conclude that automatic threat detection is a feature of all the models reviewed except the model by Wells and Mathews (1994). Cisler and Koster suggest that both the behavioural evidence, and the neuroimaging evidence concerning the amygdala’s role in automatic threat detection, support this notion.

Van Bockstaele et al. (2013) reviewed evidence for any causal effect of the threat related attentional bias upon fear and anxiety. They defined fear as a specific immediate affective response to a specific well defined type of stimuli or situations, whereas anxiety was defined as a general ongoing feeling of stressful unease. Thus, from their perspective, high fearfulness and high anxiousness would describe a person who scored highly on fear and anxiety questionnaires, respectively. They focused their review upon research studies that used either the emotional Stroop task; dot probe task; spatial cueing task; visual search task; or attentional blink task. However, the review was limited to studies published between April 2005 and May 2011. They also focused their review of theoretical accounts / models of anxiety and the attentional bias upon five perspectives. This included four of those reviewed by Cisler and Koster (2010). The perspectives of Beck and Clark (1997); Williams et al. (1988); Mogg and Bradley (1998); and Bar-Haim et al. (2007) were discussed along with the cognitive perspective of Eysenck (1992, 1997). Eysenck's earlier perspective is broadly similar to that proposed by ACT (Eysenck et al., 2007) as it revolves around distractibility and a hypervigilance to threat in high anxiety.

Van Bockstaele et al. (2013) drew attention to the fact that these five accounts make different predictions concerning the attentional bias and the causality of fear and anxiety. Van Bockstaele et al. suggest that only the perspectives of Bar-Haim et al. and Beck and Clark suggest that the attentional bias would cause fear and/or anxiety in a unidirectional fashion. Moreover, the perspectives of Eysenck, Williams et al. and Bar-Haim all suggest that the attentional bias is a cognitive vulnerability factor concerning a person developing fear and/or anxiety, whereas the perspectives of Mogg and Bradley and Beck and Clark do not. Furthermore, the perspectives of Eysenck, Mogg and Bradley, and Williams et al. suggest that the attentional bias is implicated in maintaining or exacerbating fear and/or anxiety. In contrast, the perspective of Bar-Haim et al. does not specify this, whereas the perspective of Beck and Clark suggests this is not the case. After reviewing the evidence Van Bockstaele et al. concluded that the theorising of Williams et al. and Eysenck fit the data best. Both of these perspectives proposed a mutually reinforcing relationship between the threat-related attentional bias and fear and/or anxiety, and considered the bias a cognitive vulnerability factor for the development of fear and/or anxiety. In short, Van Bockstaele et al. suggest that a causal unidirectional relationship between anxiety and this threat-related attentional bias is unlikely. Instead they propose that a reciprocal relationship would serve to maintain and reinforce levels of anxiety, and the magnitude of a person's attentional bias.

1.14. The ABCDs of anxiety

Wilt, Oehlberg and Revelle (2011) and Ortony, Norman and Revelle (2005) proposed that anxiety relates to four separate modes of functioning. They describe what they call an ABCD framework of anxiety. The 'A' component refers to affect. This component consists of internal and evaluative states such as mood patterns emotions, feelings and preferences. The 'B' component refers to behaviour. This component consists of physical activity, whether it be observable behaviour such as motor movement, talking and walking, or unobservable behaviour such as heart rate variability. The 'C' component refers to cognition. This component consists of processes that enable an individual to make sense of their environment. Thus, this component includes an individual's thoughts, modes of thinking, beliefs, and problem solving abilities. The 'D' component refers to an individual's desires. This component consists of goals, strivings, wants, and motivations, which all lead to a specific behavioural tendency. Wilt et al. suggest that personality can be seen as the integration of these ABCDs, and that one can view contemporary anxiety research as attempting to evaluate the links between the ABC and D components of an anxious personality.

Wilt et al. (2011) suggest that even though there are the ABC and D components to an anxious personality, anxiety can be researched at three different levels of information processing. They suggest that anxiety differentially relates to reactive processing, routine processing, and reflective processing (Ortony et al., 2005). Wilt et al. suggest that many if not most of the situations an individual may find themselves in demand a rapid response that has followed a fast and efficient form of information processing. Wilt et al. suggest that this simple stimulus-response behaviour occurs at the reactive level of information processing. They suggest that at this level of information processing the A (affect), B (behaviour), and D (desire, i.e., motivation) components are almost indistinguishable from each other. Whereas at this level of information processing the C component (cognition) is only minimally active. This perspective would suggest that at a reactive level of information processing, each of the A, B, and D components simply provide a different perspective on the same unitary activity. In short, situations where a reactive response has interrupted goal directed behaviour will have entailed a behaviour (B) being interrupted by emotional response (A) that then directs motivation (D) to approach or avoid the interrupting stimulus. From their perspective, anxiety at this level of information processing could therefore relate to goal conflict resolution.

Wilt et al. (2011) describe the routine level of information processing as encompassing automatic processes that control well leaned everyday activities. They suggest that at this routine level emotion (A), behaviour (B) and desire: motivation (D) are distinguishable due to the influence of cognition (C). In short at this level of information processing cognition is involved in predicting expectancies about possible up and coming events (i.e., distinguishing between current states and future states). Thus, here anxiety is manifested when expectancies of negative events occur. Wilt et al. suggest that here motivation (D) will direct behaviour (B) to avoidance initiating behaviours, thus reducing the threat.

The final level of information processing is described by Wilt et al. (2011) as the reflective level. They suggest that at this level self-awareness and meta-processing occur. They suggest that feelings that are emanated from the reactive and routine levels of information processing are elaborated upon cognitively. Thus here the experiential component of anxiety becomes enriched with explicit cognitions. Conscious processing such as planning, reasoning and thoughts will guide an individual’s behaviour towards or away from any potential goals. In summary, this perspective thus provides a framework for dividing up emotional (A), behavioural (B), cognitive (C) and motivational (D) functions that can be researched in anxiety, but also delineates the levels of information processing in which these functions can be researched (i.e., reactive, routine and reflective).

1.15. The DSM 5 and the RDOC: Trait anxiety and clinical anxiety

Clinical anxiety, phobias, and obsessive compulsive disorders have been suggested to arise from too much activity of the BIS (Gray & McNaughton, 2000). The 5th edition of the diagnostic and statistical manual of mental disorders (DSM-5; American Psychiatric Association, APA, 2013) suggests that inclusion criteria for the diagnosis of an anxiety disorder is predicated upon persons experiencing "*excessive fear and anxiety and related behavioural disturbances*" (p. 189). The magnitude of these experiences are determined by a clinician's interview and subsequent evaluation. However, it has been proposed that a latent dimension sub-serves the entire anxiety spectrum, which also overlaps with the mood disorders. Differing anxiety and mood disorders have substantial comorbidity and as such making diagnoses is difficult (Lang, McTeague, & Bradley, 2016).

A recent initiative -- the Research Domain Criteria (RDoC) initiative -- questions the decision making utility of organising data around subjective symptoms. This initiative suggests that researchers develop new methods of classifying disorders using behavioural and neurobiological measures (Lang et al., 2016). Lang et al. suggest that the affective physiology of anxiety and the mood disorders is predicated upon motivational circuits that have evolved in the brains of mammals to aid survival. Lang et al. suggest that when activate these circuits produce the subjective experience of emotion. Their perspective clearly resonates with the 'emotional survival circuit' perspective of LeDoux (2012). Lang et al. thus advocate research that is designed to measure the defensive reactivity of these circuits in anxiety and mood disorders. Research suggests that underlying personality traits exist that range from healthy adaptive levels to pathological levels in clinical anxiety and mood disorders (e.g., Bienvenu et al., 2001). Thus, it should be possible to research the reactivity of any emotional or motivational survival circuits in this 'anxiety spectrum' by investigating how variations in trait anxiety affect performance. Trait anxiety research can thus serve to aid in the development of behavioural measures of the reactivity of survival circuits, which could also be used as future clinical diagnostic measures.

1.16. Thesis rationale

The perspective on anxiety offered by Gray and McNaughton (2000) is based upon three interacting brain systems. From their perspective anxiety relates to a defensive conflict resolution system. This system resolves conflicting approach and avoid motivations that are sub-served by a reward related behavioural approach system, and a fear related behavioural avoidance system, respectively. Anxiety is said to relate to the enhanced reactivity of this conflict resolution system. Eysenck et al. (2007) offered a perspective on anxiety that is based upon two interacting brain systems. From their perspective on anxiety the activity of a goal directed attentional system is disrupted by the enhanced reactivity of a stimulus directed attentional system. Anxiety is said to relate to increased cognitive interference leading to increased distraction. The perspectives on anxiety offered by Beck and Clark (1997), Mathews and Mackintosh (1998), Mogg and Bradley (1998), Ohman (1996), Williams et al. (1988), and also Eysenck et al. (2007), all suggest that anxiety relates to the automatic and rapid detection of threat-related stimuli. Therefore, anxiety is said to relate to faster responses to visual stimuli depicting threatening information.

This suggests that anxiety may relate to variability in the activity of three interrelated cognitive processes. High levels of trait anxiety may relate to altered conflict resolution, enhanced cognitive distraction, and enhanced processing of threat relevant visual stimuli. The threat-related attentional bias in high trait anxious people may also interact with the conflict resolution and/or distraction processes. Moreover, the evidence discussed thus far suggests that trait anxiety may also be interrelated with individual differences in social anxiety, trait anger, fear, and attentional control abilities. These other three personality factors may also be interrelated with the aforementioned conflict resolution, distraction and threat processing functions.

If trait anxiety relates to a threat-related modification within any conflict resolution, distraction, and/or basic stimuli processing functions, it may reflect an anxiety related increase in the reactivity of the survival circuits discussed by LeDoux (2012). It is thus the purpose of this thesis to carry out a series of behavioural experiments designed to tap into these circuits, with particular emphasis upon conflict resolution, distraction and emotional face processing. Emotional manipulation in this thesis is solely carried out using visually emotional faces in computerised reaction time experiments. Personality traits are assessed using psychometric measures. This thesis adopts the perspective of LeDoux that suggests emotion can be researched using stimuli that represent survival circuit response triggers, as opposed to emotion circuit feeling triggers. Thus, it is the intent of this series of experiments to elicit manual responses to stimuli representing survival circuit triggers, not to elicit felt emotional responses.

The experiments described in this thesis will all use a methodology sometimes referred to as ‘mental chronometry’. Mental chronometry is the experimental study of response latencies, which are recorded as reaction times. Information processing accounts in psychology are based upon an important theoretical foundation. Processes that occur at a functionally early stage of information processing, such as the identification of stimuli, and the selection of appropriate responses, are accepted to be completed before the onset of a person’s overt response. A person’s response is proposed to be triggered when this processing is complete. Therefore, mental chronometry focuses upon the influence of factors on when a person responds, not how a person responds (Abrams & Balota, 1991). However, these response latencies (reaction times) can also be affected by processes that occur after the response has been selected and is on its way to becoming the overt response (e.g., Osman, Kornblum, & Meyer, 1986). In other words, factors can influence a person’s reaction time if they influence information processes after the selected responses’ point of no return. Mental chronometry (as a means of researching latent response triggers) is thus an ideal methodology to use when researching the existence of any survival circuit triggers such as those proposed by LeDoux (2012).

The experiments described in this thesis will also use stimuli depicting facial emotion throughout. More specifically, the stimuli used will all be either happy faces, angry faces or fearful faces. The only positive emotional faces used will be happy faces. The only other positive emotional facial expression we are aware of is surprise. Surprised faces will not be used as certain methodological considerations need to be accounted for. Adolphs (2002a) suggests that surprised faces can be experienced as either happy or fearful. Elfenbein, Mandal, Ambady, Harizuka and Kumar (2002) also suggest that emotional faces displaying fear and surprise are often confused with each other. This confusion can arise within cultural groups, but also arise more frequently during cross-cultural facial emotion recognition. Jack, Blais, Scheepers, Schyns and Caldara (2009) used behavioural and eye-tracking methods in a within culture emotion recognition study; using happy, surprised, disgusted, fearful, angry, sad, and neutral faces as stimuli. Western participants were highly accurate at recognizing all emotions. East Asian participants consistently confused surprised faces with fearful faces and also consistently confused angry faces with disgusted faces. The eye-tracking data suggested that this cultural difference in emotion perception was due to East Asian participants fixating on different face regions than western participants. It is expected that we obtain a culturally diverse sample so no surprised or disgusted faces will be used. No neutral faces will be used as in a two choice task consisting of neutral and fear faces, the entire situation could be processed as a threat situation. Moreover, in a two choice task consisting of neutral and happy faces, the entire situation could be processed as a positive situation. This would be a serious confound in our study designs. We suggest this based upon the results and interpretation of the study discussed earlier by Morel et al. (2014).

The emotional faces will require behavioural responses. This thesis does not aim to record physiological or neural responses. However, there is plenty of evidence confirming that visual emotional stimuli (i.e., photographs) used in experimental settings elicit physiological and neural responses. Previous research shows that when appetitive, neutral, and aversive photographs are used experimentally, individual valence ratings correlate with physiological responses. Heart-rate decelerates whilst viewing unpleasant photographs, but accelerates when they are pleasant (Lang, Bradley, & Cuthbert, 1997). Moreover, arousal ratings have been shown to be positively correlated with skin-conductance responses, independent of valence (Lang et al., 1997). Furthermore, neuroimaging evidence suggests that increased occipital cortex activity is present during the processing of emotional (regardless of valence) relative to neutral pictures (Lang et al., 1998b). Lang, Bradley, and Cuthbert (1998a) interpret this evidence as suggesting that emotional information is subject to increased neural processing at an early perceptual stage than neutral information. Indeed, Costafreda, Brammer, David and Fu (2008) conducted a large meta-analysis of PET and fMRI studies concerning amygdala activation to emotional stimuli. Their meta-analysis of 385 studies confirmed that the processing of emotional stimuli was related to an increased probability of amygdala activity than the processing of neutral stimuli. Costafreda et al. also showed that most negatively valenced and positively valenced emotional stimuli produced comparable effects. However, Costafreda et al. reported a higher probability of amygdala activation for stimuli depicting fear, relative to stimuli depicting happiness.

The evidence provided by Lang et al. (1997; 1998a; 1998b) and Costafreda et al. (2008) suggests that the use of photographs of emotional faces from a standardised facial emotion stimuli set will activate a biological response. The experiments described in this thesis will use visual emotional stimuli, combined with the use of mental chronometry. This will enable an investigation of how the reactivity of the survival circuits described by LeDoux (2012) are affected by sub-clinical levels of anxiety.

1.17. Thesis questions

This thesis aims to answer five questions.

Question 1: How are sub-clinical levels of trait anxiety and social anxiety related to the recognition of happy, fearful and angry facial expressions?

Question 2: How are sub-clinical levels of trait anxiety related to distraction by other emotional faces or emotional words when identifying these emotional facial expressions?

Question 3: How are sub-clinical levels of trait anxiety related to any sequential differences in how conflict resolution is achieved in these situations of emotional distraction and emotional goal conflict?

Question 4: How are sub-clinical levels of trait anxiety related to other personality variables such as trait anger, interpersonal fear, and attentional control, and how do these other traits relate to the cognitive processes described in questions 1-3?

Question 5: Can we develop a novel emotional conflict resolution paradigm that is grounded in neuroscientific theory, and is practical for other researchers to use in future sub-clinical and clinical affective trait research?

1.18. Thesis predictions

Prediction 1: Sub-clinical trait anxiety / social anxiety will be related to a reaction time bias when responding to threat-related emotional faces compared with non-threat-related emotional faces. More specifically, this should be manifested as faster reaction times to fearful faces by those high in anxiety relative to those low in anxiety.

Prediction 2: Sub-clinical trait anxiety will be related to increased distraction by emotional stimuli. More specifically, this should be manifested as slower reaction times (by those high in anxiety relative to those low in anxiety) to target stimuli in situations of emotional distraction / goal conflict. Alternatively, high anxiety may relate to the reaction time difference in responses to target stimuli when emotional distraction / goal conflict is present, relative to when no emotional distraction / goal conflict is present.

Prediction 3: Sub-clinical trait anxiety will be related to altered conflict resolution. Conflict resolution will be measured as the reaction time advantage in resolving goal conflict that is present when goal conflict has been experienced immediately beforehand, relative to when it has not (the sequential effects of conflict resolution are explained in the following chapter). At the point of inception of this PhD we were unaware of any research on anxiety and this topic. Initially we intuitively reasoned that anxiety would be related to enhanced conflict resolution. Once the PhD was underway we soon obtained two papers that suggested the opposite, followed by one paper that was in alignment with our original expectation. Accordingly, we necessarily adopted a non-directional prediction concerning this issue.

Chapter 2

2. Experiment 1

2.1. Introduction

The literature discussed thus far concerning anxiety and emotional facial expression recognition, discrimination, or categorisation has produced some very inconsistent results. This inconsistency is somewhat surprising as the processing of facial expressions of emotion serves key social functions: facilitating social communication (Darwin, 1872), and recognition of a facial expression aids identifying a person's intentions and mood (Bruce & Young, 1986). Moreover, one would expect that the study of response latencies during emotional face processing would be ideal when researching the relationship between trait anxiety and any survival circuit triggers such as those proposed by LeDoux (2012). However, it is noteworthy that the anxiety and emotional face processing studies discussed thus far all use different task instructions and therefore assess emotional face processing (and any possible relationship with trait anxiety) in slightly different ways.

Holmes, Nielsen and Green (2008) used a task where participants were required to respond to repeated emotional facial expressions, whereas Rossignol, Philippot, Douilliez, Crommelinck and Campanella (2005) used an oddball paradigm requiring the detection of infrequent emotional faces. Morel, George, Foucher, Chammat and Dubal (2014) used an emotional face categorisation task, Fonzo et al. (2015) used an emotional face matching task, and Doty, Japee, Ingvar and Ungerleider (2013) used a masked emotional face detection paradigm. Cooper, Rowe and Penton-Voak (2008) used a more simple facial emotion recognition paradigm. However, none of the studies discussed thus far required the detection of emotional faces amongst several other concurrently presented emotional faces. In a different type of experimental manipulation Byrne and Eysenck (1995) used a task requiring the detection of target faces amongst crowds of distractor faces. This has become known as the 'face in the crowd' paradigm.

In the 'face in the crowd' study carried out by Byrne and Eysenck (1995) participants high in trait anxiety were able to detect angry target faces (amongst multiple neutral faces) faster than low trait anxious participants. The two groups did not differ in the speed of detection of target happy faces presented amongst multiple neutral faces. Furthermore, happy target faces (presented amongst multiple angry faces) were detected slower by high trait anxious relative to low trait anxious participants. Reaction times (RTs) for those high in trait anxiety were the same for both angry and happy faces detected amongst crowds of neutral faces. The ‘face in the crowd task’ required participants to search for the target faces that were not always in the same location. In this task, all trials can be considered to contain a level of emotional incongruence, or conflict, as the surrounding emotional expressions were always different from the expressions of the target faces. Therefore, a direct comparison of the speed of identification of a target facial expression that is emotionally incongruent with the surrounding facial expressions (i.e., a high distraction / conflict situation), with one that is emotionally congruent with its surrounding facial expressions (i.e., a low distraction / non-conflict situation), was not possible. As the anxiety effects found in this study were search related, this still leaves open the question that anxiety may relate to differences in emotional cognitive interference experienced as emotional distraction, or emotional conflict resolution.

The relationship between anxiety and emotional distraction and conflict resolution can however be assessed by using tasks that manipulate other emotional conflict scenarios. Etkin and Schatzberg (2011) and Etkin, Prater, Hoeft, Menon and Schatzberg (2010) investigated emotional conflict processing in patients with generalised anxiety disorder (GAD) and normal controls. Etkin and colleagues used Stroop-like stimuli consisting of target fearful faces and happy faces. These faces were overlaid with words stating either ‘fear’ or ‘happy’ that were either emotionally congruent or emotionally incongruent with the facial expressions. Participants were required to respond to the emotional expression of the target face, but were also required to inhibit responding to the distractor words. Goal conflict would be high during incongruent trials as the distractor words also represent a possible conflicting response. Goal conflict would be low during congruent trials as the distractor words represent the same response as the target facial expression. As one would expect, low conflict / low distraction congruent trials consisting of target faces overlaid with words that were congruent with the facial emotion (e.g., happy face with the word happy overlaid) were responded to faster than high conflict / high distraction incongruent trials (e.g., happy face with the word fear overlaid). However, the basic RT congruency effect (incongruent RT minus congruent RT) was not related to GAD symptoms (relative to normal controls), nor to the trait anxiety scores of the combined patients and normal controls.

These findings are somewhat problematic for ACT (Eysenck et al., 2007), which proposes that anxiety relates to increased levels of distraction. In short, in this version of an emotional Stroop task an incongruent trial has a target face stimulus and a distractor word stimulus. From an ACT perspective, the goal directed attentional system would be maintaining attention to the target faces. However, if a high anxious participant completes the task their heightened stimulus driven attentional system should compromise the ability to inhibit the interference from the distractor word. ACT thus predicts a heightened RT congruency effect in the emotional face Stroop task for high trait anxious participants. Moreover, from an RST perspective (Gray & McNaughton, 2000), one might also expect anxiety to relate to differences in how this goal conflict is resolved.

Stroop-like tasks are not the only conflict tasks suitable for researching distraction, conflict resolution, and their relationships with anxiety. Larson, Clawson, Clayson and Baldwin (2013) used the Eriksen flanker task (Eriksen & Eriksen, 1974) to investigate conflict processing of neutral stimuli in clinical anxiety patients (with GAD) and healthy controls. The Eriksen flanker task uses central target stimuli (usually letters or arrows) that are surrounded by either congruent or incongruent flankers. This task requires participants to respond quickly, but accurately, via left or right handed responses to the central target symbol. Congruent trials when the target and flankers are compatible do not generate response conflict (eg., <<<<< or >>>>>). Conversely, incongruent trials where the target is different from the flankers generate strong response conflict (eg., <<><< or >><>>). RTs for correct responses to incongruent trials are slower than RTs for correct responses to congruent trials. This effect is proposed to be produced by the flankers also activating an automatic motor response, which needs to be inhibited if accurate responses are to be achieved (Gratton et al., 1992). Larson et al. (2013) reported that the RT congruency effect (incongruent RT minus congruent RT) was uncorrelated with the trait anxiety scores of their whole sample.

The same ACT (Eysenck et al., 2007) predictions can be made concerning responses to incongruent trials and/or the congruency effects in the flanker task, as with the Stroop tasks described already. In short, during incongruent trials the goal directed attentional system should be maintaining participants' attention to the central target arrow. The flanker arrows should be easily ignored by those low in anxiety, who should have a good balance between the goal directed attentional system and stimulus driven attentional system. However, according to ACT, those high in anxiety would have an inefficient balance between these two attentional systems. Thus, in high anxiety the stimulus driven attentional system would be overactive and as such would lead to increased distraction by the flanker arrows. This should lead to an anxiety related slowing on incongruent trials, or an increased RT congruency effect. As described above, this was not found to be the case. This flanker study (Larson et al.) and the Stroop studies by Etkin and colleagues (2010; 2011) provide no support for the prediction of ACT (Eysenck et al., 2007), that anxiety is related to increased distraction.

These conflict tasks do however also provide a means of researching the sequential effects of conflict processing, and thus individual differences in conflict resolution. The Stroop task and flanker task enable an analysis of congruency sequence effects (CSEs) present in the RTs. CSEs present in conflict tasks are often referred to as the Gratton effect. The Gratton effect (Gratton, Coles & Donchin, 1992) refers to slower RTs being elicited by congruent trials that follow incongruent trials (denoted iC), as opposed to congruent trials that follow congruent trials (denoted cC), and quicker RTs for incongruent trials that follow incongruent trials (denoted iI), as opposed to those that follow congruent trials (denoted cI). In short, there is a reliable RT advantage present in conflict tasks when the previous level of (in)congruency repeats (cC and iI trials) as opposed to when it alternates (iC and cI trials). This is often interpreted as evidence of top-down attentional adjustments that are triggered by the conflict experienced on the previous trial (e.g., Botvinick, Braver, Carter, Barch, & Cohen, 2001), although alternative explanations of the effect have been offered (see Egner, 2007, for review). This issue is discussed in more detail later, but it suffices to say that the CSE might thus be a good phenomenon to study when conducting experimental research on anxiety and conflict resolution.

In the two experiments carried out by Etkin and colleagues (2011, 2010), anxious patients and non-anxious healthy controls displayed a similar CSE during congruent trials. Moreover, their healthy controls (who were lower in trait anxiety) also displayed the predicted CSE during correct responses to the target faces in emotionally incongruent trials. Therefore, for healthy controls incongruent trials that followed incongruent trials (iI) were responded to faster than incongruent trials that followed congruent trials (cI). Clinical anxiety patients (who were higher in trait anxiety) did not display this effect. This finding was interpreted as evidence of defective emotion regulation processes in anxiety. In an editorial in the same journal edition that published Etkin et al's (2010) paper, Ernst (2010) discussed the implications of this finding. Ernst drew attention to the value of this paradigm as a measure of emotion regulation that is not dependent upon patient self-report data. One can extend this argument by suggesting that this type of paradigm may prove to be equally useful when assessing personality implicitly (in contrast to explicit personality assessment by questionnaires), assuming there is a personality trait which is reliably associated with the size of the CSE.

CSEs have also been found in a neutral gender word-face Stroop task. Osinksky, Alexander, Gebhardt and Hennig (2010) used a task where male and female faces had the words man or woman overlaid upon them. Participants responded to the gender of each face faster when the words were congruent with the face relative to when they were incongruent with the face. CSEs were present in the RTs but were not affected by trait anxiety. However, recordings of brain activity using EEG showed that an N400 ERP, thought to be related to conflict processing, was modulated by trait anxiety. As trait anxiety increased, the difference in the N400 amplitude between iI and cI trials, and also between cC and iC trials, increased.

Larson et al. (2013) reported in the flanker task experiment (which revealed no anxiety related interference effects) that when the data from their groups of clinical patients and normal controls were combined, trait anxiety correlated moderately, positively, and significantly with the overall magnitude of the CSE (aka the Gratton effect). This relationship is in contrast to that reported by Etkin and Schatzberg (2011) and Etkin et al. (2010) for the CSE during just incongruent trials, as in their studies high anxious participants did not display the effect during these trials. Nevertheless, these studies suggest that anxiety may be related to a difference in conflict resolution processes, but further research is required before this can be understood. Yet again we see that the anxiety-behaviour correlations appear quite unreliable.

Interpretations of how anxiety interacts with emotional face processing and the control of emotional conflict are hard to generalise across studies as paradigms differ. Moreover, the conflict elicited by the happy/fear Stroop task (Etkin & Schatzberg, 2011, Etkin et al., 2010) can be considered *between-valence* conflict. No *within-valence* conflict condition (e.g., anger/fear) was included. It is important that anxiety research delineates situations involving between-valence conflict and within-valence conflict, when both emotional expression recognition and emotional conflict resolution is required[1].

In the real world visual emotional conflict is seldom experienced by concurrently reading words and seeing faces as in the Stroop tasks above. The study in this chapter uses a more ecologically valid emotional flanker paradigm using just faces that is inspired by the 'face in the crowd' paradigm used by Byrne and Eysenck (1995). We wanted to use a more ecologically valid level of conflict as traditional

[1] Other categorisations of the emotional faces were considered (e.g., approach versus avoid) but evidence supporting this distinction is complex and surprising. In short, from Gray & McNaughtons's (2000) RST perspective happy faces might signal potential reward and thus be related to the activity of a behavioural approach system (BAS). However, anger has also been suggested to be mediated by the BAS (Carver & Harmon-Jones, 2009), and is therefore also a behaviour closely related to approach motivation (Harmon-Jones, 2003). Thus both happy and angry faces might represent an approach motivation. Fearful faces should signal fear, and generally fear leads to avoidance behaviours (e.g., Frijda, 1986; Lazarus, 1991; McNaughton & Corr, 2004; Roseman, Wiest, & Swartz, 1994). However, this dichotomy would only be valid from the perspective of the person expressing the emotions. The person perceiving fear might initiate approach behaviour in order to help the fearful person (or resolve conflict). Moreover, although a person expressing anger might initiate approach behaviour, a person perceiving anger might initiate avoidance behaviour (Marsh, Ambady, & Kleck, 2005). Thus, one needs to be careful in applying the approach and avoid dichotomy to emotional face stimuli. As both fearful and angry faces would signal potential threat in the environment, the valence based dichotomy remains valid.

incongruent flanker task stimuli (e.g., <<><< or HHFHH) facilitate very strong interference but again do not seem to correspond to typical information processing demands in the real world. We also included single face trials (i.e., no flanker trials) as a simple test of emotion recognition, and included both between-valence and within-valence conflict conditions, as we were interested in how anxiety affects the processing of fearful faces relative to both happy and angry faces. An emotional conflict situation consisting of happy and fearful faces can be considered a between-valence conflict situation. Moreover, an emotional conflict situation consisting of angry and fearful faces can be considered a within-valence conflict situation.

We aimed to generate a large data set to determine the utility of further anxiety research pertaining to three inter-related cognitive processes (i.e., emotion recognition, distraction, and conflict resolution).

The use of computerised conflict tasks such as those described thus far is logical in anxiety research for several reasons. From Gray and McNaughton's (2000) perspective cognitive control would be related to activity of the BIS, and would be partly mediated by the ACC. In the cognitive neuroscience literature the ACC is suggested to monitor environmental conflict and adjust the control of behaviour, in order to resolve this conflict (Botvinick, Braver, Carter, Barch, & Cohen, 2001). For example, ACC activation during fMRI increases during the Eriksen flanker task (Eriksen & Eriksen, 1974) when a response to a central target is not congruent with the flanking distracters (Botvinick et al., 2001). In addition, Carter and van Veen (2007) reviewed the literature concerning ACC and conflict tasks, and report that it is a consistent neuroimaging finding that ACC activity is greatest to incongruent trials following congruent trials. Moreover, Larson et al. (2013) reported that in their neutral arrow flanker task study, a conflict-related N2 ERP amplitude was less negative the higher the level of trait anxiety. Previous research using dipole models of the N2 ERP have located its source to the ACC (Mathalon, Whitfield, & Ford, 2003). This evidence adds more weight to the suggestion that the ACC has some involvement in the cognitive control processes required by the flanker task. These findings, derived from the study of neuroscience and psychophysiology, indicate that a flanker type task would be an ideal paradigm to study how the cognitive control of conflict and emotion is affected by anxiety. Moreover, an emotional flanker task should be an ideal tool to use when exploring any possible survival circuit functions

(LeDoux, 2012) relating to the control of emotional goal conflict, that might also be affected by anxiety.

2.2. Purpose of experiment 1

A threat-related emotional expression recognition advantage, and an emotional conflict resolution advantage, can be easily accommodated within the emotional survival circuit framework theorised by LeDoux (2012). Moreover, if a threat-related stimulus appears in the periphery of attention it may be adaptive to be distracted by this stimulus, which might then become the target of attention and produce safety behaviours. In this initial study, we aimed to answer four research questions. Firstly, is trait anxiety related to increased distraction? Secondly, does trait anxiety relate to a bias for faster responses to fearful faces compared to happy faces? Thirdly, does trait anxiety relate to altered emotional conflict resolution as measured by the CSE? And fourthly, do other affective traits such as trait anger or levels of interpersonal fear relate to these three processes in addition to any effects found for trait anxiety?

Concerning our first question, ACT (Eysenck et al., 2007) proposes that anxiety is linked to magnified influences of a stimulus-driven attentional system (that attends and reacts to peripheral or distracting stimuli) coupled with a decrease in the influence of a goal-directed attentional system (that attends to one's current goals). An ACT-based prediction would thus suggest that trait anxiety would be related to an increase in the slowing on incongruent trials (and/or an increased RT congruency effect), due to peripheral distracting stimuli engaging the stimulus-driven attentional system more strongly with increasing anxiety. Because Larson et al. (2013) reported that anxiety was unrelated to the RT congruency effects in their study, we were concerned to maximise the degree of flanker distraction within our task. Therefore, we reduced the frequency of incongruent trials relative to congruent trials, as this has been shown to increase congruency effects (e.g., Gratton et al., 1992; Mayr & Awh, 2009). This was a final attempt to capture an anxiety related increase in distraction. Based upon ACT (Eysenck et al., 2007) we can predict that the magnitude of distraction should be increased in high anxious participants if the distracting stimuli are threat-related relative to when they are not threat-related (e.g., fearful flankers during incongruent trials with happy target faces should be more distracting for high anxious participants than happy flankers during incongruent trials with fearful target faces). If found this effect would also be consistent with the perspectives on anxiety that incorporate a threat-related processing bias (e.g., Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mathews, Mackintosh & Fulcher, 1997; Mogg & Bradley, 1998; Ohman, 1996; Wells & Mathews, 1994; Williams, Watts, MacLeod, & Mathews, 1988).

Concerning our second question, most of the task instructions in the studies discussed deviated from requiring simple rapid emotional facial expression recognition. In short, they either required participants to respond to repeated emotional expressions, categorise emotional expressions, match emotional expressions, detect infrequent emotional expressions, or the task included several emotional expressions. Based upon the design of these studies the effect of trait anxiety upon threat-related face processing still seems somewhat inconclusive. Based upon the accounts of anxiety that incorporate a threat-related processing bias (e.g., Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mathews et al., 1997; Mogg & Bradley, 1998; Ohman, 1996; Wells & Mathews, 1994; Williams et al., 1988), the meta-analysis by Bar-Haim et al. (2007; showing that anxiety is related to a threat-related attentional bias), and the encouraging neuroimaging findings of Fonzo et al. (2015), we still predicted that trait anxiety would be related to a RT bias for fearful faces. This may be evidenced by trait anxious participants producing faster RTs to fearful faces in the between-valence condition (i.e., when discriminating fearful faces from happy faces), or by trait anxiety being related to the emotional face RT difference score (RT for fearful faces minus RT for happy faces). In this design it would not be likely that the alternative face from the fearful face (i.e., a happy face) could be processed as part of a threat-related situation, as proposed by Morel et al. (2014). In their task, neutral faces were the other face. The within-valence condition in the present study includes two threat-related face expressions as both angry and fearful expressions were used. This allows an analysis of whether any anxiety related speeding in RTs to fearful faces is also present when anger is the alternative facial expression, or if an anxiety related speeding to both threatening expressions occurs in the same task.

Concerning our third question, we predicted that anxiety would be related to conflict resolution (as evidenced by a relationship between anxiety and the magnitude of the CSE). It is not possible to make a confident directional prediction here. As discussed above, Etkin and Schatzberg (2011), and Etkin et al. (2010) showed that a CSE in an emotional face-word Stroop task was selectively abolished in high anxiety participants, but Larson et al. (2013) showed that a CSE was increased in high trait anxiety when using a neutral Eriksen flanker task.

The present study aims to extend the flanker paradigm by including within-valence emotional conflict using angry and fearful faces, in addition to between-valence conflict using happy and fearful faces. If an anxiety effect is driven by emotional conflict in general, the relationship between trait anxiety and the emotional CSE should be similar across valence contrast conditions. However, it is possible that anxiety relates to the emotional CSE only when between-valence conflict is present. If this is the case then within-valence CSEs elicited in a task requiring the discrimination of angry and fearful faces should not be modulated by trait anxiety.

It is also noteworthy that Etkin and Schatzberg (2011), Etkin et al. (2010), and Larson et al. (2013) all adopt the conflict adaptation explanation of the CSE proposed by Botvinick, Braver et al. (2001). Botvinik et al. suggest that response conflict monitored during any current trial modulates cognitive control during the following trial. However, the theoretical cognitive mechanisms that mediate the CSE during conflict tasks are fiercely debated. In short, the CSE has also been explained by episodic memory priming effects and the feature integration theory developed by Hommel (1998, 2004, 2007) and Hommel, Proctor & Vu (2004). In fact, a recent paper suggests that it is possible that conflict adaptation processes and episodic memory processes may interact when producing the CSE (Duthoo, Abrahamse, Braem, Boehler & Notebaert, 2014). However, whatever mechanism drives the effect, it is interesting that those high in anxiety could be advantageously (or disadvantageously) affected by (in)congruency repetition when dealing with emotional conflict. The finding of an anxiety-related increase or decrease in the CSE in the emotional flanker task may well have real world implications. In real life settings an (in)congruency repetition advantage may manifest as the increased speed of detection of repeated conflicting (or non-conflicting) facial emotions in the social environment. In contrast, an (in)congruency repetition disadvantage may manifest as a reduced speed of detection of repeated conflicting (or non-conflicting) facial emotions in the social environment. It is thus easy to see how an emotional CSE might represent the activity of a possible neural survival circuit as theorised by LeDoux (2012).

It was not the original purpose of this present study to prove nor disprove any of the mechanistic accounts of the CSE. In this chapter we adopt a neutral stance on this issue and analyse the CSE in a relatively atheoretical way. We want, in the first instance, to ascertain if anxiety is reliably related to the CSE in a task designed so that it can also address the other questions listed above. If a reliable relationship between anxiety and the CSE is found then it could be well worth designing a series of finer-grained paradigms that can explain how the mechanism(s) driving the CSE in emotional scenarios may relate to trait anxiety. Here we simply want to determine if trait anxiety is robustly related to any RT advantage (or disadvantage) when emotional conflict repeats (i.e., cC and iI trials), as opposed to alternates (i.e., iC and cI trials).

Concerning our fourth question, RST (Gray & McNaughton, 2000) suggests that anxiety and fear are distinct emotions, with fear being mediated by a fight/flight/freeze system in contrast to the behavioural inhibition system mediating anxiety. Approach behaviours are proposed to be mediated by a behavioural approach system. Whereas approach behaviours are often related to positive emotions, they can be related to aversive emotions as well, as in the case of anger (Carver & Harmon-Jones, 2009). In social situations anxiety, fear and anger may all interact and require the cognitive control of responses to conflicting emotional signals. From Gray and McNaughton's RST perspective this cognitive control would be related to activity of a behavioural inhibition system, which mediates levels of trait anxiety. Accordingly, we intend to establish whether other affective traits such as fear and anger modulate emotional expression recognition and/or emotional conflict resolution, or determine if these cognitive processes are solely modulated by trait anxiety.

2.3. Method

2.3.1. Participants

Participants with no reported history of neurological condition (N = 81, 57 female) were recruited from Goldsmiths, University of London, and had a mean age of 22.6 years (SD = 7). 74 were right handed, 4 were left handed, and 2 claimed to be ambidextrous (with 1 response omission regarding handedness). 56 were psychology 1st year undergraduates recruited via a research participation scheme who took part in return for course credit. The rest were paid £10 and recruited via advertisements placed around the campus, and were therefore students and staff from other departments. All gave informed written consent in accordance with standard ethical guidelines. This study was approved by the Goldsmiths psychology departments' ethics committee (approval received 24/10/2012). Data for one participant was excluded as the data for one experiment failed to save.

We base our power calculations on correlations because, as the data analysis sections below make clear, all the key effects involving anxiety that we are testing are tests of correlations. Based upon the 0.4 correlation between anxiety and the CSE reported in the study by Larson et al. (2013), 46 participants should allow 80% power for a two-tailed test at p=0.05, for a correlation of 0.4. Based upon the 0.65 correlation between anxiety and fearful face detection sensitivity reported in the study by Doty et al. (2013), 16 participants should allow 80% power for a two-tailed test at p=0.05, for a correlation of 0.65. However, as these correlations are quite strong we ran some extra participants to be sure of having enough power to detect an anxiety correlation of 0.3 in our analyses.

2.3.2. Psychometric measures.

Trait anxiety was assessed with the trait anxiety scale of the State-Trait Anxiety Inventory (STAI, Spielberger et al., 1983). Trait anger was assessed using the trait anger 10 item subscale of the State-Trait Anger Expression Inventory (STAXI, Spielberger, 1988). Individual differences in the experiencing of interpersonal fear were assessed using the 23 item subscale of the Fear Survey Schedule (Wolpe & Lang, 1969).

2.3.3. Stimuli

The emotional faces used to create the flanker stimuli were obtained from a standardised face stimuli set developed for research (NimStim; Tottenham et al., 2009). The individual face pictures were scaled so that they appeared (on the computer screen) as 20mm high x 16 mm wide and were formed into 3x3 grids of 9 faces; thus the overall grid dimensions were 60mm high and 48 mm wide. They were presented using MATLAB version R2006a on a 15.5 inch laptop screen. The laptop was running Windows XP, and we used the Psychophysics Toolbox version 3 for precision RT measurement. Four face stimulus sets were created using either one Caucasian male, or one black male, or one Caucasian female, or one black female in the set. This was an attempt to control for possible gender and race effects. The four stimulus sets were used to create two happy face/fearful face flanker task conditions, and two angry face/fearful face flanker task conditions. Examples of the stimuli used are shown in Figure 2.1.

Figure 2.1: Examples of one of the sets of stimuli used in the happy face / fearful face between-valence flanker task (top row, and angry face / fearful face within valence flanker task (bottom row). Top row left to right: single happy, congruent happy, incongruent happy, single fear, congruent fear, and incongruent fear. Bottom row left to right: incongruent fear, congruent fear, single fear, incongruent anger, congruent anger, and single anger.

2.3.4. Procedure

Participants were told that they would be presented with four short face emotion recognition tasks with a short rest in between each task. Participants were asked to sit as close to the screen as was comfortable for their eyes (typical viewing distance was approximately 70 cm). The task instructions were presented on the screen. To start each task the first screen instructed participants that they would have to judge the emotional expression showing on photos of faces (happy and fear in the between-valence condition; and anger and fear in the within-valence condition). Participants were then shown examples of the various stimulus combinations they might see and reminded to concentrate on the central face in the grid of faces and ignore any others. They were told to rest their index fingers over the responses keys (z and /) and to respond as fast as possible while maintaining high accuracy levels. They were verbally told that a high pitched tone following a response indicates a correct response, whereas a low pitched tone following a response indicates an incorrect response.

The experimental stimuli were displayed until a response key was pressed. Unbeknown to the participants, at the beginning of each task, there were two of each single and incongruent trial, and 8 of each congruent trial included as practice trials; these 24 trials were discarded and not analysed. The main experimental stimuli that followed consisted of 40 single trials, 40 incongruent trials and 160 congruent trials (in each of the four tasks). The modified flanker task was designed primarily to elicit RT effects as opposed to effects reflected in error rates. The trial type sequence was created using a random number generator function in Matlab, and was the same for all participants. We kept the sequence the same for all participants as this is an individual differences study, and we wanted as few uncontrolled variables as possible to vary across participants. We also used the same trial type sequence for each of the tasks (with happy target single, congruent and incongruent trial types being substituted for angry target single, congruent and congruent trials as appropriate). There were 240 non-practice trials in total in each task so we felt that there was no chance that using the same sequence in each task would cause any learning of the sequence of trial types and, as noted below, we counterbalanced the order of the 4 tasks across participants. Each task lasted for approximately ten minutes. The four tasks were created using a 2 X 2 combination of happy/fearful versus angry/fearful decisions, with either a male or a female face used (four different individuals across the four tasks). The two happy/fearful face discrimination tasks formed the between-valence condition of the current study, and the two angry/fearful face discrimination tasks formed the within-valence condition of the current study. There were equal proportions of happy and fearful faces in the between-valence condition, and equal proportions of angry and fearful faces in the within-valence condition. The sequence of the four tasks was counterbalanced across participants. The left/right finger response key mappings were also counterbalanced. Figure 2.2 illustrates example trial sequences used to manipulate emotional CSE scenarios.

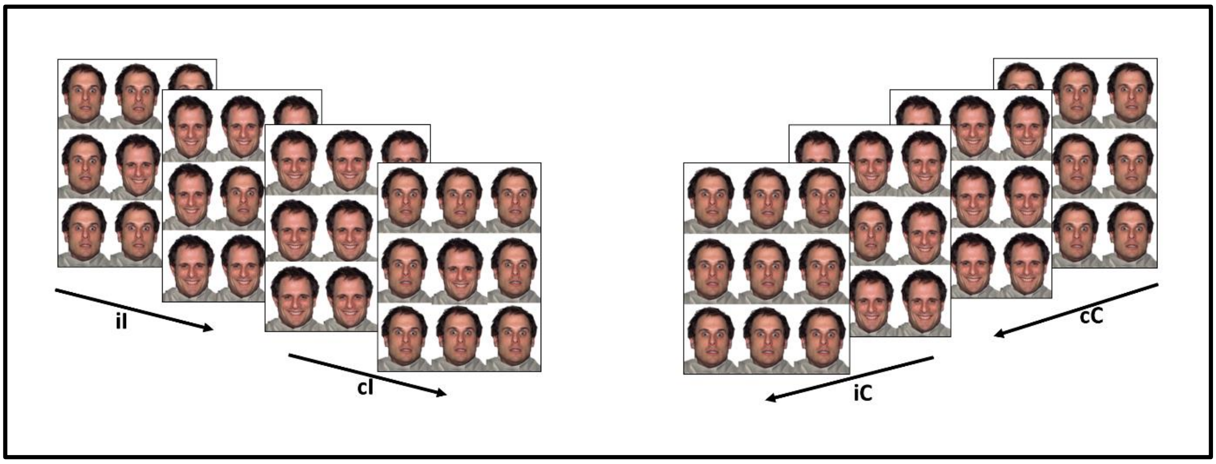

Figure 2.2: Incongruency repetition and alternation differences between iI trials and cI trials (left hand schematic). Congruency repetition and alternation differences between cC trials and iC trials (right hand schematic). The scoring method did not differentiate between central emotional face types (i.e., congruent trials with a target happy face and congruent trials with a target fearful face are aggregated, as are incongruent trials with a target happy face and incongruent trials with a target fearful face).

2.3.5: Data analysis

In our primary analysis, RTs will be analysed using ANCOVA with factors of emotion, valence contrast, and trial type, with standardised trait anxiety included as the covariate.

In this analysis ANCOVA is not used as a statistical control device, which is commonly but often erroneously employed in psychology (Miller & Chapman, 2001). Rather, ANCOVA is used as an efficient way to test the significance of correlations of interest, within a repeated-measures (factorial) design. The overall effect of the covariate, in these analyses, tests whether the overall DV values (averaged across all effects in the ANCOVA) correlates significantly with the covariate. Any interaction of other effects, with the covariate, tests whether the correlation between the contrast and covariate is significant. For 2-level factors, as in the studies in this thesis, and taking RT as an example DV, this means that a covariate by main effect 2-way interaction tests the correlation between the RT difference and the covariate. For any factor by factor by covariate 3-way interaction effect this tests the correlation between the RT difference of differences and the covariate etc. This statistuical approach is adopted throughout the thesis as the deisgns and hypotheses of interest all share these same features.

In this analysis the effect of emotion will therefore reveal whether RTs to fearful faces differ from RTs averaged across happy and angry faces, and the covariate interaction with the emotion effect will test whether trait anxiety modulates this effect (see above). The effect of valence contrast upon the effect of emotion will allow us to test whether the RT difference between fearful and happy faces differs from the RT difference from fearful and angry faces. The effect of the covariate, upon the valence by emotion interaction, specifically tests whether anxiety correlates with the RT difference between fearful and happy faces minus the RT difference between fearful and angry faces[2].

If a significant anxiety by valence by emotion interaction is found is found we planned further comparisons to separately verify that anxiety relates to the RT difference for happy and fearful faces (which was a key hypothesis), but also to test

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[2] In the computations of the ANCOVA, the direction of these differences and differences of differences, is determined by the coding of levels used

whether anxiety relates to the RT difference for angry and fearful faces (which was an exploratory interest). Thus, these emotion effects test our hypotheses concerning anxiety and emotion recognition.

The effect of trial type will allow us to test how the peripheral distracting faces affect the discrimination of the central target faces. The covariate by trial type interaction here will show if anxiety modulates (correlates with) the overall distraction effect. The effect of valence contrast on the effect of trial type will allow us to test whether the distraction effects when happy and fearful faces are discriminated, differ significantly from those when angry and fearful faces are discriminated. The 3-way interaction of covariate by emotion by trial type will allow us to test whether anxiety modulates (correlates with) the emotion by trial type interaction just described. If a significant anxiety by emotion by trial type effect is found we planned further comparisons to separate out the effects of distraction in the two tasks (i.e., the happy/fear task and the anger/fear task). Thus, these trial type effects test our hypotheses concerning anxiety and distraction.

We then conducted a planned further RT analysis to investigate the congruency sequence effects (CSE). The RT data were analysed using ANCOVA with factors of current trial type, previous trial type: (in)congruency repetition/alternation, and valence contrast, with standardised trait anxiety included as the covariate.

The key effects of interest in this sequential analysis are the (in)congruency repetition/alternation effect (which tests the RT difference between trials when the level of (in)congruency repeats relative to when it alternates; i.e., the CSE), and the effect of valence contrast upon the (in)congruency repetition/alternation effect (which tests if the CSE differs between the happy/fear task and the anger/fear task). The critical effects here are the covariate interactions with the above which will reveal if anxiety modulates (correlates with) the CSE overall or to the difference in CSE between the emotion discrimination tasks. These effects therefore test our hypotheses that anxiety will relate to a difference in how conflict resolution is achieved (as indexed by the CSE).

We also planned to conduct further analyses concerning how trait anxiety relates to trait anger and interpersonal fear, and how these other traits relate to any RT effects that relate to trait anxiety. For completeness most of the main analyses were then repeated with the accuracy data

2.4. Results

2.4.1. Psychometric assessments

In this sample participants' trait anxiety questionnaire scores as measured by the STAI ranged from 20 to 66 (mean: 43, SD: 11), their interpersonal fear questionnaire scores as measured by the FSS subscale ranged from 3 to 113 (mean: 38, SD: 23), and their trait anger questionnaire scores as measured by the STAXI subscale ranged from 10 to 34 (mean: 19, SD: 5).

2.4.2. *Primary RT analysis: Emotion recognition and emotional distraction*

There was no outlier removal conducted here to maximise the amount of correct responses used to compute mean RTs in the conditions with relatively small numbers of trials. The summary RT data for all 12 conditions of the experiment are shown in Table 2.1. These data were first subjected to a repeated measures 2 x 2 x 3 ANCOVA with factors of emotion (fear versus other); valence contrast (between-valence versus within-valence; i.e., fear versus happy and fear versus anger) and trial type (single versus congruent versus incongruent); with standardised trait anxiety as the covariate. The mean RTs, 95% confidence intervals and standard errors for each of the 12 stimulus types are shown in Table 2.1. Figure 2.3 shows the mean RTs for each of the 12 stimulus types, expressed as a function of emotion and valence contrast condition relative to trial type. The test of between-subjects effects was not significant ($F[1,76]=0.32$, $p=0.858$, $\eta^2<0.001$), indicating that trait anxiety was unrelated to mean RTs across the whole paradigm.

Table 2.1: Mean RTs, 95% confidence intervals (95% CIs), and standard errors (SE) for each of the 12 stimulus types (listed by target emotion versus trial type). All values are in msecs.

Between-valence condition				Within-valence condition			
Trial type	**Mean**	**95% CI**	**SE**	**Trial type**	**Mean**	**95% CI**	**SE**
Single fear	582	559-605	12	**Single fear**	585	566-604	9
Congruent fear	562	540-586	11	**Congruent fear**	562	544-580	10
Incongruent fear	566	542-590	12	**Incongruent fear**	574	552-596	11
Single happy	565	545-586	10	**Single anger**	579	560-599	10
Congruent happy	551	531-572	11	**Congruent anger**	566	547-584	9
Incongruent happy	563	540-585	11	**Incongruent anger**	577	556-597	10

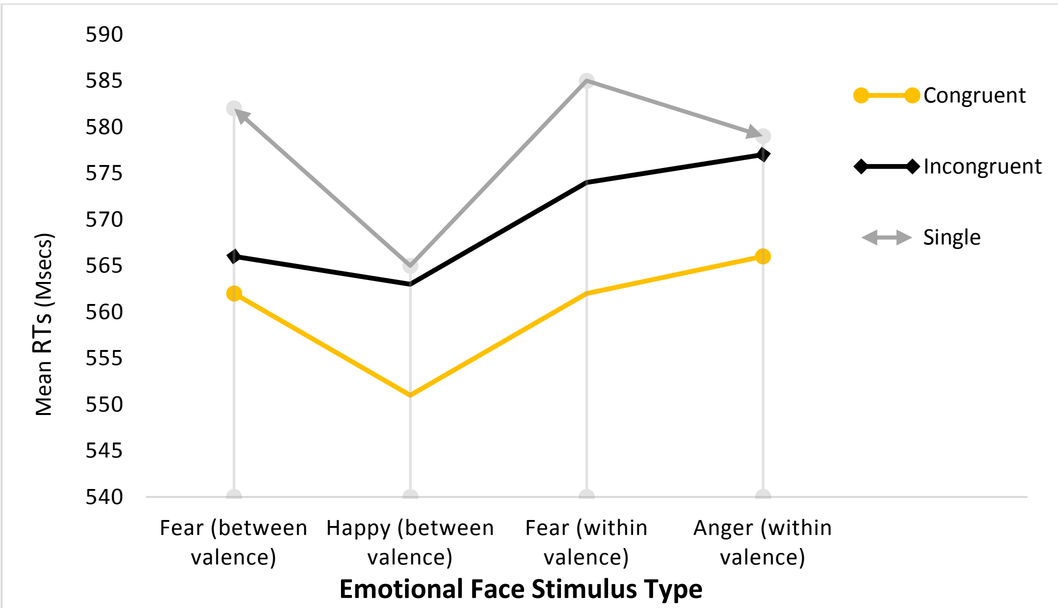

Figure 2.3: Mean RTs for each of the 12 stimulus types, expressed as a function of emotion and valence contrast condition relative to trial type. All values are in msecs.

The main effect of emotion was significant (F[1,76]=4.6, p=0.035, η^2=0.057), as averaged other faces (happy, angry) were responded to faster (mean 567 msecs; 95% CI 548-586; SE 9) than averaged fearful faces (mean 572 msecs; 95% CI 552-592; SE 10). The critical finding here was that trait anxiety robustly interacted with the effect of emotion (F[1,76]=7.4, p=0.008, η^2=0.089). This interaction tests the correlation between trait anxiety and the RT difference between averaged other emotional faces and averaged fearful faces (RT for fearful faces minus RT for other faces), which is illustrated by Figure 2.4. The correlation value was r= -0.30. As trait anxiety increased, the RT advantage for averaged other emotional faces decreased. This effect relates to our main hypothesis that trait anxiety will modulate emotion recognition, but later statistical comparisons will reveal if it is more specific.

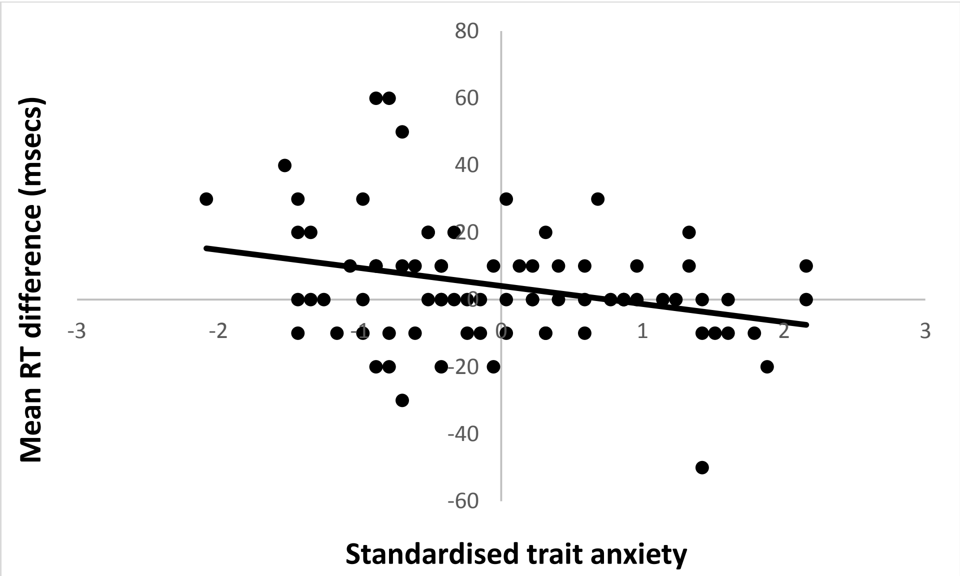

Figure 2.4: The negative correlation (r= -0.30, p=0.008) between standardised trait anxiety and the RT difference between averaged fearful faces and averaged other faces (RT fearful faces minus RT other faces).

The main effect of valence contrast was not significant (F[1,76]=2.4, p=0.129, η^2=0.030), and did not interact with trait anxiety (F[1,76]=1.2, p=0.270, η^2=0.016). Therefore mean RTs were similar in each of the valence contrast conditions, and the valence effect was similar across levels of trait anxiety. The main effect of trial type was highly significant (F[2,152]=23.4, p<0.001, η^2=0.235) as RT congruent (mean

560 msecs; 95% CI 542-579; SE 9) < RT incongruent (mean 570 msecs; 95% CI 549-590; SE 10) < RT single (mean 578 msecs; 95% CI 559-597; SE 9). The relationship between these trial types is illustrated by Figure 2.5. However, the main effect of trial type did not interact with trait anxiety (F[2,152]=0.7, p=0.936, η^2=0.001). Thus, critically trait anxiety was unrelated to any flanker distraction effects reflected in the trial type effect.

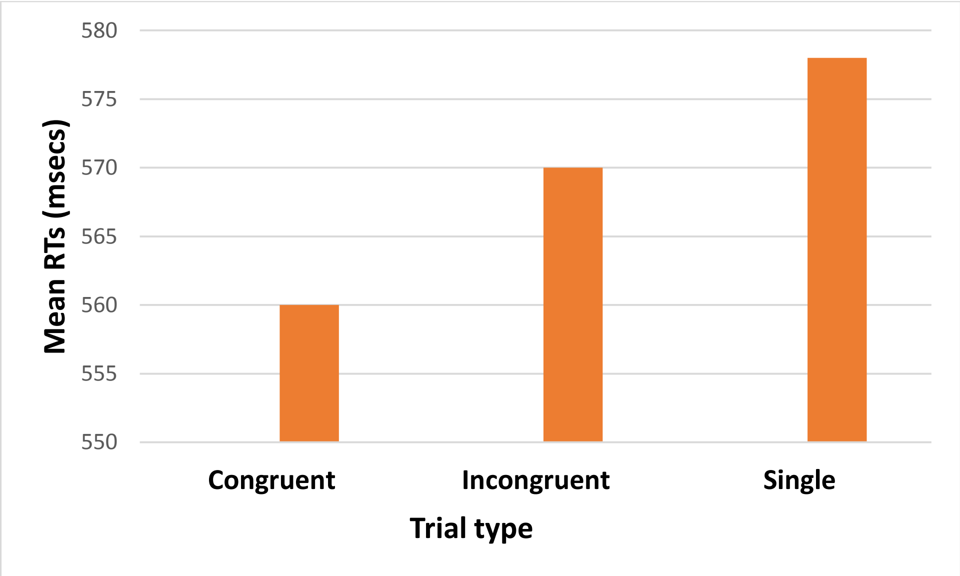

Figure 2.5: Mean RTs for congruent, incongruent and single trials.

The effect of emotion interacted with the effect of valence contrast (F[1,76]=4.7, p=0.034, η^2=0.058), indicating that the effect of emotion may be robustly present in only one of the valence contrast conditions. This interaction is illustrated by Figure 2.6, and the mean RTs, 95% CIs and SEs are contained in Table 2.2. We return to this issue later.

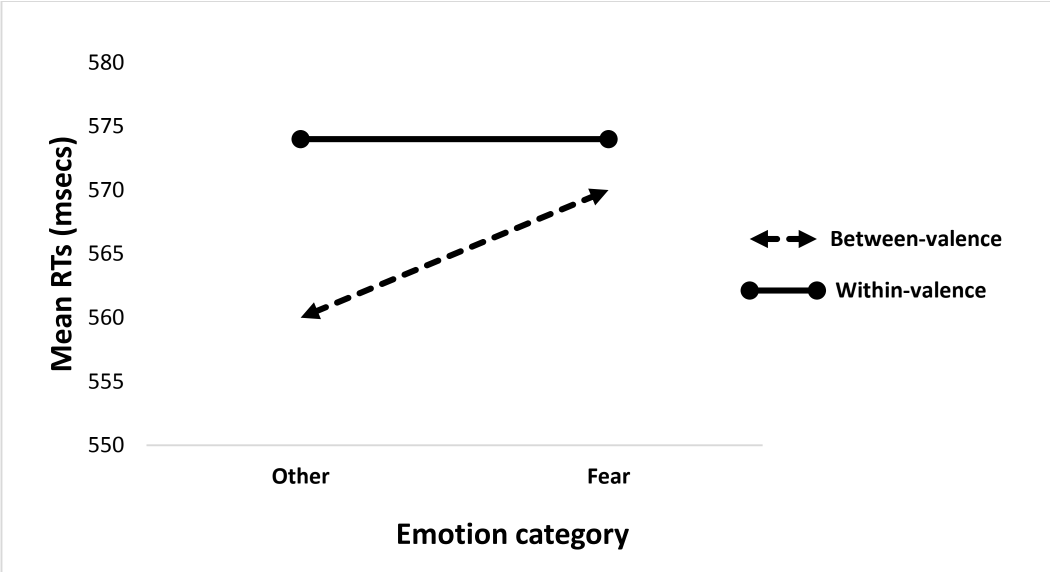

Figure 2.6: Mean RTs to each emotional facial expression expressed as a function of valence contrast and emotion category.

Table 2.2: Mean RTs, 95% confidence intervals (95% CIs), and standard errors (SE) for each emotional facial expression expressed as a function of valence contrast and emotional category. All values are in msecs.

Between-valence condition				Within-valence condition			
Trial type	**Mean**	**95% CI**	**SE**	**Trial type**	**Mean**	**95% CI**	**SE**
Happy	560	539-581	10	**Angry**	574	555-593	9
Fear	570	548-592	11	**Fear**	574	555-593	9

This interaction did not significantly further interact with trait anxiety (F[1,76]=0.9, p=0.343, η^2=0.012). The effect of emotion also interacted with the effect of trial type (F[2,152]=5.0, p=0.008, η^2=0.061), indicating that the trial type effect may show a different pattern for one of the emotion categories (this is illustrated by Figure 2.7). Critically, the emotion versus trial type interaction did not further interact with anxiety (F[2,152]=1.1, p=0.325, η^2=0.015). This 3-way interaction relates to our main hypothesis that anxiety would be related to distraction that is further increaesd when the emotion depicted by the distracting faces is fearful.

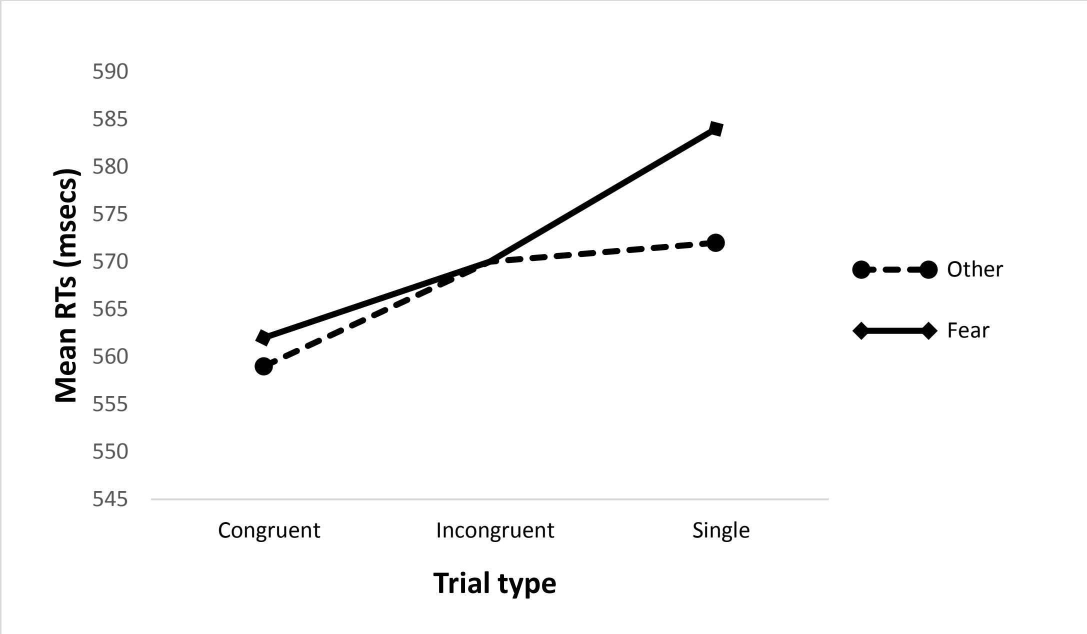

Figure 2.7: Mean RTs for each of the trials types as a function of emotion category.

Valence contrast did not significantly interact with trial type (F[2,152]=0.4, p=0.658, η^2=0.006). This is illustrated in Figure 2.8. Moreover, this interaction did not interact with anxiety (F[2,152]=0.4, p=0.676, η^2=0.005). The 3-way interaction between emotion, valence contrast and trial type was not significant (F[2,152]=0.7, p=0.497, η^2=0.009), nor was the 4-way interaction between emotion, valence contrast, trial type and anxiety (F[2,152]=0.5, p=0.601, η^2=0.007).

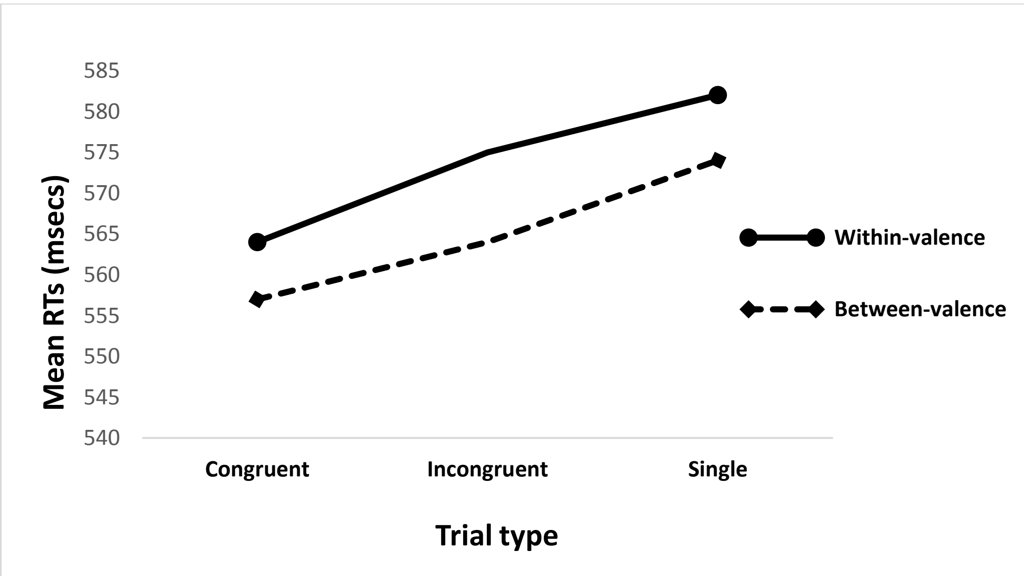

Figure 2.8: Mean RTs for each trial type as a function of valence contrast.

We then carried out further planned comparisons to explore the previously reported emotion versus valence contrast interaction by conducting two one-way ANCOVAS. Here we adopt an adjusted significance level of 0.05/2. The first ANCOVA concerned the between-valence contrast condition. The main effect of emotion was significant as happy faces were responded to faster than fearful faces (*F*[1,76]=12.4, *p*=0.001, η^2=0.141), and critically this effect further interacted with trait anxiety (*F*[1,76]=8.4, *p*=0.005, η^2=0.099).This robust interaction tests the correlation between trait anxiety and the RT difference between responses to happy and fearful faces. The correlation value was *r* = -0.32. As anxiety increased the happy face RT advantage over fearful face RT decreased. This effect is depicted in Figure 2.9, and relates to our main hypothesis that anxiety would modulate emotion discrimination in the happy/fear task.

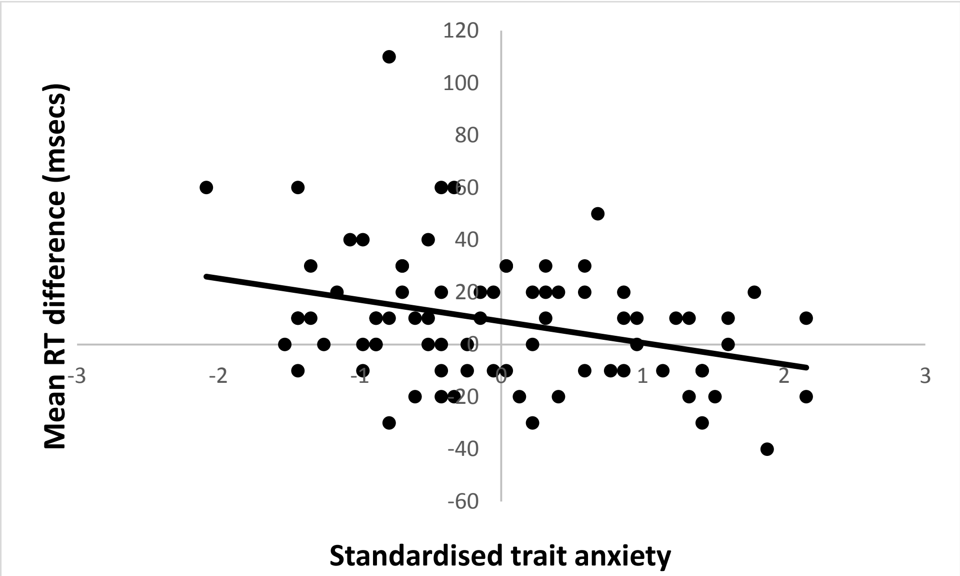

Figure 2.9: The negative correlation (r=-0.32, p=0.005) between standardised trait anxiety and the happy face recognition advantage in the between valence condition (for congruent, incongruent and single trials combined).

The second ANCOVA concerned the within-valence contrast condition. The main effect of emotion was not significant as angry faces were not responded to faster than fearful faces (*F*[1,76]=0.06, *p*=0.812, η^2=0.001), and critically this effect did not significantly further interact with trait anxiety (*F*[1,76]=0.8, *p*=0.364, η^2=0.011).This interaction tests the correlation between trait anxiety and the RT difference (RT fearful faces minus RT angry faces). The correlation value was r = -0.10. This effect relates to our exploratory interest in whether anxiety modulates emotion discrimination in the anger/fear task.

In summary thus far, we find no evidence that anxiety is related to increased flanker distraction. However, overall averaged other emotional facial expressions were responded to faster than averaged fearful facial expressions. Moreover, trait anxiety was related to a reduced RT advantage for averaged other facial expressions. Our planned comparisons showed that both of these effects were driven by the between-valence contrast condition (happy versus fearful faces), and were not present in the within-valence contrast condition (angry versus fearful faces). However, exploratory correlations showed that trait anxiety was not correlated with RTs to either happy faces (r= -0.01, p=0.905), or fearful faces (r= -0.09, p=0.437) in the between-valence condition.

We also verified that mean RTs to fearful faces were similar in the between-valence contrast condition (mean RT 570 msecs; 95% CI 548-592; SE 11) and the within-valence contrast condition (mean RT 574 msecs; 95% CI 555-593; SE 9). A one-way ANCOVA with a factor of valence contrast (fearful faces from the between-valence contrast condition versus fearful faces from the within-valence contrast condition), with standardised trait anxiety as the covariate showed that there was no significant effect of valence contrast upon RTs to fearful faces (F[1,76]=0.42, p=0.52, η^2=0.01). Trait anxiety did not interact significantly with the non-significant valence contrast difference in fearful face RTs (F[1,76]=1.95, p=0.17, η^2=0.03).

We suspected that the correlations between trait anxiety and the specific RT effects in any single condition were likely to have been suppressed by general sources of RT variance unrelated to trait anxiety and shared across all conditions. Thus, we calculated a general RT factor. Exploratory factor analyses clearly revealed a strong general RT factor across all conditions for both valence contrasts, and a second much smaller factor. To estimate the general RT factor we used a maximum likelihood extraction of two factors using mean RTs from each participant for each of the 12 stimulus types from both valence contrasts (single/congruent/incongruent x fearful face/other face x valence contrast). Factor 1 was clearly the general RT factor (all loadings > 0.86), which accounted for 83% of the variance). Factor 2 was much less important, and accounted for 7% of the variance. Factor 2 was clearly a valence contrast factor: stimuli from the between-valence contrast all loaded negatively on factor 2, whereas stimuli from the within-valence contrast all loaded positively on factor 2.

When controlling for the general RT factor score using partial correlation, trait anxiety negatively correlated with RTs to fearful faces (r= -0.25, p=0.03), but not happy faces (r=0.01, p=0.94) in the between-valence contrast condition. Therefore, as a person's level of trait anxiety increased, their RTs to fearful faces decreased, when discriminating them from happy faces, although this effect should strictly be considered only a trend at an adjusted significance level (0.025/2). This effect relates to our main hypothesis that anxiety would relate to an RT bias for fearful faces. In sum, there is evidence for an anxiety-related speeding to fearful faces when the fearful stimuli must be discriminated from positively valenced stimuli (happy faces), but not when the fearful faces must be discriminated from negatively valenced stimuli (angry faces).

2.4.3. Emotional distraction effects confirmatory analysis

We wished to confirm that trait anxiety was unrelated to any distraction effects that were specific to any target emotional facial expression type. Thus, we carried out a series of confirmatory one-way ANCOVAS, including standardised trait anxiety as the covariate, which were designed to address this confirmation. These confirmatory comparisons have not been adjusted for multiple testing. These analyses focus upon the RT comparisons between congruent and incongruent trials divided up by target emotion type. As discussed previously, Table 2.1 shows that for each of the four target emotion conditions, mean RTs for congruent trials were faster than mean RTs for incongruent trials. These confirmatory analyses relate to our main hypotheses that anxiety would relate to distraction, and that this distraction be further modulated by the type of emotion depicted by the distracting face.

The first one-way ANCOVA showed that the RT congruency effect for between-valence contrast trials with happy target faces was significant (F[1,76]=13.1,

p=0.001, η^2=0.147), but did not significantly interact with anxiety (F[1,76]=0.02, p=0.894, η^2<0.001). This shows that trait anxiety was unrelated to the RT congruency effect (incongruent RT minus congruent RT) for happy face trials in the between-valence condition. The correlation value was r= 0.02. The second one-way ANCOVA showed that the RT congruency effect for between-valence contrast trials with fearful faces was not significant (F[1,76]=0.1, p=0.724, η^2=0.002), and did not significantly interact with trait anxiety (F[1,76]=0.1, p=0.719, η^2=0.002). This shows that trait anxiety was unrelated to the RT congruency effect (incongruent RT minus congruent RT) for fearful face trials in the between-valence condition. The correlation value was r= -0.04

The third one-way ANCOVA showed that the RT congruency effect for within-valence contrast trials with angry faces was significant (F[1,76]=10.9, p=0.001, η^2=0.126), and did not significantly interact with trait anxiety (F[1,76]=0.3, p=0.593, η^2=0.004). This shows that trait anxiety was unrelated to the RT congruency effect (incongruent RT minus congruent RT) for angry face trials in the within-valence condition. The correlation value was r= -0.06. The fourth one-way ANCOVA showed that the RT congruency effect for within-valence contrast trials with fearful faces was significant (F[1,76]=5.5, p=0.021, η^2=0.068), and did not significantly interact with trait anxiety (F[1,76]=0.2, p=0.690, η^2=0.002). This shows that trait anxiety was unrelated to the RT congruency effect (incongruent RT minus congruent RT) for fearful face trials in the within-valence condition. The correlation value was r= 0.05.

In summary, in the between-valence contrast condition fearful flanker faces slowed RTs to happy target faces (i.e., happy incongruent trials) relative to happy flanker faces during congruent happy trials. In contrast, happy flanker faces did not slow RTs to fearful target faces during incongruent fearful trials relative to fearful flanker faces during congruent fearful trials. Critically, trait anxiety was not related to this effect of fearful face distraction. In the within-valence contrast condition both emotional flanker face types (fearful and angry) slowed RTs to the target faces during incongruent trials relative to their congruent equivalent trial. Critically, trait anxiety was also unrelated to this effect of emotional distraction. We can conclude from this that although the predicted distraction effects were present in our sample trait anxiety did not affect the magnitude of distraction.

2.4.4. Further RT analysis: Congruency sequence effects

The RT data were first subjected to a 2 (current trial type; congruent versus incongruent) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) x 2 (valence contrast; between-valence versus within-valence) repeated-measures ANCOVA with standardised trait anxiety as the covariate. We will denote 4 key types of trials within this analysis thus: incongruent trials preceded by incongruent trials (iI); incongruent trials preceded by congruent trials (cI); congruent trials preceded by congruent trials (cC); and congruent trials preceded by incongruent trials (iC). Each of these trial types are averaged across target emotion (e.g., happy incongruent trials and fearful incongruent trials are averaged, as are the congruent trials). However, each of these averaged 4 trial types is separated by valence contrast. To remain consistent with the traditional CSE analyses conducted in flanker experiments that average across the 2-choice responses, each of these trial types were averaged across target emotion in each valence contrast condition. For example, happy cI trials and fearful cI trials were averaged in the between-valence condition, as were angry cI trials and fearful ci trials in the within-valence condition). Thus, each averaged trial type was separated by valence contrast condition. The effects of the previous trial's congruence upon the RT congruence effect on the subsequent trial, often referred to as CSEs, thus appear in the analyses as the effect of (in)congruency repetition/alternation.

The main effect of current trial type was significant ($F[1,76]=5.8$, $p=0.019$, $\eta^2=0.07$), but this did not interact with anxiety ($F[1,76]=0.7$, $p=0.798$, $\eta^2=0.001$). In the sequential analysis congruent trials (mean RT 561 msecs; 95% CI 542-579; SE 9) were not responded to faster than incongruent trials (mean RT 553 msecs; 95% CI 534-573; SE 10; although they were when averaged across all trial types in the non-sequential analysis reported above (this inconsistency seems counterintuitive but we verified this to be correct). The main effect of (in)congruency repetition/alternation effect was also significant ($F[1,76]=51.6$, $p<0.001$, $\eta^2=0.41$), but this did not interact with anxiety ($F[1,76]=0.54$, $p=0.465$, $\eta^2=0.007$). As Figure 2.10 shows, repetition trials were responded to faster than alternation trials. These effects relate to one of our main interests concerning how trait anxiety relates to conflict resolution and the CSE.

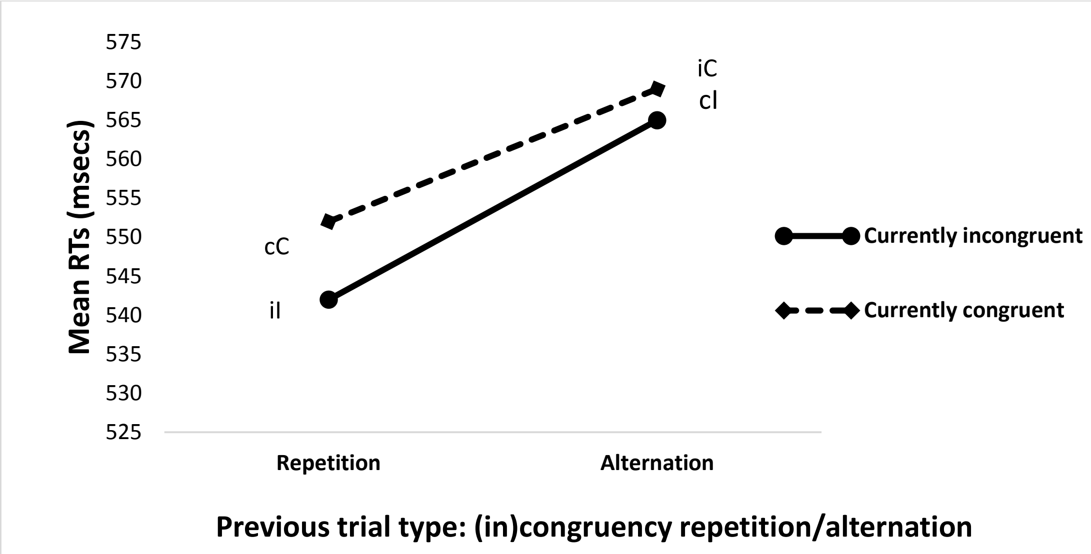

Figure 2.10: The congruency sequence effects present across the whole experiment. (In)congruency repetition trials were responded to faster than (In)congruency alternation trials. This effect was driven by faster RTs for cC trials (mean RT 552 msecs; 95% CI 533-571; SE 9) than for iC trials (mean RT 569 msecs; 95% CI 550-588; SE 10), and faster RTs for iI trials (mean RT 542 msecs; 95% CI 523-562; SE 10) than for cI trials (mean RT 565 msecs; 95% CI 545-585; SE 10).

The current trial type by (in)congruency repetition/alternation interaction was also not significant (F[1,76]=1.75, p=0.19, η^2=0.22) and did not significantly interact with anxiety (F[1,76]=0.19, p=0.661, η^2=0.003). This shows that the effect of (in)congruency repetition/alternation was very similar during currently congruent and currently incongruent trials. The non-significant current trial type by (in)congruency repetition/alternation interaction was not further modulated by valence contrast (F[1,76=0.47, p=0.497, η^2<0.006).

The main effect of valence contrast was not significant (F[1,76]=2.25, p=0.138, η^2=0.029), although the between-valence mean RT was 553 msecs (95% CIs 532-574; SE 10) and the within-valence mean RT was 562 msecs (95% CIs 543-580; SE 9). This comparison did not interact with anxiety (F[1,76]=1.23, p=0.264, η^2=0.016).

Thus there were no significant overall RT differences between the two valence contrast conditions.

The main effect of current trial type did not significantly interact with valence contrast condition (F[1,76]=1.65, p=0.203, η^2=0.021), and this potential interaction did not interact with anxiety (F[1,76]=1.85, p=0.178, η^2=0.024). Therefore, there were no differences in RTs to any trial type that were driven by the different valence contrast conditions.

Importantly, the main effect of (in)congruency repetition/alternation did not interact with valence contrast (F[1,76]<0.001, p=0.984, η^2<0.001). This shows that the differential effects of congruency repetition and alternation upon RTs to either congruent or incongruent trials did not differ between the two valence contrast conditions. Furthermore, the key finding in this analysis was a 3-way interaction of (in)congruency repetition/alternation by valence contrast condition by anxiety (F[1,76]=4.7, p=0.033, η^2=0.06). This shows that anxiety relates significantly more strongly to the main effect of (in)congruency repetition/alternation in one of the two valence contrast conditions more than the other. We analyse this interaction in more detail below, as it relates to one of our main interests concerning how trait anxiety relates to conflict resolution and the CSE. The 4-way interaction of current trial type by (in)congruency repetition/alternation by valence contrast condition by anxiety was not significant (F[1,76]=1.60, p=0.209, η^2=0.021).

In summary thus far, the CSE analysis suggests that trait anxiety relates to the effect of (in)congruency repetition/alternation in one of the two valence contrast conditions. As planned we then analysed the CSE (and its relationship with anxiety) in each valence contrast condition separately. In the between-valence condition the effect of current trial type was significant (F[1,76]=8.6, p=0.004, η^2=0.1). The critical (in)congruency repetition/alternation effect was significant (F[1,76]=26.6, p<0.001, η^2=0.26), as repetition trials (mean RT 543 msecs; 95% CI 522-564; SE 11) were responded to faster than alternation trials (mean RT 562; 95% CI 541-584; SE 11). The key finding here was an interaction between this (in)congruency repetition/alternation effect and anxiety (F[1,76]=4.6, p=0.036, η^2=0.06).

To understand this significant interaction between (in)congruency repetition/alternation and anxiety in the between-valence condition, we used an overall CSE index which can be written in terms of mean RTs (iC + cI)/2 - (cC + iI)/2. The previously reported interaction between (in)congruency repetition/alternation and anxiety tests the correlation between this index and trait anxiety: the correlation is $r = 0.24$ (p=0.036, as previously reported). The sign of this correlation (depicted in Figure 2.11) shows that, as participants are more trait anxious, they show an increased CSE; in effect an increased (in)congruency repetition advantage in RTs. These effects relate to one of our main interests concerning how trait anxiety relates to conflict resolution and the CSE.

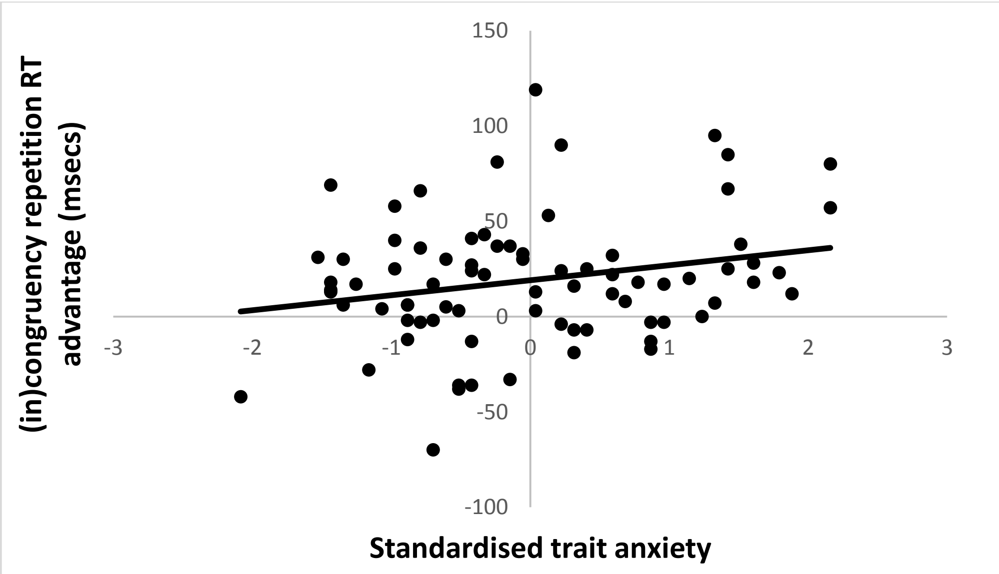

Figure 2.11: The positive correlation (r = 0.24, p=0.036) between standardised trait anxiety and the overall CSE in the between-valence condition.

The current trial by (in)congruency repetition/alternation interaction was again not significant (F[1,76]=2.23, p=0.135, η^2=0.03). Importantly, this shows that the effect of (in)congruency repetition/alternation did not differ significantly between congruent and incongruent trials. Similarly, there was no 3-way interaction between current trial, (in)congruency repetition/alternation, and trait anxiety (F[1,76]=1.5, p=0.222, η^2=0.02). This shows that there were no significant anxiety related effects on the difference between the effect of (in)congruency repetition/alternation for congruent vs. incongruent trials.

In the within-valence condition the effect of current trial type was non-significant (F[1,76]=.61, p = 0.437, η^2=0.008). However, the critical effect of (in)congruency repetition/alternation was again significant (*F*[1,76]=23.74, *p*<0.001, η^2=0.238), as repetition trials (mean RT 551 msecs; 95% CI 532-571; SE 10) were responded to faster than alternation trials (mean RT 572 msecs; 95% CI 552-591; SE 10). The key finding here was that, in contrast to the between-valence condition, this effect was not significantly modulated by anxiety (*F*[1,76]=1.03, *p*=0.314, η^2=0.13). Thus anxiety was not significantly correlated with the RT difference between repetition trials and alternation trials. The correlation value is *r*= -0.12 (p=0.314 as previously reported). These effects relate to one of our main interests concerning how trait anxiety relates to conflict resolution and the CSE. Once again, the current trial by (in)congruency repetition/alternation interaction was not significant (*F*[1,76]=0.25, *p*=0.616, η^2=0.003), nor was the current trial by (in)congruency repetition/alternation by anxiety interaction (*F*[1,76]=0.25, *p*=0.621, η^2=0.003).

Exploratory correlations showed that trait anxiety was not correlated with either (in)congruency repetition trials (*r*= -0.1, *p*=0.400) nor alternation trials (*r*= -0.01, *p*=0.913) in the between-valence condition. When controlling for the general RT factor, trait anxiety showed a negative correlation with RTs to (in)congruency repetition trials (*r*= -0.23, *p*=0.047), but was still uncorrelated with RTs to alternation trials (*r*= 0.01, *p*=0.921). However, it should be noted that these results were not adjusted for multiple comparisons. In summary, the sequential analysis shows that trait anxiety is related to an increased RT advantage when the level of emotional (in)congruency repeats, but only in the between-valence condition. The exploratory correlations suggest that this effect might be primarily driven by an anxiety related speeding on (in)congruency repetition trials, as opposed to a slowing on alternation trials.

2.4.5. Trait anger and interpersonal fear: relationships with RT effects

We first explored the relationship between trait anxiety, trait anger and interpersonal fear. Standardised trait anxiety and standardised trait anger were modestly and significantly positively correlated (*r* = 0.31, *p* = 0.007). Standardised trait anxiety scores and standardised interpersonal fear scores were also positively correlated (*r*= 0.23, *p* = 0.041); as were standardised trait anger and standardised interpersonal fear scores (*r*= 0.33, *p* = 0.003). The correlations between trait anxiety and trait anger, and between trait anger and interpersonal fear stand up to a strict Bonferroni significance adjustment for multiple testing (adjusted alpha = 0.05/3 = 0.017), but the correlation between trait anxiety and interpersonal fear should be interpreted as a trend. Exploratory analyses showed that trait anger and interpersonal fear were not correlated with the RT difference between happy and fearful faces in the between-valence contrast condition, nor any RT difference between angry and fearful faces in the within-valence condition (all rs < 0.11, ps >0.3).

We then explored the relationship between trait anger, standardised interpersonal fear and the CSEs. The p-values in these exploratory analyses have not been adjusted for multiple testing, and should therefore be treated with caution. Trait anger correlated at the borders of unadjusted statistical significance with the difference between (in)congruency repetition and (in)congruency alternation trials in the between-valence contrast condition ($r = 0.22$, $p = 0.052$), whereas interpersonal fear did not ($r = 0.13$, $p = 0.242$). The relationship between trait anger and the difference between (in)congruency repetition and (in)congruency alternation trials in the between-valence contrast condition is shown in Figure 2.12. Neither trait anger, nor interpersonal fear, correlated with the difference between (in)congruency repetition and (in)congruency alternation trials in the within-valence contrast condition (both rs < 0.01, both ps > 0.9).

Figure 2.12: The positive correlation (r = 0.22, p = 0.052) between standardised trait anger and the overall CSE in the between-valence condition.

When trait anger was partialled out, the correlation between trait anxiety and the difference between (in)congruency repetition and (in)congruency alternation trials in the between-valence contrast condition was not significant (r = 0.19, p = 0.11). Similarly, when trait anxiety was partialled out, the correlation between trait anger and the difference between (in)congruency repetition and (in)congruency alternation trials in the between-valence contrast condition was also non-significant (r = 0.16, p = 0.169). These partial correlations tentatively suggest that it may be the shared components of trait anxiety and trait anger that correlate with the CSE. Multiple regression showed that trait anger and trait anxiety combined were only a slightly better predictor than either trait alone, of the CSE (R = .29; $F[2, 74]$ = 3.26, p = 0.044). Moreover, we also verified that similarly to trait anxiety, trait anger and interpersonal fear were uncorrelated with the CSE in the within-valence condition (both rs < 0.01, both ps > 0.9).

2.4.6. Accuracy analyses

The proportion of correct responses for each of the trial types were first subjected to a repeated measures ANCOVA with factors of emotion (fear versus other); valence contrast (between-valence versus within-valence; i.e., fear versus happy and fear versus anger) and trial type (single versus congruent versus incongruent); with standardised trait anxiety as the covariate. Mean proportion correct, 95% confidence intervals and standard errors for each of the 12 stimulus types are shown in Table 2.3. Figure 2.13 shows the mean proportion correct for each of the 12 stimulus types, expressed as a function of emotion and valence contrast condition relative to trial type The test of between-subjects effects was not significant ($F[1,76]=1.0$, $p=0.332$, $\eta^2=0.013$), indicating that trait anxiety was unrelated to the proportion correct across the whole paradigm.

Table 2.3: Mean proportion correct, 95% confidence intervals (95% CIs), and standard errors (SE) for each of the 12 stimulus types (listed by target emotion versus trial type). All values are in msecs.

Between-valence condition				Within-valence condition			
Trial type	**Prop/C**	**95% CI**	**SE**	**Trial type**	**Prop/C**	**95% CI**	**SE**
Single fear	0.95	0.94-0.96	0.005	**Single fear**	0.95	0.94-0.96	0.005
Congruent fear	0.96	0.95-0.96	0.003	**Congruent fear**	0.96	0.95-0.97	0.004
Incongruent fear	0.95	0.93-0.96	0.006	**Incongruent fear**	0.94	0.93-0.95	0.005
Single happy	0.94	0.93-0.95	0.005	**Single anger**	0.93	0.91-0.94	0.007
Congruent happy	0.97	0.96-0.97	0.003	**Congruent anger**	0.96	0.95-0.96	0.003
Incongruent happy	0.96	0.95-0.97	0.004	**Incongruent anger**	0.95	0.94-0.96	0.005

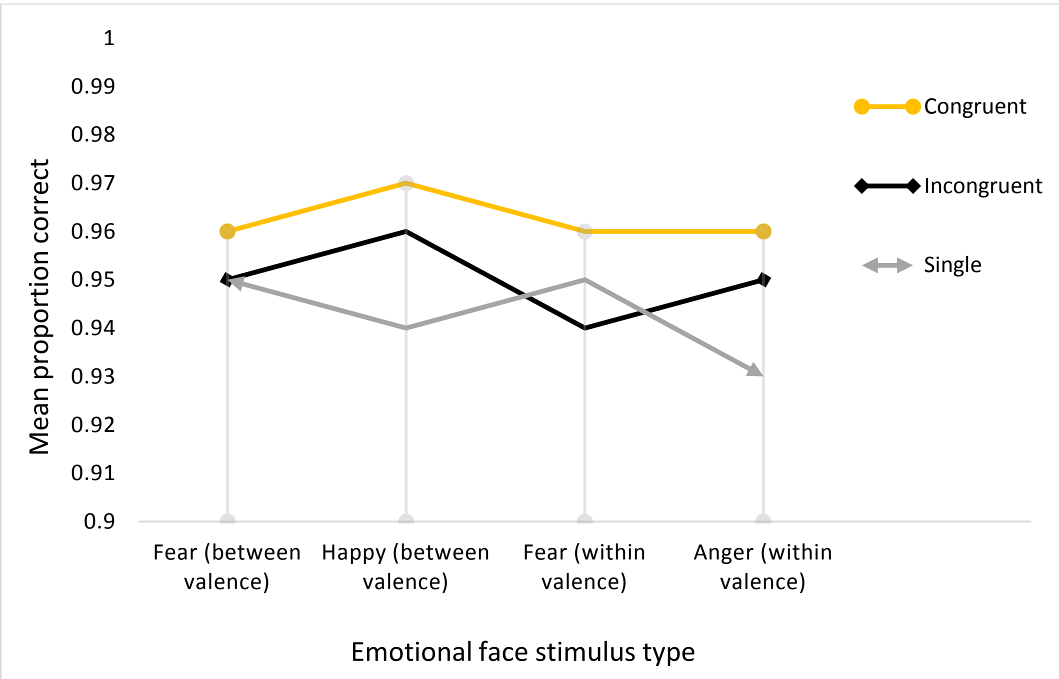

Figure 2.13: Mean proportion correct for each of the 12 stimulus types, expressed as a function of emotion and valence contrast condition relative to trial type.

The main effect of emotion was not significant (F[1,76]=0.002, p=0.965, η^2,0.001), as averaged other faces (happy, angry) were not responded to more accurately than averaged fearful faces (other faces proportion correct 0.95; 95% CI 0.94-0.96; SE 0.003; fearful faces proportion correct 0.95; 95% CI 0.95-0.96; SE 0.003). Trait anxiety did not interact with the effect of emotion (F[1,76]=1.4, p=0.236, η^2=0.018). The main effect of valence contrast was significant as accuracy levels were slightly higher in the between-valence condition (F[1,76]=5.3, p=0.024, η^2=0.065; between valence proportion correct 0.953; 95% CI 0.95-0.96; SE 0.003, within valence proportion correct 0.948; 95% CI 0.94-0.96; SE 0.004, but this effect did not interact with trait anxiety (F[1,76]=0.2, p=0.693, η^2=0.002). The correlation value was r=0.06 (p=0.693, as reported earlier).

The main effect of trial type was also highly significant (F[2,152]=23.9, p<0.001, η^2=0.240) as proportion correct congruent (mean 0.96; 95% CI 0.95-0.97; SE 0.003) > proportion correct incongruent (mean 0.95; 95% CI 0.94-0.96; SE 0.004) > proportion correct single (mean 0.94; 95% CI 0.93-0.95; SE 0.004). The relationships between these variables are also illustrated in Figure 2.14. The main effect of trial type did not interact with trait anxiety (F[2,152]=1.9, p=0.150, η^2=0.025).

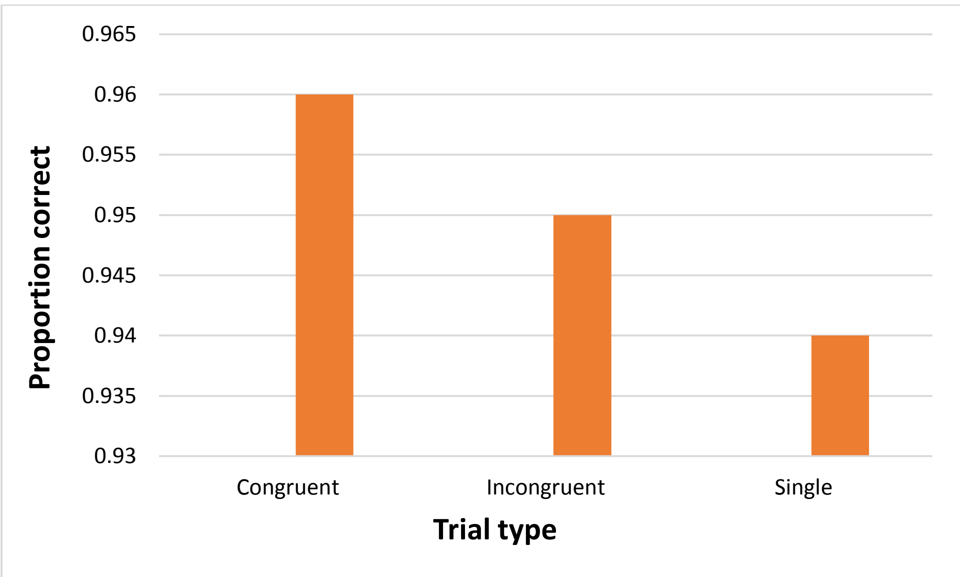

Figure 2.14: Mean proportion correct for congruent, incongruent and single face trials.

The effect of emotion interacted with the effect of valence contrast (*F*[1,76]=7.5, *p*=0.008, η^2=0.090), as illustrated by Figure 2.15. We return to this issue later. This interaction did not further interact with trait anxiety (*F*[1,76]=0.2, *p*=0.659, η^2=0.003). The effect of emotion also interacted with the effect of trial type (*F*[2,152]=15.4, *p*<0.001, η^2=0.169), indicating that the trial type effect differs between the two emotion categories. This is illustrated in Figure 2.16. This interaction did not further interact with trait anxiety (*F*[2,152]=0.7, *p*=0.498, η^2=0.009).

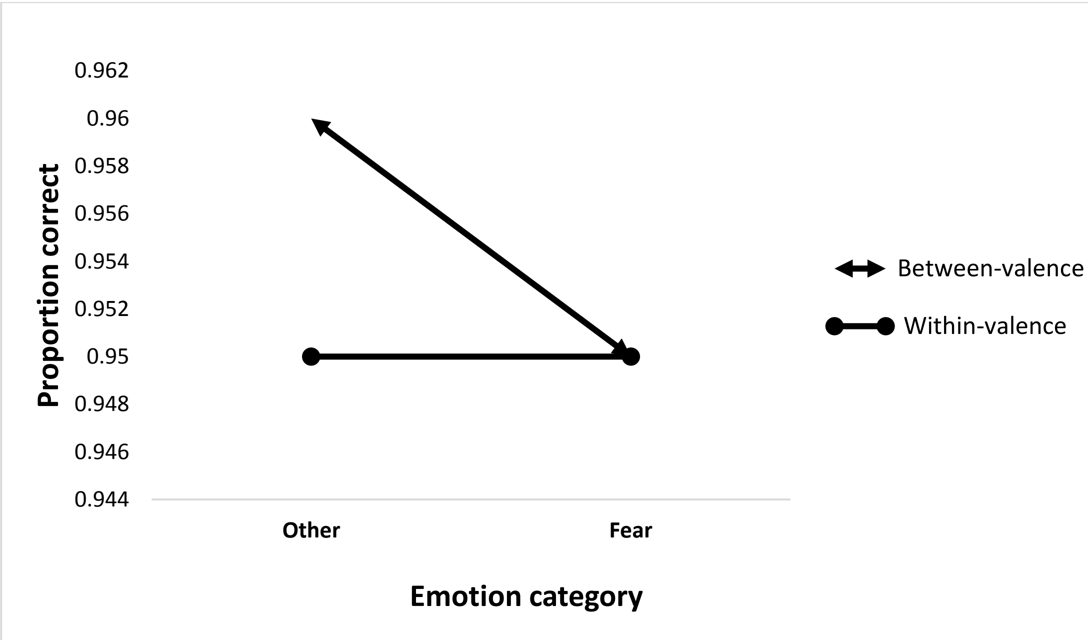

Figure 2.15: Mean proportion correct for each emotional facial expression expressed as a function of valence contrast and emotion category.

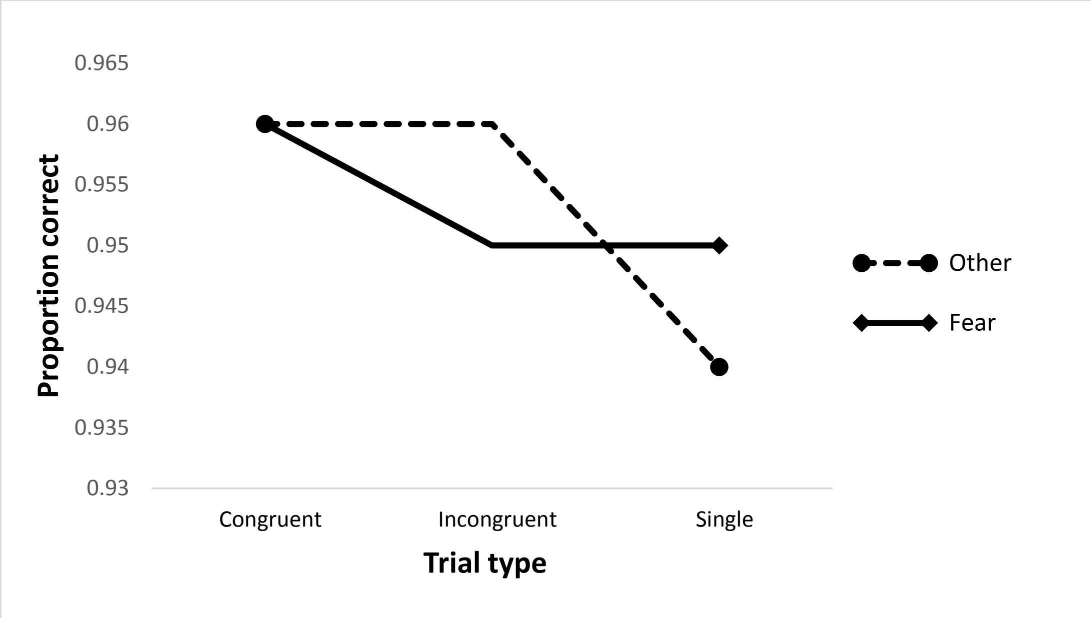

Figure 2.16: Mean proportion correct for each trial type as a function of emotion category.

The effect of valence contrast did not significantly interact with trial type (F[2,152]=0.2, p=0.853, η^2=0.002), and this potential interaction did not interact with anxiety (F[2,152]=0.2, p=0.816, η^2=0.003). The 3-way interaction between emotion, valence contrast, and trial type was also not significant (F[2,152]=0.8, p=0.454, η^2=0.010). The 4-way interaction between emotion, valence contrast, trial type and anxiety was also not significant (F[2,152]=0.2, p=0.818, η^2=0.003).

We followed up the emotion and valence contrast interaction using one-way ANCOVAS. Here we adopt an adjusted significance level of 0.05/2. The first one-way ANCOVA showed that there was a trend towards happy faces being responded to more accurately than fearful faces (F[1,76]=4.2, p=0.043, η^2=0.053), but this effect did not interact with trait anxiety (F[1,76]=1.2, p=0.270, η^2=0.016). This interaction shows that trait anxiety was not significantly correlated with the accuracy difference between these trials. The correlation value was r= -0.13, p=0.270 as reported above. The second one-way ANCOVA showed that there was a trend towards fearful faces being responded to more accurately than angry faces (F[1,76]=4.2, p=0.045, η^2=0.052), but this effect did not interact with trait anxiety (F[1,76]=0.2, p=0.643, η^2=0.003). This interaction shows that trait anxiety was not significantly correlated with the accuracy difference between these trials. The correlation value was r= 0.05, p=0.643 as reported above. Thus, the proportion correct analysis shows that there was a trend towards the effect of emotion being reversed in the within-valence condition, relative to the between-valence condition. Critically, the proportion correct analysis also shows that that trait anxiety did not reliably affect the accuracy of emotional face discrimination.

2.4.7. Further accuracy analysis: Congruency sequence effects

In order to analyse the CSEs and proportion correct, the data were subjected to a 2 (current trial type; congruent versus incongruent) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) repeated-measures ANCOVA with standardised trait anxiety as the covariate. The critical findings in this analysis were that the main effect of (in)congruency repetition versus (in)congruency alternation was highly significant ($F[1,76]=37.6$, $p<0.001$, $\eta^2=0.33$), as repetition trials (mean proportion correct 0.97; 95% CI 0.96-0.97; SE 0.002) were responded to more accurately than alternation trials (mean proportion correct 0.95; 95% CI 0.94-0.96; SE 0.004), but this effect did not interact with anxiety ($F[1,76]=0.02$, $p=0.893$, $\eta^2<0.001$). Thus, anxiety was not significantly correlated with the difference in accuracy between these trials. The correlation value was r= 0.02. The effect of current trial type approached significance ($F[1,76]=3.7$, $p=0.058$, $\eta^2=0.047$), but there were no other significant effects/interactions (all Fs < 1.6, all Ps > 0.2).

2.5. Discussion

In experiment 1 we used a novel emotional ‘face in the crowd’ flanker task with both between-valence and within-valence (fearful face versus other face) discrimination conditions. Averaged happy and angry faces were responded to faster than averaged fearful faces. The critical finding here was that trait anxiety was robustly negatively correlated with the RT difference between averaged happy and angry faces and averaged fearful faces. We then wished to determine if these effects were due to a general difference in the processing of fearful faces and other faces, or whether the effects were specific to one of the valence contrast situations. In the between-valence condition happy faces were responded to faster than fearful faces, which is consistent with the findings of Cooper et al. (2008). However, we found that high trait anxiety was related to a decreased happy face RT advantage. Trait anxiety was uncorrelated with RTs to either happy or fearful faces. This RT finding is somewhat in alignment with the neuroimaging study of Fonzo et al. (2015). Fonzo et al. reported the difference in right amygdala activation during happy face processing vs. fearful face processing was related to levels of trait anxiety. Similarly to our RT findings, right amygdala activation in their study did not relate to either happy or fearful face processing. In the present study, analysis of the within-valence condition showed that RTs to angry and fearful faces did not differ and were unrelated to trait anxiety, which is also consistent with the findings of Cooper et al. We can conclude from this that the trait anxiety effects upon emotional face discrimination were not due to a general difference in the processing of fearful faces and other faces. The anxiety effect was specific to making between-valence (happy vs fear) discriminations, as opposed to within-valence (anger vs. fear) discriminations.

A standard RT congruency effect was present as incongruent trials were responded to slower than congruent trials. This effect was unaffected by the type of valence conflict. Trait anxiety was unrelated to the RT congruency effect which is consistent with the findings of Larson et al. (2013), who used neutral arrow stimuli. Thus, the ACT-based prediction that trait anxiety would be related to increased distraction was not supported. However, it is noteworthy that Eysenck et al. (2007) also postulate that high anxious participants can adopt compensatory processing strategies, which although inefficient, render behavioural effects unobservable. However, this argument does tend to make ACT rather unfalsifiable. We suggest that further anxiety research concerning congruency effects in flanker tasks is unlikely to be fruitful unless the magnitude of emotional distraction/conflict can be increased in a different way.

We next considered that general sources of RT variation would act to obscure the specific RT correlations with trait anxiety in particular emotional face conditions. When controlling for these ‘general RT effects’ using partial correlations, trait anxiety was related to faster mean RTs to fearful faces in the between-valence condition. This suggests that the correlation between trait anxiety and the RT difference between happy and fearful faces is driven by high anxious participants responding to fearful faces faster than their low anxious counterparts. Controlling for general RT effects confirmed that trait anxiety was not related to mean RTs to happy faces in the between-valence condition, nor fearful faces or angry faces in the within-valence condition.

The faster responses to fearful faces (presented amongst happy faces) in high trait anxiety might represent the enhanced reactivity of a neural survival circuit as theorised by LeDoux (2012). Indeed, this finding is also in alignment with the theories of anxiety that incorporate an enhanced threat processing system, as described by Beck and Clark (1997), Mathews and Mackintosh (1998), Mogg and Bradley (1998), Ohman (1996), and Williams et al. (1988). Our results also show that those low in trait anxiety showed a happy face recognition advantage relative to those high in trait anxiety, which was driven by slower responses to fearful faces. It is possible that the happy faces would activate the same neural circuits that would be active in situations of adaptive reward. For example, LeDoux (2012) suggests that behaviours such as happiness, pleasure and joyfulness are products of the biological circuits that are also implicated in nutrition, energy, fluid balance, thermoregulation and procreation. It seems possible that those high in trait anxiety have a more reactive survival circuit response to threat-related stimulation relative to adaptive reward stimulation, whereas those low in trait anxiety may have a more reactive survival circuit response to adaptive reward stimulation relative to threat-related stimulation, although the correlation with happy face RTs is not directly related to anxiety.

The correlations in the present study show that trait anxiety directly affects the speed of processing and responding to fearful faces, but not happy faces. This is somewhat inconsistent with the findings of Rossignol et al. (2005). They showed that high anxious participants were faster than low anxious participants at detecting both fearful and happy faces. This may reflect anxiety-related speeding in RTs to infrequent emotional faces, as opposed to discriminating between the actual emotional facial expressions per se. Rossignol et al. suggested that anxiety is related to an enhanced vigilance towards general emotion processing. An alternative explanation of their results could be that trait anxiety modulates RTs to happy faces but this depends upon the context provided by other task relevant emotional faces. In their study happy faces were predominantly discriminated from neutral faces, and some infrequent fearful faces. In contrast, in the present study fearful and happy faces were equal in frequency, and the task was to discriminate happy faces from fearful faces, not neutral faces. This argument can also be accommodated within the perspective of LeDoux (2012) and the existence of emotional survival circuits in the brain. For example, in a situation where fearful faces must be discriminated from happy faces this might consistently trigger a threat-related survival circuit in high anxious participants. In contrast in a situation where intermittent fearful and happy faces are discriminated from neutral faces, the intermittent emotional faces might trigger phasic responses from both threat-related and adaptive reward related survival circuits in high anxiety. Thus, the different anxiety effects found in the present study and that of Rossignol et al. can possibly be reconciled.

In the present study, RTs to fearful faces were similar in both valence contrast conditions. Trait anxiety did not modulate the RT difference between fearful faces that were discriminated from happy faces and fearful faces discriminated from angry faces. Trait anxiety selectively correlated with RTs to fearful faces only in the between-valence condition (after controlling for general RT effects). One could suggest that there were no anxiety-related differences in RTs to the emotional faces in the within-valence condition, by arguing that both emotions were threat-related. However, we suspect this explanation is unlikely as we would expect anxiety to correlate with overall mean RTs in the within-valence condition, and this was not the case. Instead, we offer an explanation based upon theories of face processing.

Calder, Young, Keane and Dean (2000) suggest that the perception of emotional faces can require configural processing. Configural and featural processing may play different roles when processing different emotional facial expressions (Adolphs, 2002a). Indeed, Calvo and Nummenmaa (2008) showed that an increase in featural processing is used during the visual search for happy faces compared to fearful and angry faces, whereas the visual search for fearful and angry faces is more reliant upon configural processing. In the present study distinguishing between and happy and fearful faces may have only required a basic featural processing style, but distinguishing between angry and fearful faces may have required additional configural processes. The finding that anxiety modulated RTs to fearful faces in the fear / happy discrimination condition, but not the fear / anger discrimination condition, is consistent with the idea that different types of processes are required to distinguish fearful faces from happy faces than are required to distinguish fearful faces from angry faces. In short, the anxiety-modulated RT advantage for fearful faces may have been lost when discriminating the fearful faces from angry faces, due to increased configural processing demands in the within-valence condition. This explanation supposes that the configural processing operations of the within-valance condition are not dependent on, or affected by, anxiety-related mechanisms, whereas the featural processing operations of the between-valence conditions are. This post hoc suggestion needs to be tested appropriately.

In sum, in answer to our second question, trait anxiety did relate to a RT bias for fearful faces. But this occurred only when happy faces were the alternative face being discriminated, and not when the alternative was an angry face. We suggest that clarifying the boundaries of this bias is a valuable line of further research.

In summary, our analyses thus far showed that trait anxiety modulated emotional facial expression recognition, as opposed to the magnitude of emotional face flanker interference. Our next analyses focused upon how anxiety relates to conflict resolution and the CSE. CSEs in the RTs were analysed using the standard cC, iI, iC and cI trial sequences. The critical (in)congruency repetition versus (in)congruency alternation effect was robustly significant and was not further modulated by valence contrast condition. In short, (in)congruency repetition trials were responded to faster than (in)congruency alternation trials in both valence contrast conditions. This (in)congruency repetition RT advantage did not differ in magnitude for either congruent or incongruent trials. However, the key finding in this analysis was a 3-way (in)congruency repetition/alternation by valence contrast by anxiety interaction. *Anxiety modulated the magnitude of the CSE, but only in the between-valence condition, not the within-valence condition.* As a participant’s level of trait anxiety increased so did their overall CSE in the between-valence condition. This effect did not further interact with trial type. This suggests that the anxiety-related CSE did not significantly differ between congruent and incongruent trials.

The finding that anxiety relates to an increased CSE is in alignment with the findings of Larson et al. (2013) who used a non-emotional flanker task. The results of the present study therefore appear to lend some support to Gray and McNaughton's (2000) suggestion that anxiety is related to the reactivity of a conflict resolution system, assuming that the CSE depends upon processing within the conflict resolution system. However, it is noteworthy that they proposed that the perception of task-relevant goal conflict often inhibits much of the motor activity that is being carried out at the time. They suggested that when conflict-inducing stimuli are re-experienced, they are dealt with in a more inhibited manner. By contrast, the RT effects of repeated incongruent trials that contribute to the CSE occur when iI trials are responded to faster than cI trials (e.g., Gratton et al., 1992). It therefore seems probable that the methods employed in the original rodent paradigms produced results that are not activating the same systems that are responsible for generating the CSE, or are doing so in a different way. An increased (in)congruency repetition advantage in high anxiety could still be explained as evidence of the reactivity of a neural survival circuit, from the perspective of LeDoux (2012). The speeded resolution of emotional conflict, or even the speeded detection of emotional congruence by those high in anxiety, could well be adaptive.

It is noteworthy that the current CSE results are in contrast to the results of the emotional Stroop studies carried out by Etkin and Schatzberg (2011), and Etkin et al. (2010). These authors found that the CSE during incongruent trials was abolished in GAD patients, who were higher in trait anxiety than normal controls. It is possible that this was due to differences in how emotional Stroop conflict and emotional flanker conflict is processed. Alternatively, anxiety may affect the CSE differently in clinical patients compared to the sub clinical levels of anxiety present in our sample.

It is also noteworthy in the present study that anxiety modulated the CSE only in the between-valence condition. The reason for this difference seems unlikely to be to do with the emotional content of the judgements per se; we have already noted that Larson et al. (2013) found anxiety effects in a similar direction to those observed in current study when they were using entirely neutral stimulus displays. This is also consistent with our prior suggestion that differences in processing requirements in the between-valence discrimination condition, relative to the within-valence discrimination condition (e.g. such as within-valence discriminations requiring more configural processing) abolish any anxiety-related effects. In short, in the present study, both the anxiety-related RT effects on expression recognition and conflict resolution were present only in the between-valence condition.

We suggest that further anxiety research concerning conflict resolution will be fruitful. However, we suggest that it would be advantageous to design a finer-grained emotional flanker paradigm that enables one to determine the precise mechanism that underlies the anxiety effects upon the CSE. Nieuwenhuis et al. (2006) and Mayr, Awh and Laurey (2003) reported that the CSE was present only with both target and response repetition. Nieuwenhuis et al. suggested that response priming drives the effect. In contrast, Clayson and Larson (2012, 2011a, & 2011b) found robust CSEs after removing stimulus and response repetitions. Recently it has been shown, using a much modified conflict paradigm, that a CSE can occur when precluding any target and response repetitions in the design (Duthoo et al., 2014). However, from the perspective of anxiety research it would be interesting to compare pairs of trials where just conflict is implicated, with trials where conflict plus response priming is implicated. This could allow researchers to determine whether the present CSE correlations with trait anxiety may be present only when there is target response repetition, or whether target response repetition modifies the CSE and its dependence on anxiety. It would be useful not to preclude these trials if one wishes to determine whether conflict adaptation or episodic memory processes are responsible for the anxiety-related modulation of the CSE. It is entirely plausible that there may be mechanisms responsible for the CSE, which are independent of anxiety, and these may be distinct from other mechanisms that facilitate the anxiety-related enhancement of the CSE. Future studies should focus upon this issue.

We administered additional individual difference measures as trait anxiety is not the only variable that is likely to be implicated in emotional distraction, expression recognition or conflict resolution. Trait anxiety and trait anger were positively correlated, and both correlated positively with interpersonal fear. Neither trait anger nor interpersonal fear modulated RTs to any of the emotional face types, nor the difference in RTs to either pair of conflicting emotional face types. This is somewhat in contrast to the finding that trait anger (but not trait anxiety) has been related to an attentional bias for angry faces, relative to neutral faces (van Honk, Tuiten, de Haan, van den Hout & Stam, 2001). The task used by van Honk et al. required participants to respond to the colour of the tinted photographs (red, yellow, blue or green), not the facial emotion. Thus the emotion expression was not task relevant, which is in contrast to the task used in the present chapter.

In the present study, trait anger was positively correlated with the overall CSE in the between-valence condition. In contrast, interpersonal fear scores were not. When trait anger was partialled out the correlation between trait anxiety and the CSE was non-significant. Similarly, when trait anxiety was partialled out the correlation between trait anger and the CSE was non-significant. These partial correlations tentatively suggest that it may be some shared components of trait anxiety and trait anger that modulate the CSE. Moreover, we also verified that, similarly to trait anxiety, trait anger and interpersonal fear did not modulate the CSE in the within-valence condition.

Anger is considered an approach-related behaviour (Carver & Harmon-Jones, 2009), whereas anxiety is described as related to cautious, defensive approach behaviour that arises in conflict situations (Gray & McNaughton, 2000). Shared resources related to approach behaviour may explain why the traits are both implicated in the CSE, whereas fear (an avoidance behaviour, Gray & McNaughton) appears much less implicated. Alternatively, anger has previously been shown to be psychometrically related to anxiety, but after controlling for general negative affect the correlation disappeared (Harmon-Jones, 2003). Therefore, shared negative affectivity could explain the present findings, although the absence of a relationship with fearfulness (which also concerns a negative affect) does not fit this explanation.

The relationship between trait anxiety and trait anger (and their combined relationship with the CSE) in the present study also resonates with the findings reported in a recent clinical paper. Lang, McTeague and Bradley (2016) administered 14 different individual difference questionnaires that measure depression, anhedonia, trait anxiety, trait anger, and life stressors, to 425 patients seeking treatment for a spectrum of DSM-IV anxiety diagnoses. A principal components analysis of the responses to all of the questionnaires isolated three components. Lang et al. defined these as negative affectivity, anxious arousal, and cumulative life stress. Trait anxiety measured by the STAI and trait anger measured by the STAXI both loaded on the negative affectivity component, whereas the total scores of the fear survey schedule (FSS) did not load on any of the three components. In the present study the interpersonal fear subscale of the FSS was unrelated to the CSE, whereas both trait anxiety and trait anger were. In answer to our fourth and final research question, we suggest it is likely that there will be some shared components of interrelated affective traits that can influence emotion and cognition, across several domains of information processing. We suggest that it will be beneficial for future studies concerning trait anxiety and cognition to also administer trait anger measures at the very least.

The current study has investigated how affective traits are related to variations in cognitive control in an emotional goal conflict situation. We suggest that a replication of this study should also assess whether any neural differences exist, between the three affective traits. For example, cognitive control processes require ongoing performance evaluation. A proposed neural basis of this evaluative function (illustrated by EEG recordings of ERPs) has been termed the error-related negativity (ERN). ERP recordings derived from fronto-central electrodes contain a large negative deflection in the response-locked ERPs that peak at 100 milliseconds following error commission**.** The ERN is possibly the neural basis of error-detection, or a general action plan evaluation, originating from an executive control system (Gehring, Coles, Meyer & Donchin, 1995). Alternatively the ERN may represent a neural estimate of any current events motivational worth, as illustrated in financially incentivised paradigms where higher value trials illicit a larger ERN (Pailing & Segalowitz, 2004; Hajcak et al., 2005). Research using dipole modelling techniques suggests that the ERN originates from the ACC (Dehaene, Posner, & Tucker, 1994). The ACC is a neural component of the posterior medial frontal cortex (pMFC). fMRI evidence shows that increased activity in this area is present during erroneous responses compared to correct responses. This pMFC activity is also present following response conflict and unfavourable outcomes (Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004b).

These theories of the ERN resonate substantially with the theoretical function of the septo-hippocampal defence system proposed by Gray and McNaughton (2000). From an RST perspective the neurobiology and neurochemistry, of the proposed explanations of the ERN, resonate with the proposed basis of BIS and BAS activity. For example, Boksem, Tops, Wester, Meijman and Lorist (2006) draw attention to the fact that Holroyd & Coles (2002) postulate that dopaminergic neurotransmission is critical if the ERN is to occur. However, Boksem et al. point out that in Gray and McNaughton's theory punishment and prediction error responses are controlled by the BIS which is based upon cholinergic neurotransmission. Boksem et al. continue by explaining that the BIS inhibits the BAS which is dopamine based, therefore the two theories are compatible with each other. Accordingly, these authors suggest that this leaves open an interesting area for research as the non-dopamine based BIS (response monitoring) system has not featured greatly in theoretical accounts of the ERN. In a study using the traditional Eriksen flanker task Boksem et al. found that BIS scores (as measured with the BIS scale; Carver and White, 1994) correlated positively and moderately with the ERN amplitudes. However their sample was quite small (N=24). We suggest that the current study is replicated using EEG. The recordings of the ERN may help to further differentiate how trait anxiety, trait anger and interpersonal fear are implicated in the cognitive control of emotion.

2.6. Conclusion

To conclude, trait anxiety does seem to be selectively related to a RT bias for fearful faces, but it is dependent upon the context provided by the other task relevant faces. Trait anxiety was not related to distraction caused by emotional flankers, even though the predicted effects were detected in the whole sample. However, trait anxiety was related to the sequential effects of emotional conflict processing. This was evidenced by an enhanced CSE. However, this effect was dependent upon the type of emotional conflict present. Moreover, trait anger was positively related to trait anxiety. It seemed to be the shared variance of trait anxiety and trait anger that accounted for the trait effects upon the CSE. In contrast, trait anger was unrelated to RTs to fearful faces. Future studies should focus upon how both trait anxiety and trait anger modulate sequential effects present during emotional conflict processing, and how trait anxiety modulates emotional face processing. Moreover, it would also be beneficial to include a social anxiety measure in future emotional face processing experiments. The use of these RT paradigms that tap into emotional face recognition, and emotional conflict resolution processes, should be a fruitful means of researching how the suggested survival circuits described by LeDoux (2012) might be triggered.

Chapter 3

3. Experiment 2

3.1. Introduction

Experiment 1 showed that our new emotional face flanker task was a useful measure of emotional distraction, emotional expression recognition, and emotional conflict resolution that can be used in personality and individual differences research. Our novel flanker paradigm was partially inspired by the 'face in the crowd task' (Byrne & Eysenck, 1995), but some of the inspiration for creating this new emotional conflict paradigm came from studies using another conflict task, referred to as the Stroop task. This chapter reports experiment 2 which focuses upon this type of emotional conflict paradigm. Emotional variants of the Stroop task have been used in anxiety research for many years (see Phaf & Kan, 2007). This present experiment (experiment 2) has now been published (du Rocher & Pickering, 2017). This paper can be sourced at: http://www.sciencedirect.com/science/article/pii/S0191886917300855

In the classic Stroop task (Stroop, 1935) performance when naming the font colour in which single words are written is affected by the meaning of the words: especially if the word names a colour that is incongruent with the font colour. For example if the word blue is presented in green font (i.e., an incongruent trial), participants will be slower or less accurate when responding to the green font colour than if the word green was presented in green (i.e., a congruent trial). These Stroop effects were traditionally explained as an automatic effect of participants reading written words. Performance on this task reflects two different types of conflict. Informational conflict exists between the font colour and word, during incongruent trials. Task conflict exists between the necessary colour naming task, and the irrelevant automatic word reading effect (Kalanthroff, Avnit, Henik, Davelaar, & Usher, 2015). Stroop effects consist of facilitative effects and interference effects. Facilitative effects are the improvement in performance for congruent relative to neutral trials, whereas interference effects are the reduction in performance for incongruent relative to neutral trials (Goldfarb & Henik, 2007). However, it is noteworthy that most Stroop studies do not include these neutral trials. In these cases the relative contributions of facilitation effects, and/or interference effects, to the overall Stroop effect cannot be quantified.

Basten, Stelzel and Fiebach, (2011) used a traditional colour word Stroop task where the words red, yellow, blue or green were presented in font colours that were either congruent or incongruent with the words. Congruent and incongruent trials were presented in equal proportions. Congruent trials were responded to faster and more accurately than incongruent trials. Trait anxiety was not significantly related to any reaction time (RT) trial type effects. However, high anxiety was related to faster RTs averaged across all trial types at a trend level. Using a median split, high and low trait anxiety groups differed significantly in trial type accuracy rates. For high anxious relative to low anxious participants the error rate for incongruent trials relative to congruent trials was increased. To confirm this effect the anxiety groups were combined and the correlation between the Stroop effect in errors (proportion correct congruent minus proportion correct incongruent) and trait anxiety was positive and moderate in magnitude (the correlation value was r=0.32, p=0.031). Basten et al. also reported fMRI analyses that showed increased conflict-related brain activity in the dorsolateral prefrontal cortex (DLPFC) in high anxious participants relative to their low anxious counterparts. Basten et al. suggest that this activity represents a processing efficiency impairment in high anxious participants that is in alignment with the predictions of attentional control theory (ACT; Eysenck et al., 2007). Basten et al. also suggested that the trend towards an anxiety related speeding in RTs across conditions, and the trend towards a reduction in accuracy for incongruent trials may reflect a speed-accuracy trade-off (this is discussed in detail in the discussion but see Meyer, Irwin, Osman, & Kounios, 1988; Wickelgren, 1977). This strategy would prioritise faster responses but produce reduced accuracy rates.

Kalanthroff, Henik, Derakshan and Usher (2015) investigated the effects of emotion upon anxiety during Stroop performance using a traditional colour word Stroop task. The words red, yellow, blue or green or the character string XXXX (all in Hebrew) were presented in font colours that were either congruent or incongruent with the words. However, in this study negative and neutral pictorial distractors were briefly presented (100 milliseconds) before the Stroop stimuli, with a 50 millisecond interval included between the distractor and Stroop stimuli. The use of the neutral XXXX stimuli allowed for a calculation of both RT facilitation and RT interference contributions to the Stroop effect. RT facilitation is the RT difference between congruent trials and neutral trials, whereas RT interference is the RT difference between incongruent trials and neutral trials. Low trait anxious participants were unaffected by either pictorial distractor valence. However, high trait anxious participants showed increased interference effects and decreased facilitation effects for trials following negative distractors, relative to trials following neutral distractors. Kalanthroff et al. suggest that the high anxiety related slowdown in RTs for both congruent and incongruent trials (that followed negative distractors relative to neutral distractors) reflects disrupted pro-active control processes. Pro-active control relies upon active maintenance of task context as preparation for conflict or task difficulty. In contrast, a reactive strategy involves control that is initiated precisely when needed, and is thus less goal focused (Braver, 2012). Kalanthroff et al. suggest that their results support the ACT suggestion that anxiety relates to a bias in bottom-up processing over top-down processing (Eysenck et al., 2007). In this case, the emotional impact of the negative emotional distractors was suggested to impair the executive control processes necessary in the Stroop task, but only in high anxious participants. Thus, it is the combination of the pressure on these executive control mechanisms by negative distractors and high anxiety that causes the effect. The anxiety related slowing in RTs following negative distractors was not evident for neutral (XXXX) trials. Kalanthroff et al. note this and suggest that the slowing effect was not an overall slowing in RTs. They suggest it is more likely a specific modulation of reactions to both response conflict and task conflict during incongruent trials, and just task conflict during congruent trials.

It is noteworthy here that the results of the study by Kalanthroff et al. (2015) do allow for an alternative explanation (of ours). In short, the presence of negative distractors could have activated the BIS, which from an RST perspective mediates anxiety (Gray & McNaughton, 2000). The BIS could thus have slowed responses to incongruent trials (conflict trials) and congruent trials (potential conflict trials), but not neutral trials (no conflict trials), as processing the conflict trials and potential conflict trials needed the BIS, whereas the neutral trials did not.

The effect of emotion upon cognitive control during the Stroop task has traditionally been researched in a different way. The colour naming Stroop task itself is often modified to include threat-related emotional words and neutral words. Stroop effects during font colour naming in traditional Stroop tasks (using colour words) and modified emotional Stroop tasks (using emotional and neutral words) have been found to correlate. However, blood pressure tests show that the colour task is more arousing, possibly due to increased conflict between colours and colour words as opposed to colours and emotion words (Cothran & Larsen, 2008). This can be explained easily as emotional Stroop colour naming tasks will still elicit task conflict between the necessary colour naming task, and the irrelevant automatic word reading effect. However, no informational conflict will exist between the font colour and word during emotional word trials. The only conflict present in the task would be task conflict. The emotional Stroop task thus requires a different explanation than the colour naming Stroop task, as emotional word meanings and font colours do not occupy the same semantic dimension (Algom, Chajut, & Lev, 2004).

Performance during emotional Stroop tasks has been shown to be modulated by levels of anxiety. For example, Taake, Jaspers-Fayer and Liotti (2009) used an emotional Stroop task with words that were either neutral, positive or threat related presented in either red, yellow, blue or green font. Two types of blocks of stimuli were presented. In one block type threat and neutral words were presented equally often in each of the four colours, whereas in the other block type positive and neutral words were presented. High anxious participants showed significant slowing in RTs when naming the font colour in the threat/neutral block, but not the positive/neutral block. Low anxious participants did not exhibit this effect. Moreover, EEG recordings showed that for high anxious participants only, words from the threat/neutral block type elicited an increased negative amplitude (at 350-450 milliseconds) at frontocentral brain regions, relative to words from the positive/neutral block type. In their RT analyses, the effect of trial type versus block type was insignificant. Critically, there was no RT slowing for threat words relative to neutral words in the same block. However, EEG recordings showed for threat words versus neutral words in the same block a positive enhancement of an ERP (200-300 milliseconds) was present at anterior frontal brain regions. This effect did not differ between high and low anxious participants. However, Taake et al. report that in high anxious participants only, this effect was preceded by a very early response (30-70 milliseconds) to threat words relative to neutral words in the same block in the left frontomedial brain region. They propose that this early emotional processing may represent a hyper-vigilance towards threat in high anxious participants. In emotional Stroop studies anxiety is often suggested to modulate processing priorities towards threat-related stimuli which leads to interference when naming the colours of the words (Fox, 1996; Mathews & Mackintosh; 1998, Mathews & MacLeod, 2002; Mogg & Bradley, 2005). The slower RTs when naming the colour of fear words in high anxiety was traditionally explained as an automatic attentional bias towards the emotional meaning of the fear words (Williams, Watts, MacLeod, & Mathews, 1988).

Designs where emotion words are blocked together can produce larger Stroop effects than designs where emotion and neutral words are mixed in the same block (Richards, French, Johnson, Naparstek, & Williams, 1992; Waters, Sayette, & Wertz, 2003). McKenna and Sharma (2004) found that interference occurred in a neutral trial following a fear trial, not in the actual fear trial. They interpreted this as a slow emotional Stroop effect with the effect of the fear words carrying over to the following trial. However, Bailey, Paret, Battista and Xue (2012) showed that attachment anxiety was related to increased immediate interference, as well as delayed interference, by threat related words. They suggest that the effect was primarily due to a subset of participants with reduced top-down attentional control ability. Frings, Englert, Wentura and Bermeitinger (2010) investigated the issue of whether the emotional Stroop effect is due to fast or slow effects. They controlled the stimuli order so that fast and slow effects could be assessed separately. They found that both fast and slow effects were present. Frings et al. suggest that the results reported by McKenna and Sharma (2004) were the result of contingency learning confounds as the sequences McKenna and Sharma used were somewhat predictable.

Phaf and Kan (2007) conducted a meta-analysis of 70 emotional Stroop studies that used words as stimuli. Phaf and Kan distinguished between slow Stroop effects (subsequent neutral trial) and fast Stroop effects (current fear trial) when designing their meta-analysis. Stroop effects were reportedly the largest for anxious patients when emotional stimuli were blocked together and neutral stimuli were blocked together. The second largest Stroop effect was more modest, was again for blocked designs, but with non-clinical high anxious participants. When designs used mixed presentation methods where emotional and neutral stimuli appeared in the same block the effects were half the magnitude of those found with blocked presentation designs. For clinically anxious patients the Stroop effect was still significant. However, for non-clinically anxious participants the effect was not significant, as there were approximately as many facilitation effects as interference effects. Phaf and Kan suggest that emotional Stroop interference is reduced considerably by using mixed presentation relative to blocked presentation designs. It is also noteworthy here that all these findings were in fully conscious presentation conditions. They did not find significant Stroop effects in less conscious presentation conditions (e.g., masked conditions). Phaf and Kan suggested that the emotional Stroop effect is primarily due a slow attentional disengagement from the emotional words, as opposed to a fast automatic attentional bias towards the emotional words. They suggest that anxiety may relate more to a difficulty in disengaging from fear stimuli than to an automatic engagement with the fear stimuli.

Van Honk, Tuiten, de Haan, van den Hout and Stam (2001) used a further modified emotional Stroop task where pictures of neutral and angry faces were tinted with the colours red, yellow, blue or green. Trait anxiety was not related to an attentional bias to angry faces relative to neutral faces when naming the colours. Reinholdt-Dunne, Mogg and Bradley (2009) used a similar design but included happy and fearful faces in addition to the angry and neutral faces. High trait anxiety was related to an increased emotional Stroop effect for the emotional faces (happy, fearful and angry combined). In contrast, their word version of the emotional Stroop task elicited no anxiety-related modulation of the emotional Stroop effect. This may have been due to fatigue effects as the word task was always administered after the face task. The anxiety-related increase in the emotional Stroop effect during the face task was further modulated by a behavioural measure of attentional control; the attention network task. Participants high in trait anxiety, whose performance was poor at the attention network task, showed greater emotional Stroop effects than other participants. In the face version of the emotional Stroop task, as with the word version, there is task conflict present but no informational conflict present.

Emotional processing during Stroop tasks has recently been investigated using a further modification of the task. Zhu, Zhang, Wu, Luo and Luo (2010) showed that during an emotional face-word Stroop task that emotional congruency and incongruencey was differentiated at an early perceptual stage. Emotional words (fear and happy in Chinese) were presented over fearful and happy emotional faces. The words were either congruent or incongruent with the emotions depicted by the faces. When participants were required to respond via a key press to either emotional facial expression incongruent trials elicited a more negative N170 ERP over posterior lateral brain regions than congruent trials. Moreover, when participants were required to respond to the emotional word incongruent trials elicited a less negative N170 ERP than congruent trials. This word-face emotional Stroop design re-introduces the informational conflict back into the task, which is not present in the word colour naming emotional Stroop task, or the face-colour naming emotional Stroop task.

As discussed in chapter 2, Etkin and Schatzberg (2011) and Etkin, Prater, Hoeft, Menon and Schatzberg (2010) also used a word-face emotional Stroop task. To briefly reiterate, the Stroop effect was not related to anxiety. However, general anxiety disorder patients and normal controls displayed a similar CSE during congruent trials. Moreover, their normal controls (who were lower in trait anxiety) also displayed the predicted CSE during correct responses to the target faces in emotionally incongruent trials. Therefore, for normal controls incongruent trials that followed incongruent trials were responded to faster than incongruent trials that followed congruent trials. Clinical anxiety patients (who were higher in trait anxiety) did not display this effect.

Krug and Carter (2010) used two word-face Stroop tasks; a non-emotional gender Stroop task; and an emotional expression Stroop task using fearful and neutral faces overlaid with the words fear or neutral. In both tasks there were 70% congruent trials and 30% incongruent trials. There were slower RTs overall in the emotional task than the non-emotional task, but no differences in the magnitude of Stroop effects in the RTs, but there was a larger Stroop effect in the emotional task in the accuracy data. Trait anxiety did not modulate the Stroop effects in RTs or accuracy in either task. However, trait anxiety was positively correlated with the RT difference between incongruent trials in the emotional task. High trait anxious participants were slower to respond to neutral faces overlaid with the word fear, than fearful faces overlaid with the word neutral. However, low trait anxious participants were faster to respond to the latter stimuli type. It is noteworthy here that this comparison compares RTs during threat-related distraction with RTs during neutral distraction, and thus differs from comparing distraction (incongruent trials) to no distraction (congruent trials; i.e., the Stroop effect).

Krug and Carter (2012) used the emotional word-face Stroop task again, but this time two versions were used. In a high conflict expectancy task 65% of trials were incongruent, whereas in a low conflict expectancy task 35% of trials were incongruent. The Stroop effects in RTs and accuracy were reliably present in both tasks. Moreover, these effects were larger in the low conflict expectancy task (35% incongruent trials) than in the high conflict expectancy task (65% incongruent trials). Neither the Stroop effects, nor performance during incongruent trials (in either RTs or accuracy) were correlated with trait anxiety in either task.

Osinksky, Alexander, Gebhardt and Hennig (2010) used an emotionally neutral version of the word-face Stroop task. In this task male and female faces had the words man or woman overlaid upon them. The words were either congruent or incongruent with the gender of the faces. In this task two thirds of trials were congruent. As expected, target faces for congruent trials were responded to faster and more accurately than incongruent trials. This Stroop effect was uncorrelated with trait anxiety. Osinksky, Geghardt, Alexander and Hennig (2012) also used a word-face gender Stroop task, but with equal amounts of congruent and incongruent trials, and a smaller amount of face only and word only trials. Once again trait anxiety was uncorrelated with the Stroop effect.

The studies discussed thus far suggest that trait anxiety modulates the processing of indirect emotional distraction during colour naming Stroop tasks, but the effects of anxiety upon direct emotional conflict during word-face emotional Stroop tasks are very inconsistent. The study by Krug and Carter (2010) produced an encouraging behavioural effect that related to trait anxiety, when using a reduced proportion of incongruent trials relative to congruent trials. In contrast, the studies by Etkin and Schatzberg (2011) and Etkin et al. (2010) did not show any current trial Stroop effects that related to trait anxiety using equal amounts of incongruent and congruent trials. It is noteworthy here that the other difference between these studies is that Etkin and colleagues used happy and fearful stimuli, whereas Krug and Carter used neutral and fearful stimuli. This leaves open the question as to whether using happy and fearful stimuli, coupled with a reduced amount of incongruent trials (relative to congruent trials), would produce more robust effects than those reported by Krug and Carter. A noticeable similarity between all of these word-face Stroop studies is that none of them used neutral control trials to differentiate the effects of facilitation and interference upon the Stroop effect. This would have been particularly interesting in the studies that featured unequal proportions of congruent and incongruent trials (Krug & Carter, 2010, 2012; Osinksky et al., 2010).

In Stroop tasks increasing the proportion of congruent trials relative to incongruent trials results in an increased Stroop effect (i.e., the RT difference between congruent and incongruent trials). The traditional explanation of this 'proportion congruency effect' has been that the detection of the proportions leads to participants modulating their attention towards the word in word/colour tasks (Cheesman & Merikle, 1986; Lindsay & Jacoby, 1994). This attentional based account is referred to as the modulation account, but cannot explain some results. For example, a proportion congruent effect has been reported when high and low proportion congruent stimuli were randomly mixed in the same block. Blocks of trials contained words presented mostly in their congruent colour and also critically other words were also presented mostly in a specific incongruent colour (Jacoby, Lindsay, & Hessels, 2003). The proportion congruent effect in this study cannot be explained by participants simply attending to the words, as participants would have to have been modulating their attention to the words (i.e., attending or ignoring) in a trial by trial fashion (depending upon the word). This is not a viable explanation as it means that participants would have to decide if they attend to the word or not, after they have already read the word (Schmidt & Besner, 2008).

An alternative account was proposed by Schmidt, Crump, Cheesman and Besner (2007) which suggests that contingency learning accounts for the increase in the Stroop effect. The contingency learning account proposes that participants implicitly learn the correlations (contingencies) between the words and responses. Thus, they learn to predict the response required based upon the distracting word. Schmidt and Besner (2008) conducted several reanalyses and new experiments that supported the contingency learning account of the proportion congruency effect. They suggest that participants make speeded responses to high contingency trials based upon response predictions. They continue by proposing that participants lower a response threshold for any expected response, but not any other possible response. Thus facilitation in

RTs is evident for high contingency trials relative to medium contingency trials (which would be chance level contingency trials), but no interference in RTs is evident in low contingency trials relative to medium contingency trials (chance level contingency trials). The contingency learning account also predicts increased facilitation in accuracy for high contingency trials. Critically, this account also predicts increased interference resulting in reduced accuracy for low contingency trials. This is due to the response threshold being lowered for the word when it was predictive.

Levin and Tzelgov (2016) recently showed that contingency learning is not a function recruited by the cognitive control system in order to overcome conflict, but is an independent function that can operate in parallel with the cognitive control processes. This suggests that trait anxiety related conflict effects may be present with or without significant anxiety-related contingency learning effects, or vice-versa. Moreover, response conflict and contingency learning are not the only variables that can affect information processing in situations of goal conflict.

It is well known that people slow their responses following the commission of an error (Rabbitt & Rodgers, 1977). Post-error slowing during RT tasks has been explained as a strategic adaptation in control that enhances task performance (Botvinick, Braver, Barch, Carter, & Cohen, 2001). In contrast, it has been reported that post-error slowing does not always facilitate enhanced task performance (Danielmeier & Ullsperger, 2011). An alternative account proposed by Notebaert et al. (2009) suggests that errors are salient but infrequent occurrences. From this perspective, when an error occurs this activates an orienting response that directs attention away from the current task. This orienting response therefore hinders subsequent stimuli processing. This account therefore offers a non-functional explanation. Another non-functional account of post-error slowing, referred to as the bottleneck account, suggests that error detection occupies time and resources and thus interferes with goal directed behaviour (Dudschig & Jentzsch, 2009; Jentzsch & Dudschig, 2009). Houtman and Notebaert (2013) designed an experiment that dissociates between the two accounts which suggested that the bottleneck account was a better explanation. However, they also suggested that it is possible that both attentional orienting, and performance monitoring, are part of a combined mechanism that mediates post-error slowing. Whatever the mechanism behind the effect, committing an error is suggested to be an aversive experience (Hajcak & Foti, 2008). It is easy to see how any neural or cognitive response that facilitates the slowing down of responses after an 'aversive' error, could reflect the activity of a survival circuit as proposed by LeDoux (2012).

Research suggests that error commission increases activity of the autonomic nervous system and thus increases arousal, which primes reflexive defence mechanisms (Hajcak & Foti, 2008; Hajcak, McDonald, & Simons, 2003b; Wessel, Danielmeier & Ullsperger, 2011). Therefore, intuitively one might expect anxiety to modulate post-error slowing. However, several studies show this not to be the case (e.g., Hajcak McDonald, & Simons, 2003a; Weinberg, Olvet, & Hajcak, 2010). Van der Borght, Braeme, Stevens and Notebaert (2016) predicted that trait anxiety should modulate post-error behaviour during a Simon task. Trait anxiety was unrelated to post-error slowing, but did modulate post error accuracy. There was a negative correlation between the post-error accuracy increase and trait anxiety, but only with a long inter-trial interval (ITI), but not with a short or medium length ITI. We suggest that further research is required to determine whether emotional goal conflict activates the post-error slowing mechanisms in high anxiety.

3.2. Purpose of experiment 2

This chapter aims to answer three questions concerning individual differences in the cognitive control of emotional conflict during a word-face emotional Stroop task. Firstly, we wished to clarify how trait anxiety affects performance at this task. Secondly, considering the relationships discussed in chapter 1, we wished to clarify how both trait anxiety and Stroop task performance are affected by individual differences in self-reported attentional control. Thirdly, we wished to clarify how trait anxiety and self-reported attentional control affect behaviour following a performance error.

The first question this experiment addresses is how trait anxiety (measured by the STAI; Spielberger et al., 1983) relates to the processing of emotional conflict in an emotional word-face Stroop task. Krug and Carter (2010) showed that trait anxiety affected the processing of infrequent incongruent trials, whereas their (2012) study did not replicate this finding. Etkin and colleagues (2010, 2011) did not report any current trial Stroop effects that related to anxiety using equal proportions of incongruent and congruent trials. The stimuli used by Etkin and colleagues represented two different emotions (i.e., happy versus fear words/faces), whereas the stimuli used by Krug and Carter consisted of one neutral stimulus type, and one emotional stimulus type (i.e., neutral versus fear words/faces). In short, none of these designs combined two conflicting emotional stimulus types with infrequent incongruent trials.

We used a two emotion (happy versus fear) word-face Stroop task, with a contingency biased design with infrequent emotional conflict trials (i.e., 17% incongruent trials). We included neutral word trials to help elucidate the contribution of both facilitation effects and interference effects, to the Stroop effect. Thus, we could determine whether trait anxiety differentially modulated any interference effects or facilitation effects. We predicted that trait anxiety would impair cognitive performance during rare incongruent trials, resulting in either slower RTs or reduced accuracy, or even an increased Stroop effect. This prediction is based upon the suggestion that that high anxiety is related to increased cognitive interference which can be experienced as distraction (Eysenck et al., 2007). We predicted that this effect would be magnified for incongruent trials consisting of happy faces overlaid with the word “fear” as, according to Eysenck et al., distraction would be increased in high anxious individuals, when distracting stimuli are threat-related. Indeed, as discussed in detail in the introduction of this thesis, several other cognitive perspectives on anxiety have proposed that anxiety relates to the automatic detection of threat-related stimuli (Bar-Haim et al., 2007; Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Ohman, 1996; Williams, Watts, MacLeod, & Mathews, 1988).

The design of this Stroop task is identical to our flanker task used in experiment 1 (chapter 2). The script that ran the experiment was exactly the same, except the stimuli were changed. Thus, we can ascertain if the two tasks are in any way similar, as far as the detection of anxiety effects goes. In short, in the Stroop task a happy or fearful face is the equivalent of the central happy or fearful face in the flanker task. In the Stroop task the word is the distractor, which is the equivalent of the flanker faces in the outer eight squares in the grid of faces that we used in the flanker task.

Thus, in both tasks the distractors can be incongruent or congruent with the target face stimulus. The neutral word trials in the Stroop task are broadly equivalent to the single face trials used in the flanker task as there is no emotional distraction present. However, the neutral word trials do differ from the single face trials used in the flanker task as they contain a neutral distractor, and serve a slightly different purpose as described above.

The second question this experiment addresses is how do individual differences in self-reported attentional control relate to trait anxiety and Stroop performance. Here we mainly focus upon the sub-factors of the attentional control scale as opposed to the total scores. We aimed to clarify if either of the two sub-factors discussed in chapter 1 (i.e., attentional focusing and attentional shifting) is a better predictor of trait anxiety than the other. We aimed to clarify if either of them mediates the relationship between trait anxiety and behavioural performance. We aimed to elucidate whether either sub-factor modulates any of the key behavioural effects independently of trait anxiety.

The third question this experiment addresses is whether post-error slowing is affected by trait anxiety in an emotional conflict situation, and whether self-reported attentional control is related to post-error slowing.

3.3. Method

3.3.1. Participants

Participants (20 of whom also completed experiment 1) with no reported history of neurological disorder (N = 77, 62 female) were recruited from Goldsmiths, University of London, and had a mean age of 23.4 (SD = 7). Of these, 68 were right handed and 35 were psychology 1st year undergraduates recruited via an online research participation scheme who took part in return for course credit. The rest were paid £5, and were recruited via advertisements placed around the campus; they were therefore students or staff from other departments. All gave informed written consent in accordance with standard ethical guidelines. This study was approved by the

Goldsmiths psychology departments' ethics committee (approval received 24/10/2012).

Here we can make a sample size and power calculation based upon the word/face Stroop task study by Krug and Carter (2010). They reported that anxiety correlated at 0.4 with the RT difference between incongruent fearful and incongruent neutral trials. Thus, 46 participants should allow 80% power for a two-tailed test at p=0.05, for a correlation of 0.4. They also reported effects of anxiety on the sequential cI trials. Thus, we can make a sample size and power prediction based upon these 0.3 correlations between anxiety and responses to the cI trials. 82 participants should allow 80% power for a two-tailed test at p=0.05, for a correlation of 0.3. We thus aimed for approximately 80 participants in this study.

3.3.2. Psychometric measures

Trait anxiety was assessed with the trait anxiety subscale of the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983). Attentional control was assessed with the Attentional Control Scale (Derryberry & Reed, 2001, 2002). We also used attentional focusing and attentional shifting sub-scales which were predicated on the sub-factors identified by Olafsson et al. (2011). Olafsson et al. reported that nine items loaded on factor 1, whereas ten items loaded on factor 2. One item (question 9) did not load on either factor. The attentional focusing sub-scale thus consisted of 9 items (items 1-8 and item 12). The attentional shifting sub-scale consisted of 10 items (items 10, 11, and 13-20).

3.3.3. Stimuli

The emotional faces used to create the Stroop stimuli were obtained from a standardised face stimuli set developed for research (NimStim; Tottenham et al., 2009). The overall picture dimensions were 65mm high and 53 mm wide (when presented using MATLAB version R2006a on a 15.5 inch laptop screen). The laptop was running Windows XP, and we used the Psychophysics Toolbox version 3 for precision RT measurement. Two face stimulus sets were created using one male, and one female in each set. This was an attempt to control for the effects of the gender of the face. Congruent stimuli were created by placing the word “fear” or “happy” across the nose of the fearful or happy faces, so that the mouths and eyes were not obscured. Incongruent stimuli were created in the same way except the emotion words were placed over the opposite emotional face. Neutral stimuli were created by placing neutral words (bowl or cellar) over both emotional face types. Figure 3.1 shows one of the sets of emotional face/word Stroop stimuli.

Figure 3.1: An example of one of the sets of emotional face/word Stroop stimuli (the emotion of the face is the target and the word is the distractor). Clockwise from top left: congruent fear; incongruent fear; neutral fear; congruent happy; incongruent happy; neutral happy.

3.3.4. Procedure

Participants were told that they would be presented with two short facial emotion recognition tasks with a short rest in-between (i.e., one task with a male face and one task with a female face, as described above). Participants were asked to sit as close to the screen as was comfortable for their eyes (typical viewing distance was approximately 70 cm). The task instructions were presented on the screen. To start each task the first screen instructed participants that they would have to judge the emotional expression showing on photos of happy or fearful faces. Participants were then shown examples of the various stimulus combinations they might see and reminded to concentrate on the face and ignore the words. They were told to rest their index fingers over the responses keys (z and /) and to respond as fast as possible while maintaining high accuracy levels. They were verbally told that a high pitched tone following a response indicates a correct response, whereas a low pitched tone following a response indicates an incorrect response.

The experimental stimuli were displayed until a response key was pressed. Unbeknown to the participants, at the beginning of each task, there were two of each neutral and incongruent trials, and 8 of each congruent trial included as practice trials; these 24 trials were discarded and not analysed. The main experimental stimuli that followed consisted of 40 neutral trials, 40 incongruent trials and 160 congruent trials (in each of the two tasks). The modified Stroop task was designed primarily to elicit RT effects as opposed to errors. The trial type sequence was created using a random number generator function in Matlab, and was the same for all participants. We kept the sequence the same for all participants as this is an individual differences study, and we wanted as few uncontrolled variables as possible to vary across participants. We also used the same trial type sequence for each of the tasks. There were 240 non-practice trials in total in each task so we felt that there was no chance that using the same sequence in each task would cause any learning of the sequence of trial types and, as noted below, we counterbalanced the order of the 2 tasks across participants. Each task lasted for approximately ten minutes. The sequence of the 2 tasks was counterbalanced across participants. The left/right finger response key mappings were also counterbalanced.

3.3.5: Data analysis

RTs will be analysed using ANCOVA with factors of trial type and emotion, with standardised trait anxiety included as the covariate.

The effect of trial type will allow us to test how the differing types of distracting words affect the discrimination of the target faces. The effect of the covariate here will show if anxiety modulates (correlates with) the overall distraction effect. The effect of emotion on the effect of trial type will allow us to test whether the distraction effects differ when happy vs. fearful faces are used as targets. The effect of the covariate here will allow us to test whether anxiety modulates (correlates with) the difference in distraction effects across these 2 emotion conditions. We also planned to repeat the main analyses with the accuracy data.

We then conducted a planned further RT analysis to investigate the congruency sequence effects (CSE). The RT data were analysed using ANCOVA with factors of current trial type and previous trial type: (in)congruency repetition/alternation, with standardised trait anxiety included as the covariate. The key effect of interest in this sequential analysis is the (in)congruency repetition/alternation effect (which tests the RT difference between trials when the level of (in)congruency repeats relative to when it alternates; i.e., the CSE). The critical effect here is the covariate interaction with the CSE which will reveal if anxiety modulates (correlates with) the size of the CSE. These effects therefore test our hypothesis that anxiety will relate to a difference in how conflict resolution is achieved (as indexed by the CSE).

We also planned to conduct further analyses concerning how trait anxiety relates to attentional shifting and attentional focusing, and how these attentional traits relate to any RT effects that relate to trait anxiety. We also planned an analysis of post error behaviour.

3.4. Results

3.4.1. Psychometric assessments

In this sample participants' trait anxiety scores, as measured by the STAI trait version, ranged from 20 to 70 (mean: 42, SD: 10). Participants' attentional control scale scores ranged from 33 to 71 (mean: 50, SD: 8). When the attentional control subscales were analysed separately, attentional focusing scores ranged from 13 to 36 (mean: 22, SD: 5). Attentional shifting scores ranged from 17 to 36 (mean 26, SD: 4).

3.4.2. Reaction times

Including all participants the experiment contained 36000 responses in total. 34732 of these were correct responses. Correct responses ranged from 79 msecs to 6085 msecs. RT outliers for correct responses were removed if RTs < 250 msecs and RTs > 1000 msecs. Of these 793 were where RT > 1000msecs, and 70 were where RT < 0.250 msecs. Thus, 863 correct responses were removed. Thus, 2.48 % of correct response trials were excluded.

863 / 34732 * 100

The RT data for correct trials (excluding trials with RTs < 250 msecs and RTs > 1000 msecs) were first subjected to a repeated measures 3 x 2 ANCOVA with factors of trial type (congruent versus neutral versus incongruent) and emotion (fearful face versus happy face) with standardised trait anxiety as the covariate. RTs for all trial types are shown in Figure 3.2. The mean RTs, 95% confidence intervals and standard errors for each of the 6 stimulus types are shown in Table 3.1.

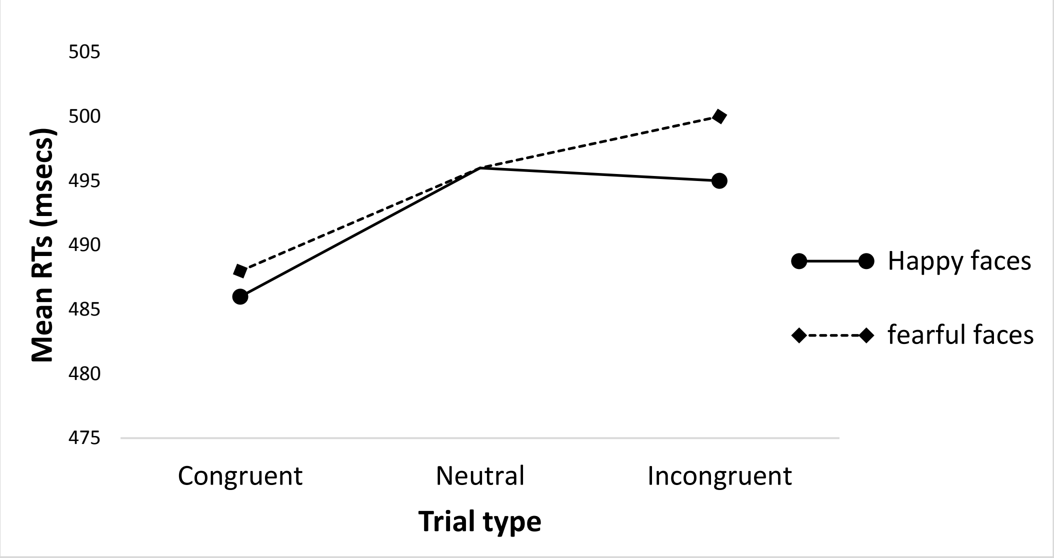

Figure 3.2: Mean RTs for each of the stimulus types.

Table 3.1: Mean reaction times, 95% confidence intervals (95%CI) and standard errors of the mean (SE) for each stimulus type. All are given in milliseconds.

Happy target faces				**Fearful target faces**			
Trial type	**Mean RT**	**95% CI**	**SE**	**Trial type**	**Mean RT**	**95% CI**	**SE**
Congruent	486	472-499	7	**Congruent**	488	574-502	6
Neutral	496	481-511	7	**Neutral**	496	583-512	7
Incongruent	495	479-511	8	**Incongruent**	500	484-516	8

The test of between-subjects effects was significant ($F[1,72]=6.45$ $p=0.01$, $\eta^2=0.082$), indicating that anxiety was significantly correlated with RTs across the whole experiment (the corresponding correlation value was $r = -0.3$). This negative relationship is shown in Figure 3.3. This finding was unexpected therefore we confirmed that this negative correlation was present for both target fearful faces ($r= -0.29$, $p=0.012$), and with target happy faces ($r= -0.31$, $p=0.007$) considered separately. These correlations are significant at an adjusted significance level of 0.025.

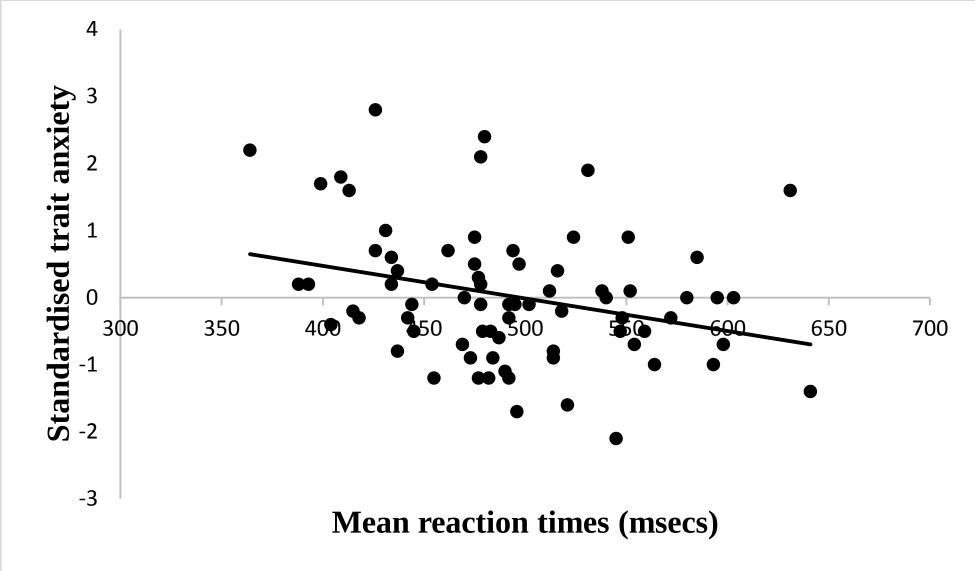

Figure 3.3: The negative correlation (r= -0.3) between standardised trait anxiety and mean RTs.

The test of within-subjects effects showed that the main effect of trial type was significant (*F*[2,144]=15.1, $p<0.001$, $\eta^2=0.17$) as RT congruent (mean 487 msecs; 95% CI 474-500; SE 7) < RT incongruent (mean 497 msecs; 95% CI 482-513; SE 8) = RT neutral (mean 497 msecs; 95% CI 482-511; SE 7). The critical finding here was that trait anxiety did not modulate the main effect of trial type (*F*[2,144]=1.6, $p=0.21$, $\eta^2=0.022$). This effect is critical to our main hypothesis that anxiety would relate to increased distraction.

The effect of emotion was also non-significant (*F*[1,72]=1.23, $p=0.27$, $\eta^2=0.017$; mean RT for happy faces 489 msecs; 95% CI 475-503; SE 7; mean RT for fearful faces 491 msecs; 95% CI 477-505; SE 7). Critically the effect of emotion did not interact with anxiety (*F*[1,72]=0.13, $p=0.72$, $\eta^2=0.002$). The effect of trial type did not further interact with emotion (*F*[2,144]=0.46, $p=0.63$, $\eta^2=0.006$; see Figure 3.2), and there was no significant three way interaction between trial type, emotion and anxiety (*F*[2,144]=0.29, $p=0.75$, $\eta^2=0.004$).

We conducted three planned comparisons to clarify the main effect of trial type using an adjusted significance level of 0.05/3. A one-way ANCOVA with standardised trait anxiety as the covariate showed that congruent trials were responded to significantly faster than incongruent trials (*F*[1,72]=22.1, $p<0.001$,

η^2=0.235). This effect was unrelated to anxiety (F[1,72]=0.09, p=0.76, η^2=0.001). This confirms that anxiety was uncorrelated with the Stroop effect (incongruent RT minus congruent RT), which relates to one of our main hypotheses. Our next one-way ANCOVA with standardised trait anxiety as the covariate showed that congruent trials were responded to significantly faster than neutral trials (F[1,72]=25.9, p<0.001, η^2=0.265). This effect was unrelated to anxiety (F[1,72]=2.3, p=0.13, η^2=0.031). This confirms that anxiety was uncorrelated with the facilitation effect (neutral RT minus congruent RT). Our final one-way ANCOVA with standardised trait anxiety as the covariate showed that incongruent trials were not responded to significantly slower than neutral trials (F[1,72]=1.4, p<0.711, η^2=0.002). This comparison was unrelated to anxiety (F[1,72]=2.6, p=0.112, η^2=0.035). This confirms that anxiety was uncorrelated with the interference effect (incongruent RT minus neutral RT).

3.4.3. Further RT analysis: Congruency sequence effects

In order to analyse the CSEs the RT data were subjected to a 2 (current trial type; congruent versus incongruent) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) repeated-measures ANCOVA with standardised trait anxiety as the covariate. We will denote 4 key types of trials within this analysis thus: incongruent trials preceded by incongruent trials (iI); incongruent trials preceded by congruent trials (cI); congruent trials preceded by congruent trials (cC); and congruent trials preceded by incongruent trials (iC). Each of these trial types are averaged across target emotion (e.g., happy incongruent trials and fearful incongruent trials are averaged, and the same for the congruent trials). The effects of the previous trial's congruence upon the RT congruence effect on the subsequent trial, often referred to as CSEs, thus appear in the analyses as the effect of (in)congruency repetition/alternation.

The critical findings in this analysis were that the main effect of (in)congruency repetition versus (in)congruency alternation was highly significant (F[1,72]=28.2, p<0.001, η^2=0.28), as repetition trials (mean RT 479 msecs; 95% CI 464-493; SE 7) were responded to faster than alternation trials (mean RT 492 msecs; 95% CI 477-

507; SE 7). This effect did not interact with anxiety (*F*[1,72]=0.21, p=0.646, η^2=0.003). This interaction tests the correlation between anxiety and the RT difference between alternation trials and repetition trials. The correlation value was r=0.05. This comparison relates directly to our main interest in how anxiety relates to conflict resolution and the CSE. There was, however, a near significant 3-way interaction between trial type, (in)congruency repetition/alternation, and trait anxiety (*F*[1,72]=3.71, p=0.058, η^2=0.049). There were no other significant effects/interactions (all *F*s < 1.3, all *p*s >0.2). As the aforementioned 3-way interaction approached significance, we explored it by running correlations between trait anxiety and the CSE for congruent trials (i.e., the RT difference iC – cC), and incongruent trials (i.e., the RT difference cI – iI), separately. Trait anxiety was not significantly correlated with the CSE during congruent trials (r= -0.19, p=0.098), or incongruent trials (r= 0.15, p=0.2), at an adjusted significance level (0.05/2). In summary, trait anxiety was not significantly related to the CSE in the RT data. However, it is noteworthy here that the near significant 3-way interaction reported above shows that the relationship between anxiety and the CSE was near-significantly different for congruent compared to incongruent trials, even though it was not significant for either trial type considered separately.

3.4.4. Accuracy analysis

We then analysed the proportion correct for each of the trial types (excluding trials with RTs < 250 msecs and RTs > 1000 msecs) using a 3 x 2 ANCOVA with factors of trial type (congruent versus neutral versus incongruent) and emotion (fearful face versus happy face) with standardised trait anxiety as the covariate. Proportion correct for all trial types are shown in Figure 3.4. The mean proportion correct, 95% confidence intervals and standard errors for each of the 6 stimulus types are shown in Table 3.2.

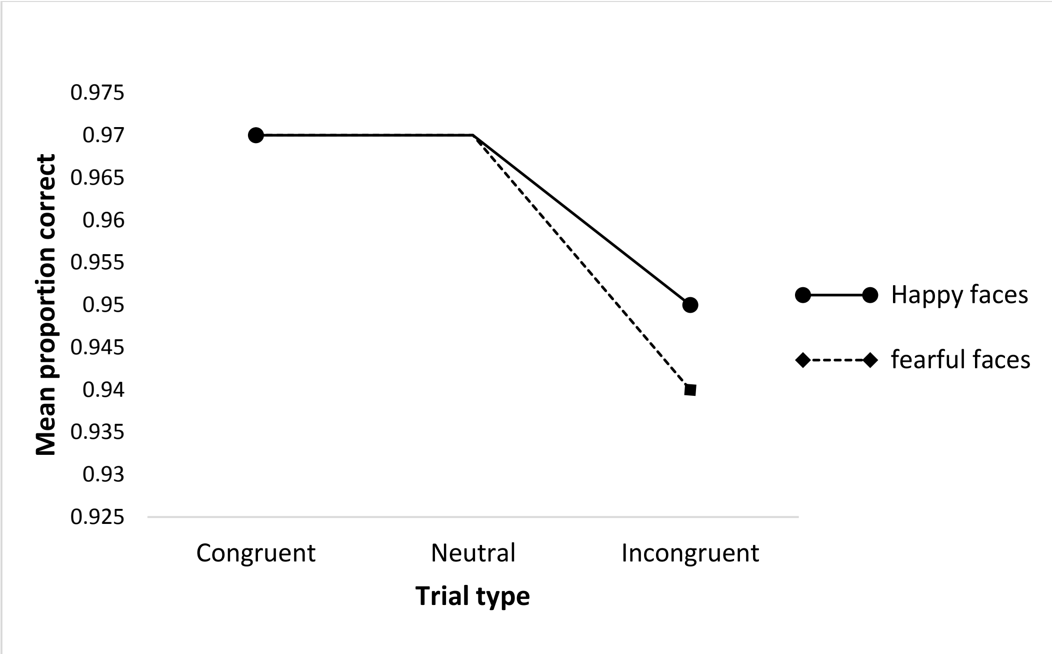

Figure 3.4: Mean proportion correct for each of the stimulus types.

Table 3.2: Mean proportion correct (Prop/C), 95% confidence intervals (95%CI) and standard errors of the mean (SE) for each stimulus type.

Happy target faces				Fearful target faces			
Trial type	**Prop/C**	**95% CI**	**SE**	**Trial type**	**Prop/C**	**95% CI**	**SE**
Congruent	0.97	0.97-0.98	0.003	**Congruent**	0.97	0.96-0.97	0.004
Neutral	0.97	0.96-0.97	0.004	**Neutral**	0.97	0.97-0.98	0.004
Incongruent	0.95	0.93-0.96	0.007	**Incongruent**	0.94	0.92-0.95	0.007

As with the RT analysis, the test of between-subjects effects was significant (F[1,72]=4.79 p=0.032, η^2=0.062), indicating that anxiety was significantly correlated with proportion correct across the whole experiment (the correlation value was r = -0.25). Thus, the overall speeding in RTs by high anxious participants also seemed to result in an overall reduction in accuracy. This negative relationship is shown in Figure 3.5. This finding was unexpected therefore we followed up this test by verifying whether average proportion correct for fear targets and for happy targets were each implicated in this anxiety-related reduction in accuracy. Here, we adopt an adjusted significance level of 0.025. Correlational analysis showed that anxiety negatively and significantly correlated with proportion correct for fear trials overall (r= -0.29, p=0.013), but did not significantly correlate with proportion correct for happy trials overall (r= -0.16, p=0.185). We wished to determine which of the fear trials were driving the anxiety and overall fear trial correlation. We ran three separate exploratory correlations between anxiety and the proportion correct for the three fearful face trial types (i.e., incongruent, neutral and congruent), using a further adjusted significance level (0.025/3). Anxiety correlated with the proportion correct for incongruent fear trials (r= -0.28, p=0.017; see Figure 3.6), although this was above the further adjusted criterion for statistical significance. The anxiety relationship with the proportion correct was not anywhere near significant for neutral fear trials (r= -0.170, p=0.149), or congruent fear trials (r= -0.174, p=0.138).

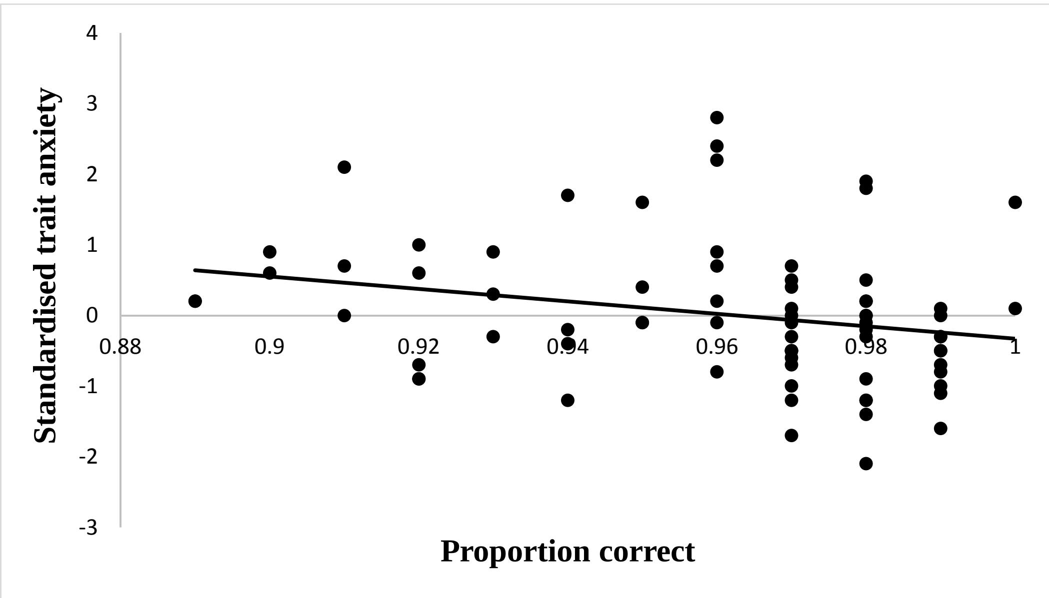

Figure 3.5: The negative correlation (r= -0.25) between standardised trait anxiety and overall accuracy.

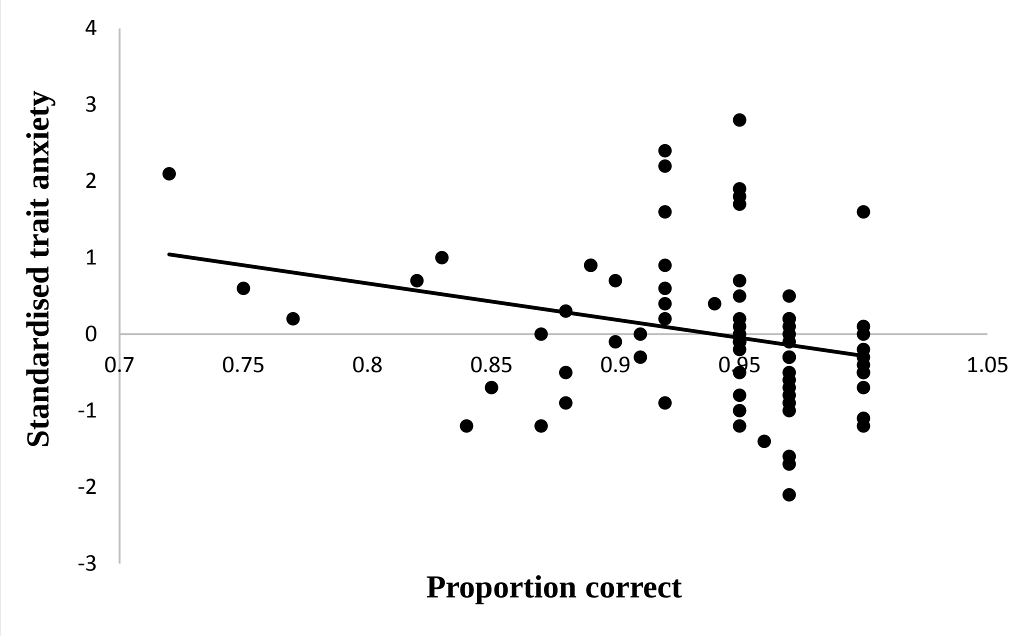

Figure 3.6: The negative correlation (r= -0.28) between standardised trait anxiety and accuracy for incongruent fear trials.

The test of within-subjects effects showed that the main effect of trial type was significant (*F*[2,144]=24.6, $p<0.001$, $\eta^2=0.255$), as mean proportion correct incongruent (0.94; 95% CI 0.93-0.95; SE 0.006) < mean proportion correct congruent (0.97; 95% CI 0.96-0.98; SE 0.003) = mean proportion correct neutral (0.97; 95% CI 0.96-0.98; SE 0.003). The critical finding here was that trait anxiety modulated the trial type effect (*F*[2,144]=3.0, $p=0.054$, $\eta^2=0.040$) at a near significant level. This suggests that anxiety is related to the difference in accuracy between two or more of the trial types. This effect relates to our hypothesis that anxiety would relate to increased distraction (although we initially predicted the effect would be reflected in RTs not accuracy). However, there was no significant main effect of emotion (*F*[1,72]=1.06, $p=0.307$, $\eta^2=0.014$; mean proportion correct for happy faces 0.96; 95% CI 0.96-0.97; SE 0.004; mean proportion correct for fearful faces 0.96; 95% CI 0.95-0.97; SE 0.004). Thus, accuracy levels did not differ between happy target trials and fearful target trials. Critically the effect of emotion did not interact with anxiety (*F*[1,72]=1.70, $p=0.194$, $\eta^2=0.023$). This non-significant emotion versus anxiety interaction shows that anxiety did not correlate with any difference in accuracy between happy and fearful target trials. The effect of trial type significantly interacted with emotion (F[2,144]=4.74, p=0.010, η^2=0.062), but there was no significant three way interaction between trial type, emotion and anxiety (F[2,144]=0.30, p=0.74, η^2=0.004).

We followed up the trial type effect using three one-way ANCOVAs with standardised trait anxiety as the covariate. Here we adopt an adjusted significance level of 0.05/3. A traditional Stroop effect (congruency effect) was evident as congruent trials were responded to more accurately than incongruent trials (F[1,72]=27.2 p<0.001, η^2=0.274). Trait anxiety was related to this difference in accuracy but only at a weak trend level (F[1,72]=3.67 p=0.059, η^2=0.048). The sign and value of the Stroop effect versus anxiety correlation was r=+0.22. Thus, as anxiety increased so did the Stroop effect. Again, this effect relates to our hypothesis that anxiety would modulate distraction. Congruent trials were not responded to significantly more accurately than neutral trials (F[1,72]=0.10 p=0.749, η^2=0.001), and this comparison did not interact with anxiety (F[1,72]=0.37 p=0.543, η^2=0.005). Therefore, there were no facilitation effects in the accuracy data. However, responses to neutral trials were more accurate than responses to incongruent trials, indicating the presence of an interference effect (F[1,72]=27.56 p<0.001, η^2=0.277). This interference effect was not significantly related to anxiety (F[1,72]=2.85 p=0.096, η^2=0.038).

As the anxiety and trial type analyses focus upon the difference between trial types we wished to determine if anxiety correlated with accuracy during each of the 3 trial types separately. Trait anxiety was related to reduced accuracy for incongruent trials (r= -0.26, p=0.024). This effect relates to our hypothesis that anxiety would modulate distraction. However, this result should be judged against an adjusted significance level of 0.025/3. Anxiety was not significantly correlated with accuracy to congruent trials (r= -0.12, p=0.307) or neutral trials (r= -0.17, p=0.144). Clearly the effect of anxiety is weak, but numerically the strongest action is upon incongruent trials in this analysis, in keeping with the previous exploratory correlations which showed the relationship is driven mostly by the incongruent fearful trials.

We followed up the trial type versus emotion interaction using six one-way ANCOVAS with standardised trait anxiety as the covariate and the adjusted significance level of 0.05/6. Congruent fear trials were responded to more accurately than incongruent fear trials (F[1,72]=22.34 p<0.001, η^2=0.237). This comparison was not significantly related to anxiety (F[1,72]=2.81 p=0.098, η^2=0.038). Accuracy during congruent fear trials was similar to neutral fear trials (F[1,72]=2.73 p=0.103, η^2=0.037). This comparison was not significantly related to anxiety (F[1,72]=0.015 p=0.903, η^2<0.001). Neutral fear trials were responded to more accurately than neutral incongruent trials (F[1,72]=32.08 p<0.001, η^2=0.308). However, this comparison was not significantly related to anxiety (F[1,72]=2.92 p=0.092, η^2=0.39).

Congruent happy trials were responded to more accurately than incongruent happy trials (F[1,72]=17.23 p<0.001, η^2=0.193). This comparison was not significantly related to anxiety (F[1,72]=2.50 p=0.118, η^2=0.034). Congruent happy trials were responded to more accurately that neutral happy trials (F[1,72]=6.24 p=0.015, η^2=0.80) at a trend level. This effect was unrelated to anxiety (F[1,72]=1.11 p=0.296, η^2=0.015). Neutral happy trials were also responded to more accurately than incongruent happy trials (F[1,72]=8.51 p=0.005, η^2=0.106), but this effect was unrelated to anxiety (F[1,72]=1.114 p=0.295, η^2=0.015).

3.4.5. Further accuracy analysis: Congruency sequence effects

In order to analyse the CSEs and proportion correct, the data were subjected to a 2 (current trial type; congruent versus incongruent) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) repeated-measures ANCOVA with standardised trait anxiety as the covariate. Only trials where current trial and previous trial were correct are included here (i.e., excluding trials with RTs < 250 msecs and RTs > 1000 msecs). The critical findings in this analysis were that the main effect of (in)congruency repetition versus (in)congruency alternation was highly significant (F[1,72]=31.97, p<0.001, η^2=0.31), as repetition trials (mean proportion correct 0.97; 95% CI 0.97-0.98; SE 0.004) were responded to more accurately than alternation trials (mean proportion correct 0.95; 95% CI 0.94-0.96; SE 0.004), but this effect did not interact with anxiety (F[1,72]=2.21, p=0.141, η^2=0.03). Thus, anxiety was not significantly correlated with the difference in accuracy between these trials. The correlation value was r= -0.17. There was a significant trial type versus (in)congruency repetition/(in)congruency alternation interaction ($F[1,72]=9.51$, $p=0.003$, $\eta^2=0.12$), as the congruency repetition advantage in accuracy was larger for incongruent trials than congruent trials. However, there were no other significant effects/interactions (all *F*s < 2.4, all *P*s > 0.1).

3.4.6. Attentional control

We also ran further planned analyses concerning how trait anxiety relates to attentional shifting and attentional focusing, and how these attentional traits relate to any RT effects that relate to trait anxiety. The overall attentional control score negatively correlated with trait anxiety ($r= -0.35$, $p=0.002$). Attentional shifting and attentional focusing were positively correlated ($r= 0.54$, $p<0.001$). When controlling for attentional shifting, trait anxiety was not significantly correlated with attentional focusing ($r= -0.131$, $p=0.267$). The zero-order correlation value was $r= -0.29$, $p=0.012$. When controlling for attentional focusing, trait anxiety was not significantly correlated with attentional shifting ($r= -0.23$, $p=0.045$) using an adjusted (0.05/2) significance level. However, the zero-order correlation value was $r= -0.344$, $p=0.003$. This suggests that it is the shared variance of attentional focusing and shifting that drive the bulk of the attentional control correlation with trait anxiety.

We therefore determined whether the overall scores on the attentional control scale showed any sign of a relationship with the key effects that related to trait anxiety. Conversely to trait anxiety, overall attentional control was unrelated to the overall RTs ($r= 0.162$, $p=0.17$) and also proportion correct ($r= 0.116$, $p=0.329$). We confirmed that the key trait anxiety correlations remained stable after controlling for overall scores on the attentional control questionnaire. When controlling for variations in overall attentional control, trait anxiety still significantly correlated with overall RTs ($r= -0.312$, $p=0.008$), overall proportion correct ($r(69)= -0.282$, $p=0.017$), and proportion correct for incongruent fear trials ($r= -0.353$, $p=0.003$).

3.4.7. Speed-accuracy trade-off

A reliable speed accuracy trade-off was present, as overall RTs correlated positively with overall proportion correct (r= 0.39, p=0.001). As trait anxiety was significantly correlated with both an overall decrease in RTs, and an overall decrease in accuracy, we considered that this was likely to reflect an anxiety related speed-accuracy trade-off. To verify this we correlated trait anxiety with the overall proportion correct across the experiment whilst controlling for overall RTs. When partialling out the effects of RTs, trait anxiety was no longer significantly correlated with proportion correct (r= -0.15, p=0.20). Moreover, the correlation between trait anxiety and RTs was no longer reliable when controlling for accuracy (r= -0.22, p=0.06). We suggest that these partial correlations indicate a speed-accuracy trade-off that is partly mediated by anxiety.

3.4.8. Post-error behaviour

We also ran a planned analysis of post error behaviour. It is noteworthy here that the traditional method of calculating the post-error slowing index has recently been shown to contain subtle confounds that could render the index inaccurate (Dutilh et al., 2012). Dutilh et al. showed that fluctuations in performance across the duration of RT tasks can lead to the illusion of spurious post-error slowing effects (or the lack of them), when using the traditional measure (post-error RT minus post-correct RT). They showed that using their robust measure (post-error RT minus pre-error RT) alleviates this confound.

We used the robust post-error slowing index proposed by Dutilh et al. (2012; post-error RTs minus pre-error RTs). This index is the difference between mean RTs for trials immediately after an error, and mean RTs for trials immediately before an error. We examined these effects for correct responses only, but without imposing any minimum or maximum RT constraints. A one-way ANCOVA (averaged pre-error RTs versus averaged post-error RTs) with standardised trait anxiety as the covariate was highly significant (F[1,67]=101.4 p<0.001, η^2=0.602). Thus, averaged post-error trials were responded to significantly slower (mean RT 730 msecs; 95% CI 723-734; SE 2) than averaged pre-error trials (mean RT 500 msecs; 95% CI 498-502; SE 1). Trait anxiety did not significantly interact with this effect (F[1,67]=0.3

p=0.58, η^2=0.005). This interaction shows that trait anxiety was not correlated with the robust post-error slowing index (the correlation value was -0.07). Out of theoretical interest, and for comparison with other published work we also computed the traditional post-error slowing index (averaged correct RT following error – averaged correct RT following correct response), in order to confirm that trait anxiety was not correlated with this effect either (the correlation value was also -0.07).

When controlling for attentional focusing, robust post-error slowing was not correlated with attentional shifting (r= -0.154, p=0.211). The zero-order correlation value was r= 0.004, p=0.973. However, when controlling for attentional shifting, robust post-error slowing was positively correlated with attentional focusing (r= 0.276, p=0.023). The zero-order correlation value was r= 0.233, p=0.055. We also confirmed that the overall attentional control questionnaire scores would not have correlated with post-error slowing, had we chosen to use the total instead (r= 0.147, p=0.228).

We were also interested in the differences in the proportion correct for trials that followed correct responses relative to trials that followed incorrect responses. We also wished to determine if trait anxiety was related to any differences between these proportions correct. A one-way ANCOVA (averaged proportion correct following correct responses versus averaged proportion correct following incorrect responses) with standardised trait anxiety as the covariate was not significant (F[1,68]=3.4 p=0.071, η^2=0.047). Post-error proportion correct was 0.97, whereas post correct response proportion correct was 0.96. Trait anxiety did not interact with this null effect (F[1,68]=0.001 p=0.98, η^2<0.001). Therefore there were no anxiety modulation of differences in response accuracy based on whether the previous trials response was an error or not.

3.5. Discussion

We used a word-face emotional Stroop task which produced a robust RT congruency effect and RT facilitation effect, but no RT interference effect. Our accuracy analysis showed a robust congruency effect, robust interference effect, but no facilitation effect. Our RT data lends some support to the contingency learning theory proposed by Schmidt et al. (2007) and Schmidt and Besner (2008), which predicts that the RT Stroop effect (congruency effect) in contingency biased designs (i.e., those including predominantly congruent trials) will be driven mainly by facilitation not interference. Our accuracy data only partially supports the contingency learning account, as although the expected interference effects were found, the expected facilitation effects were not found. In other words, we found reduced accuracy for incongruent trials relative to neutral trials, but no increase in accuracy for congruent trials relative to neutral trials. However, Schmidt and Besner used equiprobable contingency trials (50% Incongruent and 50% congruent) to compare to high and low contingency trials (and thus separate facilitation and interference effects differently). In contrast, we used neutral word trials (in the same proportion as incongruent trials) that were not predictive or emotionally conflicting.

In the present study, the effect of trait anxiety predicted overall for incongruent trials, was not found for RTs, but was marginally present for accuracy. The critical finding here was that trait anxiety did not modulate the overall Stroop effect (i.e., the RT difference between congruent and incongruent trials). Moreover, trait anxiety did not modulate the overall RT facilitation effect, or the overall RT interference effect. Trait anxiety was related to the overall Stroop effect present in the accuracy data, but at a weak trend level. As trait anxiety increased so did the Stroop effect. However, neither the overall facilitation effect in accuracy nor the overall interference effect in accuracy were significantly related to anxiety. Thus, our initial analyses suggested that trait anxiety was not reliably related to increased cognitive interference/distraction, which is somewhat inconsistent with ACT (Eysenck et al., 2007). Moreover, we found no evidence of an anxiety-related attentional bias towards threat-related stimuli, which is inconsistent with several theoretical perspectives on anxiety (Bar-Haim et al., 2007; Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Ohman, 1996; Williams et al., 1988). In contrast to the above, the present study found that trait anxiety was related to faster RTs across the whole paradigm, which was related to an overall reduction in accuracy (i.e., a speed accuracy trade-off). However, further analyses suggested that there was actually a more specific effect of anxiety upon cognitive interference/distraction and emotion processing. Anxiety was related to reduced accuracy for fearful trials, which seemed primarily due to the incongruent fearful trials (a fearful target face overlaid with the word happy). We now offer a novel explanation of the effects of anxiety upon the speed accuracy trade-off, and the resulting decrement in accuracy for incongruent fearful trials.

The finding of an anxiety-related speed-accuracy trade-off is in alignment with the results reported by Basten, Stelzel & Fiebach (2011). They found that high anxiety was related to a trend towards an overall speeding in RTs, and increased errors in a neutral Stroop task. It is possible that both the present study, and the study carried out by Basten et al., may have tapped into an anxiety related speed-accuracy trade-off mechanism. The speed-accuracy trade-off is considered to be a strategic adjustment in decision processes that enables an organism to adapt to changes in environmental demands (Heitz & Schall, 2012). This behaviour has been reported in humans (Wickelgren, 1977; Bogacz et al., 2010), but also in animals such as rats (Kaneko, Tamura, Kawashima, & Suzuki, 2006), ants (Stroeymeyt, Giurfa, & Franks, 2010) and bees (Chittka, Dyer, Bock, & Dornhaus, 2003). It is easy to see how this adaptive behaviour could be accommodated within any theory that conceptualises anxiety in humans as an adaptive trait. For example, anxiety is considered to be adaptive, as it increases fitness during potentially threatening situations (Marks & Nesse, 1994). The question remains open as to what triggered the speed-accuracy trade-off, in high anxious participants in the present study.

Van Veen, Krug and Carter (2008) proposed that when a stimulus is perceived, evidence is processed that relates to each possible response. They suggest that neural activity relevant to making a possible response will start from baseline and gradually increase until a response threshold is reached. Schmidt and Besner (2008) suggest that in Stroop tasks participants make speeded responses to high contingency trials based upon response predictions. They suggest that participants lower a response threshold for expected responses, but not for any alternative possible responses. They also suggest that increased interference during low contingency trials will produce more errors, as the response threshold was reduced for the word because it was previously predictive.

In the present study anxiety did not modulate any RT facilitation effects for congruent trials. Thus we suggest that the contingency learning effect was of the same magnitude at all levels of anxiety. However, we suggest that contingency learning may still have been the trigger for the speed-accuracy trade-off, and its increase in high anxious participants. The anxiety-related speed-accuracy trade-off was much stronger in the present study than the trend in the study by Basten et al. (2011). In their study their results may have reflected an underlying response tendency that was not yet fully triggered. Indeed, in their study no contingency learning would have been present as congruent and incongruent trials were equal in proportions.

It is also noteworthy here to compare with the findings for experiment 1 (chapter 2), an emotional face flanker study using the same proportions of trial types. In experiment 1, we did not find an anxiety related speed-accuracy trade-off. We suggest that effects of contingency learning of the association between target face and flanker faces in experiment 1 would either not be present, or be only weakly present, as the target and flanker stimuli received very different amounts of attention. In contrast, in the word-face Stroop task the target stimuli are visual and are overlaid with very salient verbal distractor stimuli, so that the distractors in the Stroop task receive much more attention.

It is plausible that the speed-accuracy trade-off in high anxiety can be accommodated within the emotional survival circuit framework proposed by LeDoux (2012). It seems possible that contingency learning of the relationship between distractor word and target and response could have triggered an emotional survival circuit function that facilitated the speed-accuracy trade-off. During most responses this strategy would have been advantageous. However, this trade-off obviously caused some detrimental effects. The main detrimental effects of the anxiety-related speed-accuracy trade-off seemed to be an anxiety-related reduction in accuracy during incongruent trials requiring responses to target fearful faces, overlaid with the distractor word happy. These results are in contrast to the predictions of ACT (Eysenck et al., 2007), which predicts that distraction in high anxious participants will be magnified by threat-related distractor stimuli, and in contrast to the finding that anxiety is related to a threat-related attentional bias (e.g., Bar-Haim et al., 2007). However, the meta- analysis carried out by Bar-Haim and colleagues only included studies that compared threat-related stimuli to neutral stimuli, but the present study included combinations of fearful and happy stimuli. The question is why in the present study was it harder for high anxious participants to suppress responses to happy words than fear words during incongruent trials?

Pool, Brosch, Delplanque and Sander (2016) conducted a large meta-analysis concerning attentional biases towards positively valenced stimuli relative to neutral stimuli. Pool et al. reported that the magnitude of the attentional bias is increased when measured at the initial orienting stage as opposed to the later disengagement stage. Their findings contradict the notion that attention is exclusively biased towards any stimuli that are threat-related (e.g., Ohman & Mineka, 2001). Ohman and Mineka suggested that this perceptual threat bias would be predicated upon organisms being biologically prepared. However, Pool et al. have shown that attention towards positive stimuli is also rapid and involuntary. Moreover, some theorists suggest that those high in anxiety have difficulty disengaging their attention from threat (e.g., Fox, Russo, Bowles, & Dutton, 2001; Yiend & Mathews, 2001). Phaf and Kan (2007) suggested that, in word versions of the emotional Stroop, task anxiety may relate more to a difficulty in disengaging from fear stimuli than to an automatic engagement with the fear stimuli.

We offer an explanation of the anxiety modulations of accuracy in the present study, based upon the following two suggestions. The magnitude of the attentional bias to positive stimuli may be increased at the initial orienting stage as opposed to the later disengagement stage (Pool et al., 2016), whereas anxiety may relate to the difficulty in disengaging attention from threat (Fox et al., 2001; Phaf & Kan, 2007; Yiend & Mathews, 2001).

According to these two perspectives, in the present study all participants' attention to the target happy faces and happy distractor words would have been affected at an early orienting stage of information processing. However, a delayed attentional disengagement from target fearful faces and fearful distractor words, by high anxious participants, would occur at a slightly later stage of information processing. In the present study the initial orienting to happy words, their learned contingencies, and the anxiety related speed-accuracy trade-off could have made it particularly hard for those high in anxiety, to inhibit responding to the happy words. This may explain the anxiety related decrement in accuracy for incongruent fearful trials. In short, the target fearful faces may not have had the chance to affect attention (and thus the responses) of those high in anxiety, if the responses to happy words were prepared exceptionally quickly.

In the present study anxiety did not relate to reduced accuracy during incongruent trials consisting of target happy faces overlaid with fearful words. We suggest that the fearful words should have affected the attention of high anxious participants at the later disengagement stage. However, in all participants the happy target faces would have affected attention at the initial orienting stage. Thus, even though responses to the fearful words would have been contingency learned, it may have been slightly easier for high anxious participants to respond to the target happy face by inhibiting responding to the fearful word (during incongruent happy trials), than it would be for them to respond to the target fearful face by inhibiting responding to the happy word (during incongruent fear trials). In short, we suggest that the different effects of the two types of incongruent trials, upon those high in anxiety, was due to differences in when and how their attention was affected by the differentially valenced emotional stimuli. However, we suggest that this account should be treated with some caution as when adjusting the significance levels for multiple testing the effects involved were marginal ones at best.

It is noteworthy here that we have previously found in experiment 1 that when participants are required to discriminate between happy and fearful faces, anxiety was related to a reduced happy face recognition advantage relative to fearful faces. However, in this previous study there were no words printed over the faces that would compete strongly for attentional resources. Moreover, Krug and Carter (2010) showed that high anxious participants were slower (whereas low anxious participants were faster) to respond to incongruent trials with neutral faces overlaid with the word “fear” than fearful faces overlaid with the word “neutral”. We suggest that the accuracy effects in the present study produced results inconsistent with the RT results of Krug and Carter, because the neutral stimuli were replaced with happy stimuli in our study.

An alternative explanation of the anxiety-related distracting effects of the positive words (during incongruent fear trials) may well be possible. Kuchinke et al. (2005) found that that positive words facilitated enhanced anterior cingulate cortex and hippocampal activity relative to negative words. Ashby, Isen and Turken (1999) suggested that positive verbal stimuli initiate a processing advantage as they are better elaborated upon and interconnected within the cognitive-emotional system than negative verbal stimuli. However, it should be noted that this alternative explanation does seem to be much less clear than the previous explanation that was based upon the differential effects of positive and negative stimuli upon information processing and attention.

It should also be noted that trait anxiety may not be the only individual difference variable that is implicated in situations requiring the cognitive control of conflict or distraction, or even the processing of an error. When proposing ACT Eysenck et al. (2007) drew attention to the fact that individual differences in self-reported attentional control negatively correlate with trait anxiety (e.g., Derryberry & Reed, 2002). We are unaware of any studies that have been carried out investigating whether attentional control modulates how trait anxiety affects Stroop performance. Moreover, we are unaware of any studies investigating whether the attentional focusing and attentional shifting subscales used by Olafsson et al. (2011), differentially modulate goal conflict.

Overall, attentional control scores in the present experiment were negatively correlated with trait anxiety scores. This correlation is consistent with the studies carried out by Derryberry & Reed (2002), Reinholdt-Dunne et al. (2009), and Walsh et al. (2009). We also investigated the construct validity of the two subscales used by Olafsson et al. (2011). The attentional shifting and attentional focusing sub-scales were positively correlated at a moderate level (0.5), but were less strongly correlated than in the study by Olafsson et al. (0.7). This suggests that they measure two at least partially separate constructs. However, when controlling for attentional shifting, trait anxiety was not significantly correlated with attentional focusing. When controlling for attentional focusing, trait anxiety was not significantly correlated with attentional shifting. This analysis suggested that it is the shared variance of attentional focusing and attentional shifting that drives the bulk of the attentional control correlation with trait anxiety. We therefore determined whether the overall scores on the attentional control scale showed any sign of a relationship with the key effects that related to trait anxiety. Conversely to trait anxiety, overall attentional control was not related to the overall RTs or proportion correct. When controlling for variations in overall attentional control, trait anxiety still significantly correlated with overall RTs, overall proportion correct, and the strength of the relationship between anxiety and proportion correct for incongruent fear trials was unchagned. So, whatever the relationships between behaviour and anxiety in the current study signify, they are not related to variance captured by scores on the attentional control scale.

We were also interested in how trait anxiety affects cognitive performance following the commission of an error. Individuals' responses are reportedly slower following the commission of an error (Rabbitt & Rodgers, 1977), which was true in the present study. However, in the present study anxiety was not related to the robust measure of post-error slowing (the measure advocated by Dutilh et al., 2012). This finding is consistent with the null results reported in previous studies (e.g., Hajcak McDonald, & Simons, 2003a; Van der Borght et al., 2016; Weinberg, Olvet, & Hajcak, 2010). When controlling for attentional focusing, post-error slowing was uncorrelated with attentional shifting. When controlling for attentional shifting, post-error slowing was positively correlated with attentional focusing. In short, attentional focusing and attentional shifting have different predictive validity. Attentional focusing predicted post error slowing whereas attentional shifting did not. We suggest that the attentional control questionnaire should be used as two subscales. Our main interest concerned how trait anxiety and self-reported attentional control affected the slowing down of responses after error commission. However, we did verify that there were no differences in accuracy relative to whether the previous response was an error or not, and verified that trait anxiety did not modulate this null effect in any way.

Behavioural adjustments following errors were not the only sequential effect we were interested in. We analysed the CSEs in both the RT data and in the proportion correct data. The critical finding in the RT data was that, as predicted, (in)congruency repetition trials were responded to faster than (in)congruency alternation trials. The effects were of a similar magnitude to those found in our flanker study (experiment 1). However, in the present Stroop study the CSE was not modulated by trait anxiety in contrast to our earlier finding for the flanker task. Trait anxiety was not significantly correlated with the CSE during congruent trials, or incongruent trials. The CSE analysis of the proportion correct data showed that repetition trials were responded to more accurately than alternation trials, but again this effect was not modulated by anxiety. The anxiety-related CSE effects in the studies by Etkin et al. (2010) and Etkin and Schatzberg (2011) were not replicated in the present study. Critically, the anxiety-related CSE effects in experiment 1 were also not replicated in the present study (experiment 2), even though the structure of the task was the same except for the stimulus changes (flanker to Stroop). Moreover, in experiment 2 the relationship between anxiety and the CSE was near-significantly different for congruent compared to incongruent trials. This is further evidence that CSE here behaves differently from on the flanker task (where there was no hint of an effect of trial type congruency on the relationship between anxiety and the CSE). It seems likely that emotional Stroop conflict tasks and emotional flanker conflict tasks may tap into slightly different brain functions and thus elicit information processing that differs with respect to its involvement of trait anxiety. It also seems likely that trait anxiety in sub-clinical participants may affect Stroop task performance differently from the way trait anxiety affects behaviour in clinical patients (as used in the studies by Etkin and colleagues).

Tillman and Wiens (2011) compared participants' congruency effects from both a neutral Stroop task and a neutral flanker task. When the tasks contained 20% incongruent trials relative to 80% congruent trials, participants RT congruency effects were correlated between the two tasks (but only at an r=0.4 magnitude). However, the proportion correct for these two tasks was uncorrelated. In addition, when the tasks contained 80% incongruent trials relative to 20% congruent trials there was no RT congruency effect correlation between tasks. Tillman and Wiens suggest that the behavioural indices of these tasks reflect similar cognitive control processes such as goal conflict detection and goal conflict resolution. However, we suggest that the correlations between the tasks were not really that strong for the RTs, and non-existent for the accuracy levels. Under the best conditions the tasks correlated at only 0.4, thus just 16% of the variance was shared. It is not really possible to argue that this shows that they reflect similar processes. Rather it shows that they share relatively few processes. The Stroop and flanker tasks may in fact produce some considerable differences in behaviour.

To summarise, there is inconsistency between the anxiety effects in our emotional flanker task and our emotional Stroop task. There is also inconsistency between anxiety effects in our emotional Stroop task and those of Etkin et al. (2010) and also Etkin & Schatzberg (2011). There is inconsistency between the anxiety effects in the Stroop study by Etkin and colleagues and the anxiety effects in the flanker study by

Larson, Clawson, Clayson and Baldwin (2013). We have suggested that the differences between the anxiety effects in the present study, and in the studies by Etkin and colleagues, may be due to differences in how levels of trait anxiety in clinical and sub-clinical participants may differentially modulate cognition. However, both the Stroop studies of Etkin and colleagues and the flanker study of Larson et al. were carried out with clinical patients with GAD (and normal controls). Moreover, the anxiety effects upon the CSE in our flanker study were in the same direction to those reported by Larson et al. with clinical patients included in the sample. Therefore we suggest that the two tasks may involve differences in the cognitive control processes elicited.

3.6. Conclusion

To conclude, we used a contingency biased emotional word-face Stroop task that resulted in an anxiety-related speed-accuracy trade-off. This resulted in an anxiety-related reduction in accuracy which was numerically largest for incongruent trials (particularly those with positive distracting words). Future studies should seek to ascertain if the anxiety related speed-accuracy trade-off is replicable, and further explain how this mechanism is triggered. Moreover, we suggest that the present study should be replicated using EEG with a view to determining if any relationship exists between the ERN (as described in chapter 2) and the anxiety related speed-accuracy trade-off. It would also be useful to explore whether and how the ERN relates to the interaction between post-error slowing and self-reported attentional focusing scores. The differential effects of anxiety upon the CSE in this experiment compared to experiment 1 show that the Stroop and flanker tasks are not interchangeable when researching cognitive goal conflict and anxiety. We suggest that a further CSE study using equal proportions of congruent and incongruent trials should be conducted using our emotional flanker task. Equal proportions of congruent and incongruent trials would enable a more detailed analysis that includes dividing the sequential trial types by emotional target type (e.g., happy cI trial versus fear cI trial). Thus, we would be able to determine how emotion type effects the CSE, in addition to delineating trials where target and response repeat, relative to trials where target and response do not repeat. This may be important when assessing anxiety effects. As discussed briefly in chapter 2, Nieuwenhuis et al. (2006) and Mayr, Awh, and Laurey (2003) reported that the CSE occurred only when target and response repeated, but Clayson and Larson (2012, 2011a, & 2011b) found robust CSEs without target and response repetitions. In short, anxiety may relate differentially to these two stimulus and response situations.

Chapter 4

4. Experiment 3

4.1. Introduction

Experiment 1 showed that mean RTs for happy faces were faster than for fearful faces. However, those high in trait anxiety displayed a negative relationship with this effect. Those high in anxiety showed a reduced happy face recognition advantage that was driven by faster responses to fearful faces (although this effect of the fearful faces was initially supressed by general sources of RT variance). Experiment 1 also showed that RTs to angry and fearful faces were similar, and were not affected by trait anxiety. The finding that trait anxiety affects how fearful faces are discriminated from happy faces is not surprising from an RST perspective. There is considerable overlap between brain regions implicated in the septo-hippocampal system proposed to mediate the BIS and thus trait anxiety (Gray & McNaughton, 2000), and the facial emotion recognition system proposed by Adolphs (2002b). For example, the amygdala and extended hippocampal formation are critical in both of these neurobiological systems.

In accordance with the original suggestions of Lissauer (1890), Adolphs (2002a) suggests that perception and recognition are distinct processes. Visual perception refers to the early sensory processing of the features of stimuli and their configuration. This process would aid discriminating between faces that are concurrently in one's visual field. However, Adolphs suggests recognition requires extra information about the perceived stimulus that aids identification. Recognizing facial emotion would require memories of the relationship between the expression and instances when it has been previously experienced. This information would often be complemented with information concerning how one felt when the expression was experienced. It is easy to see how these memories and feelings might be magnified by anxiety. The theoretical account of face recognition proposed by Bruce and Young (1986) focused upon discrete cognitive processes that facilitate both expression identification, and person identification. This account suggests that analyses of facial speech and facial expression, in addition to the identification of a person, are mediated by discrete processes. However, Calder and Young (2005) suggest that expression identification and person identification processes may interact more than was originally thought.

Recognizing facial emotion employs multiple brain regions including the occipito-temporal cortex, orbito-frontal cortex, right fronto-parietal cortices and amygdala (Adolphs, 2002b). Adophs proposes that sensory information pertaining to a face appearing in one's visual field would proceed through occipito-temporal cortices. Adolphs suggests that after approximately 100 milliseconds, perceptual information aids the coarse categorisation of whether the stimulus has emotional significance or not. This would be based upon the structural properties of the face. Adolphs proposes that orbito-frontal cortices and amygdala may then contribute to emotional face recognition in three separate ways. Firstly, Adolphs suggests that these brain regions might control perceptual representations by providing feedback, thus directing attention to specific features and aiding expression categorization. Secondly, Adolphs postulates that these regions may mediate the retrieval of conceptual knowledge related to the facial emotion via neural projections to the hippocampal formation as well as other areas of the neocortex. Thirdly, the orbito-frontal cortices and amygdala may mediate the response to the face via neural projections to motor regions, brainstem nuclei and hypothalamus. Adolphs proposes that these latter regions would mediate a person's response to the emotional face.

Evidence suggesting neutral and emotional faces are processed differently can be gained from studies using EEG. Sato, Kochiyama, Yoshikawa and Matsumura (2000) recorded event related potentials (ERPs) obtained whilst participants categorised the gender of fearful, happy and neutral faces. Fearful and happy faces compared to neutral faces boosted the N270 ERP as shown by greater negativity recorded at posterior temporal electrodes. The distribution of this activity covered a large area of visual cortex. The authors propose that this increased activity may reflect amygdala re-entrant projections to visual areas that represents early emotional processing, that is independent of task instructions. A review by Eimer and Holmes (2007) provides ERP evidence supporting the view that perceptual structural encoding processes, and the detection and subsequent analysis of the expressions of emotional faces are functionally independent processes that work in parallel.

The theoretical account of face recognition presented by Bruce and Young (1986) suggests that a structural encoding stage provides information about features and their global configuration. Bruce & Young suggest that the configuration of observed facial features results in facial expression categorisation. Facial speech (movement of facial components), and facial expression analyses may operate independently of the face recognition units. From this perspective, these different components of the face recognition system supply information to the rest of a person's cognitive system. Bruce and Young suggest that the rest of a person's cognitive system can also influence the activity of components of the face recognition system, and is also responsible for decision making processes. Face expression analysis is an important feature of this account of face recognition. From this perspective it is possible that high trait anxious participants demonstrate enhanced reactivity of the face expression analysis component of the system represented by this model. More specifically, in experiment 1 this enhanced reactivity seemed to occur only when processing intermingled happy and fearful faces, or possibly just the fearful faces in the between-valence condition. As already discussed, it is possible that increased configural processing demands present in the within-valence condition (discriminating angry faces versus fearful faces) reduced a trait anxiety related advantage in the reactivity of the expression analysis component of this system during the processing of fearful faces.

The structural encoding and expression analysis components of Bruce and Young's (1986) account of face processing are in alignment with the suggested neural stages of emotional face processing proposed by Adolphs (2002b). Following a structural encoding phase, Adolphs (2002b) suggests that the orbito-frontal cortices and amygdala might direct attention to specific features of a face thus aiding expression categorization. Adolphs also suggests that these regions possibly mediate the retrieval of information relating to the facial emotion via neural projections to the hippocampal formation and neocortex. Bruce & Young's account of face processing and Adolph's proposed neural system together provide further insights into how trait anxiety may relate to facial emotion identification. The orbito-frontal cortices and amygdala of those high in trait anxiety might retrieve certain kinds of information from the hippocampal formation differently and/or more efficiently than those low in trait anxiety. This may aid an enhanced fearful facial expression analysis in high trait anxiety, which results in faster RTs to fearful faces relative to happy faces. Moreover, this may reflect the enhanced activity of a neural survival circuit, as proposed by LeDoux (2012).

Calvo and Nummenmaa (2008) showed that the role of featural processing is highly important when detecting target emotional expressions in a visual search situation. They showed that the mouths of facial stimuli played a major role, whereas eyes played only a minor role in predicting participants' visual search performance. Moreover, Neath-Tavares and Itier (2016) showed that the mouth region and eye region play a major role in the processing of fearful facial expressions. They also showed that the mouth region was important when processing happy facial expressions. Their results are also consistent with another study that suggests that the mouth region, may be important when processing fearful facial expressions (Blais, Roy, Fiset, Arguin, & Gosselin, 2012). Messinger, Mattson, Mahoor, and Cohn (2012) showed that both the magnitude of eye constriction, and the magnitude of mouth opening, were related to the intensity of both negatively valenced and positively valenced facial expressions of 6 month old infants. Another study with adult participants showed that the display of teeth (relative to no display of teeth) increased both valence ratings and arousal ratings for happy faces and grimacing faces. In addition, this study also showed that the presence of teeth also enhanced ERP recorded brain responses to the mouth expressions (daSilva et al., 2016).

It is possible that in emotional face discrimination situations that a more salient feature that belongs to any specific target face could enhance expression recognition. For example, a happy expression or fearful expression with an open mouth should be more emotionally salient (and/or represent a more enhanced version of the emotion) than a happy expression or fearful expression with a closed mouth. It is possible that open mouths relative to closed mouths may aid discriminating between happy and fearful facial expressions. One would expect happy and fearful facial expressions with open mouths (depicting a more enhanced version of the emotion), to be more arousing than the same emotional expressions with closed mouths. Variations in arousal levels of different emotional facial stimuli have been previously shown to relate to the perceived intensity of the facial expression (Lundqvist, Juth, & Ohman, 2014). Based upon these studies it seems possible that more intense emotional facial expressions (with open mouths) might facilitate an information processing advantage relative to those that are less intense (with closed mouths). This makes initiative sense from the emotional survival circuit perspective of LeDoux (2012), as the detection of subtle differences in facial signals of potential threat, or potential reward, would both be adaptive.

Further insights into these issues can be obtained from studies using eye tracking methods. Mogg, Garner, and Bradley (2007) showed using eye tracking techniques together with a dot-probe task, that moderate intensity or high intensity angry and fearful faces (which had very salient open mouths) elicited an increased tendency for participants to orient their gaze towards them, relative to neutral control faces. This effect was not elicited by mild intensity angry and fearful faces (which had mouths that were slightly open, but were less salient than the moderate or high intensity faces). Intense emotional facial expressions were also discriminated more accurately. High trait anxiety, relative to low trait anxiety, was related to an increased tendency to gaze at the most intense angry and fearful faces, and an increased dot probe attentional bias score in RTs caused by the high intensity threat-related faces. Mogg et al. showed that there were no trait anxiety related effects that related to faces with weaker low intensity emotional expressions. Moreover, trait anxiety levels did not affect participants' face expression intensity ratings. It is noteworthy here that these findings are somewhat inconsistent with the theory that stimuli indicating a mild level of threat will be appraised as being more threat-relevant by those high in anxiety relative to those low in anxiety (Mogg & Bradley, 1998). However, inconsistencies in behavioural effects of anxiety on emotion processing may occur due to varying types of paradigms being used in research (i.e., the task instructions may vary between paradigms).

The study by Mogg et al. (2007) showed how anxiety is affected by emotional expression salience, but the study was limited for two reasons. Firstly, they only included threat-related and neutral faces, as happy faces were not included. It is thus unknown whether high intensity happy faces would have facilitated any increase or decrease in anxiety related gazing behaviours. Secondly, they measured only trait anxiety, which is a closely related construct, in psychometric terms, to social anxiety (e.g., Mattick & Clarke, 1998). However, as discussed previously, Silvia, Allan, Beauchamp, Maschauer and Workman (2006) showed that those high in social anxiety are slower to recognise happy face expressions relative to those low in social anxiety. It is possible that the effects of expression intensity may affect social anxiety differently than the broader construct of trait anxiety.

Several studies, other than those discussed in detail in this thesis, reported a happy face recognition advantage relative to negatively-valenced faces (e.g., Leppanen & Hietanen, 2003; Kirita & Endo, 1995; Feyereisen, Malet, & Martin, 1996). This advantage has been found to be present when stimuli are schematic, and thus control for complexity of features (Leppanen & Hietanen, 2004; Kirita & Endo, 1995). Leppanen and Hietanen (2004) also found this effect and proposed that this positivity bias results from participants' tendencies to form positively biased judgments about people. Silvia et al. (2006) suggested that positive information concerning other people may be less readily available or retrievable in high social anxiety, even though generally people are suggested to perceive others as a source of rewarding interaction (Baumeister & Leary, 1995; Fleeson, Malanos, & Achille, 2002). Silvia et al suggested that a lack of availability of positive information about other people in high socially anxious individuals may slow down applying conceptual information to the percept of a face.

The results in the study by Silvia et al. (2006) differ from the results of experiment 1 in this thesis as in their study social anxiety was related to slower RTs to happy faces but in experiment 1 in this thesis trait anxiety was primarily related to faster RTs to fearful faces, rather than slower RTs to happy faces. It is possible that trait anxiety and social anxiety affect emotional information processing slightly differently. Mansell, Ehlers, Clark, and Chen (2002) used a dot-probe paradigm to investigate whether social anxiety is related to attention to socially evaluative words that are negative (e.g., pathetic, stupid) or positive (e.g., attractive, friendly). Social anxiety was unrelated to attention to socially evaluative words of either valence. However, trait anxiety was related to an attentional bias for negative words relative to positive words. These effects were present in both an experimentally induced socially evaluative condition, and a non-socially evaluative condition.

In an earlier study Mansell, Clark, Ehlers and Chen (1999) used a similar task using emotional faces as opposed to words, in addition to the social evaluation versus non-social evaluation manipulation. In this study socially anxious participants avoided positive and negative emotional faces in the social evaluative condition. In contrast, trait anxious participants showed a bias towards negative faces in the non-social evaluative condition. These studies, together with the differential effects observed in the study by Silvia et al. (2006) and experiment 1 of this thesis, suggest that participants high in trait anxiety and participants high in social anxiety may process emotional stimuli in slightly different ways.

Experiment 1 in this thesis measured participants' levels of trait anxiety but did not measure participants' levels of social anxiety. It is possible that the anxiety effects in the experiment 1 of this thesis would have differed if the trait anxiety measure was replaced with a social anxiety measure. Alternatively, it is possible that the anxiety effect upon fearful and happy face discrimination in experiment 1 of this thesis was driven by social anxiety accounting for some of the variance in trait anxiety, as previously found by Mattick and Clarke (1998). In which case, trait anxiety and social anxiety may have affected the results similarly. In short, it is possible that both trait anxiety and social anxiety may be related to increased reactivity of the emotional survival circuits theorised by LeDoux (2012). However, these emotional survival circuits may be triggered in a different way or by slightly different stimuli, by the two types of anxiety.

It is also not clear if the anxiety effect upon between-valence face discrimination found in experiment 1 is specific to fearful faces versus happy faces, or if this anxiety effect would occur for angry faces versus happy faces. A discrimination task including angry and happy faces would clarify if the effects during the happy/fear discrimination task is emotion specific or related to a more general between-valence effect. Moreover, it may be that the effects of trait anxiety and/or social anxiety are completely different concerning the presence of fearful faces or angry faces.

4.2. Purpose of experiment 3

This next experiment uses two emotional face discrimination tasks with just single faces (this time with no flankers present). The issues discussed above are accounted for by including a happy versus fear task and a happy versus anger task. To counteract any possible effects of participants adopting an increased featural processing strategy specific to any specific component of a single person's identity, six distinct people pose the stimuli for each emotional expression. Moreover, facial expressions with open and closed mouths were included to ascertain any effect of mouth salience upon emotional expression recognition and/or the effect of anxiety upon this.

This time a specific social anxiety measure was administered as well as the trait anxiety measure. Silvia et al. (2006) measured social anxiety using the Social Phobia Scale (SPS) and Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998). Based upon the method used in previous research by Kashdan (2002) and Kashdan and Roberts (2004), Silvia et al. calculated social anxiety scores by standardising and then averaging together the scores of the SPS and SIAS. We adopt this method of measuring social anxiety as one of two primary anxiety measures in the present study. We also use the STAI (Spielberger et al., 1983) as the other primary measure. However, we also note some controversy concerning the construct validity of the STAI.

Bieling, Antony and Swinson (1998) suggested that, although the STAI is a popular and widely used measure of trait anxiety, it may measure more than one underlying factor. Bieling et al. suggested that the scale does not measure 'pure' anxiety, but in also includes items that measure depression and also a general form of negative affect. Exploratory and confirmatory factor analyses supported the notion of a hierarchical model with an umbrella factor of negative affect, and two lower order more specific affective factors. Bieling et al. suggest that one of these factors contains items relating to worry, rumination and disturbing thoughts, and reflects the construct of anxiety. The other factor, they suggest, contains items that relate to negative self-appraisal and dysphoric mood, and thus measure depression. Bieling et al. confirmed the convergent and discriminant validity of the resulting subscales by conducting correlational analyses with other measures of anxiety and depression. As predicted, the two scales correlated with the other measures in a way that was consistent with the items they contain. The construct validities of the STAI and the subscales proposed by Bieling et al. were further investigated by Bados, Gomez-Benito and Balaguer (2010). Bados et al. suggested that the discriminant validity of the anxiety subscale of the STAI may be questionable, as the correlation between the anxiety subscale and other measures of anxiety was of a similar magnitude to the correlation between the anxiety subscale and other measures of depression. The anxiety subscale also had lower convergent validity than the depression subscale which was also the case in the study by Bieling et al.

As discussed previously, Judah, Grant, Mills and Lechner (2013) reported that scores on the attentional focusing subscale of the attentional control scale (Derryberry & Reed, 2002) were much more reliably negatively correlated with the STAI measured anxiety subscale than the STAI measured depression subscale, whereas scores on the attentional shifting subscale of the attentional control scale was much more reliably negatively correlated with STAI measured depression than STAI measured anxiety. Moreover, Judah et al. reported that depression measured by the BDI-II (Beck, Steer & Brown, 1996) correlated positively and at identical magnitudes with both the supposed anxiety and depression subscales of the STAI. However, Reinholdt-Dunne, Mogg and Bradley (2013) also reported that lower attentional focusing scores predicted increased STAI measured anxiety, whereas lower attentional shifting scores predicted increased STAI measured depression. These studies do lend support to the notion that the discrete STAI subscales proposed by Bieling et al. (1998) have some discriminant validity, concerning other individual difference measures, but their discriminant validity concerning other affective trait measures is somewhat uncertain. In the present study we also aimed to carry out exploratory analyses using behavioural measures of emotional expression recognition, and self-reported attentional focusing and shifting measures, to investigate the discriminant validity of the proposed STAI-anxiety and STAI-depression subscales.

We predicted that both trait anxiety and social anxiety would relate to a reduced happy face recognition advantage relative to fearful faces. Based upon experiment 1 we predicted that trait anxiety would relate to faster RTs for fearful faces (but this may be suppressed by general RT effects, until we adopt statistical procedures to de-suppress them). Based upon the paper by Silvia et al. (2006) we predicted that social anxiety will relate to slower RTs for happy faces. As discussed, the anger versus happy contrast condition is included to determine if angry faces elicit the same anxiety effects as the fearful faces, and if any social anxiety effects for happy faces can be observed across two different types of emotion discrimination. The open versus closed mouth contrast will determine how enhanced feature saliency affects the overall happy face recognition advantage and any observed anxiety effects.

4.3. Method

4.3.1. Participants

Participants with no reported history of neurological disorder (N = 90, 64 female) were recruited from Goldsmiths, University of London, and had a mean age of 24.6 (SD = 6). 76 of these participants were right handed. 22 participants were psychology 1st year undergraduates recruited via a research participation scheme who took part in return for course credit. The rest were paid £10 and recruited via advertisements placed around the campus, and were therefore students and staff from other departments. All gave informed written consent in accordance with standard ethical guidelines. 8 participants were excluded from the analyses due to data saving problems. This study was approved by the Goldsmiths psychology departments' ethics committee (approval received 24/10/2012).

Based upon the 0.48 correlation between social anxiety and fearful face detection sensitivity reported in the study by Doty et al. (2013), 31 participants should allow 80% power for a two-tailed test at $p=0.05$, for a correlations of 0.48 in this experiment. However, based upon the 0.32 correlation between trait anxiety and the RT difference between responses to happy and fearful faces in experiment 1 of this thesis, 74 participants should allow 80% power for a two-tailed test at $p=0.05$, for a correlation of 0.32 in this experiment. We thus aimed for 75 participants approximately (in the end we tested a few more participants than this).

4.3.2. Psychometric measures

Social anxiety was assessed using the Social Phobia Scale (SPS) and the Social Interaction Anxiety Scale (SIAS) developed by Mattick and Clarke (1998). Based upon previous research (Silvia et al., 2006; Kashdan, 2002; Kashdan & Roberts, 2004) we standardised and averaged the total scores of the SPS and total scores of the SIAS to obtain a unitary social anxiety score. Trait anxiety was initially assessed with the trait anxiety scale of the State-Trait Anxiety Inventory (STAI, Spielberger et al., 1983). However, we refer to this as the STAI-trait scale hereafter, as we also use the previously proposed anxiety and depression subscales of the STAI, as described by Bieling, Antony and Swinson (1998). The STAI-anxiety subscale consists of STAI-trait items 22, 28, 29, 31, 37, 38, & 40. The STAI-depression subscale consists of STAI-trait items 21, 23-27, 30, 32-36, & 39. Attentional control was assessed with the Attentional Control Scale (Derryberry & Reed, 2001, 2002). We also used the attentional control scale subscales as used by Olafsson et al. (2011). The attentional focusing sub-scale thus consisted of 9 items (items 1-8 and item 12). The attentional shifting sub-scale thus consisted of 10 items (items 10, 11, and 13-20).

4.3.3. Stimuli

The emotional faces used were obtained from a standardised face stimuli set developed for research (NimStim; Tottenham et al., 2009). The individual face pictures were were 60mm high and 48 mm wide (when presented using MATLAB version R2006a on a 15.5 inch laptop screen). The laptop was running Windows XP, and we used the Psychophysics Toolbox version 3 for precision RT measurement. Three face stimulus sets containing different people's faces in each were created for use in two tasks, one task consisted of happy and fearful faces and one task consisted of happy and angry faces. Each of the three face sets included happy, fearful and angry facial expressions (with versions of each expression included that had both open mouths and closed mouths) posed by six different models from the NimStim. Thus in each task (happy face and fearful face or happy face and angry face) photographs each of the six models were used, with both closed and open mouths (for both facial expressions). Thus, in each task, 24 unique stimuli were presented (two emotions x 2 mouth types x six people). Figure 4.1 shows an example of one of the sets of emotional faces used.

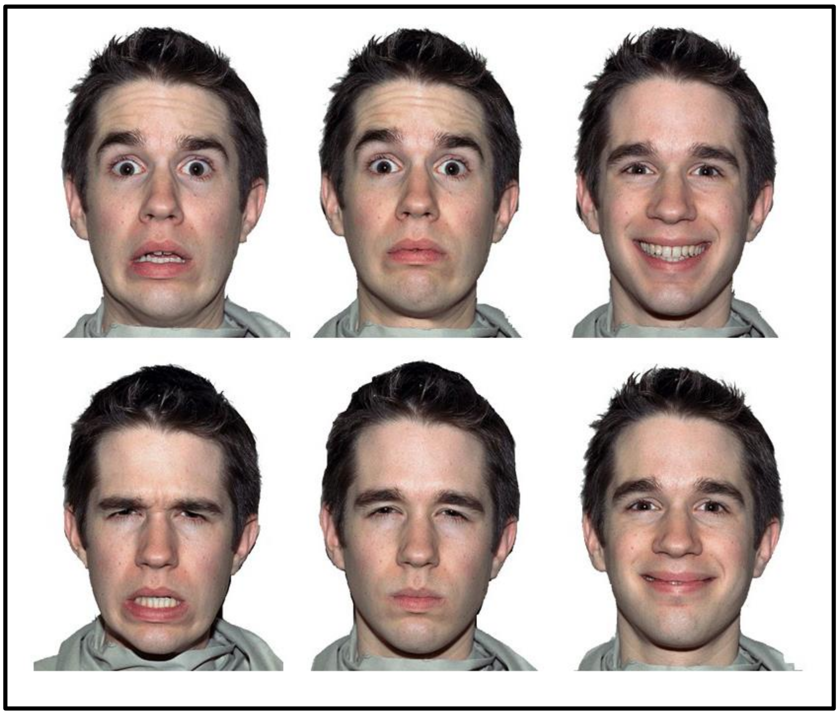

Figure 4.1: Example of one of the sets of emotional faces used. Clockwise from top left: fear open mouth; fear closed mouth; happy open mouth; happy closed mouth; anger closed mouth; anger open mouth.

4.3.4. Procedure

Participants were told that they would be presented with two short emotional facial expression recognition tasks (i.e., conditions) with a short rest in between. Participants were asked to sit as close to the screen as was comfortable for their eyes (typical viewing distance was approximately 70 cm). The task instructions were presented on the screen. To start each task the first screen instructed participants that they would have to judge the emotional expression showing on photos of faces (happy and fear in the one task; and happy and anger in the other task). Participants were then shown examples of the various faces they might see. They were told to rest their index fingers over the responses keys (z and /) and to respond as fast as possible while maintaining high accuracy levels. They were verbally told that a high pitched tone following a response indicates a correct response, whereas a low pitched tone following a response indicates an incorrect response.

The experimental stimuli were displayed until a response key was pressed. Unbeknown to the participants, at the beginning of each task, there were 24 trials included as practice trials; these were discarded and not analysed. The main experimental stimuli that followed consisted of 120 happy face trials and 120 threat-related face trials (in each of the two tasks). The emotional facial expression discrimination paradigm was designed primarily to elicit RT effects as opposed to errors. The trial type sequence was created using a random number generator function in Matlab, and was the same for all participants. We kept the sequence the same for all participants as this is an individual differences study, and we wanted as few uncontrolled variables as possible to vary across participants. We also used the same trial type sequence for each of the tasks (with fearful faces being substituted with angry faces where appropriate). There were 240 non-practice trials in total in each task so we felt that there was no chance that using the same sequence in each task would cause any learning of the sequence of trial types and, as noted below, we counterbalanced the order of the 2 tasks across participants. Each task lasted for approximately ten minutes. The experiment was thus created using a 2 X 2 X 2 combination of valence (happy face versus threat-related face) x mouth salience (closed mouth versus open mouth) x discrimination task (happy/fear discrimination versus happy/anger discrimination). We included equal proportions of male and female faces, with different facial identities used across the two tasks. The left/right finger response key mappings were also counterbalanced. Each participant was tested using one of the three face identity sets for each of the two tasks (i.e., a different face set was used per condition for each participant, and the mapping of the face-set was counterbalanced using an incomplete Latin square).

4.3.5: Data analysis

Our RT data will be analysed using ANCOVA with factors of valence, mouth salience, and discrimination task, with standardised social anxiety as the covariate. The effect of valence will reveal whether RTs to threat-related faces differ from RTs to happy faces, and the covariate interaction with valence will test our key hypothesis that social anxiety modulates (correlates with) this valence effect.

The effect of mouth salience upon the effect of valence will allow us to test whether the RT difference between threat-related and happy faces differs significantly as a function of mouth salience (i.e., open vs. closed mouths). The 3-way interaction between the covariate, the effect of mouth salience, and the effect of valence, specifically tests whether social anxiety modulates (correlates with) the difference in the RT differences between threat-related faces and happy faces for open vs. closed mouth trials.

The effect of discrimination task on the effect of valence will allow us to determine if the RT difference between threat-related faces and happy faces differs significantly when fearful faces are the threat-related emotion, relative to when angry faces are the threat-related emotion. The effect of the social anxiety covariate upon this interaction will allow us to test whether social anxiety modulates (correlates with) the RT difference between happy and fearful faces minus the RT difference between happy and angry faces. The effect of mouth salience here will allow us to tease apart whether these effects differ significantly between faces with open vs. closed mouths.

We also planned to repeat the analyses including STAI-trait scores as the covariate. To follow we planned to investigate whether the STAI-subscales, discussed above, differentially affect any of the key RT correlations. We also planned to conduct some exploratory correlations using the attentional control scale. For completeness most of the main analyses above were then repeated with the accuracy data.

4.4. Results

4.4.1. Psychometric test scores

In this sample, participants' STAI-trait scores ranged from 23 to 69 (mean: 43, SD: 9), whereas their social anxiety scores (calculated as [SIAS + SPS]/2) ranged from 2 to 65 (mean: 19, SD: 11). Participants' total attentional control scale scores ranged from 23 to 71 (mean: 49, SD: 9). Participants' attentional focusing scale scores ranged from 9 to 36 (mean: 22, SD: 5), whereas their attentional shifting scale scores ranged from 13 to 38 (mean: 26, SD: 5). The STAI-anxiety scale scores in this sample ranged from 8 to 27 (mean: 15, SD: 4), whereas the STAI-depression scale scores ranged from 15 to 43 (mean: 28, SD: 6).

4.4.2. Reaction time analyses

Including all participants the experiment contained 41280 responses in total. 39134 of these were correct responses. Correct responses ranged from 1 msec to 8682 msecs. RT outliers for correct responses were removed if RTs < 200 msecs and RTs > 1250 msecs. Of these 1675 were where RT > 1250msecs, and 4 were where RT < 0.200 msecs. Thus, 1679 correct responses were removed. Thus, 4.29 % of correct trials were excluded.

1679 / 39134 * 100

The correct RT data were first subjected to a 2 (valence; happy face versus threat-related face) x 2 (mouth salience; closed mouth versus open mouth) x 2 (discrimination task; happy/fear discrimination versus happy/anger discrimination) repeated-measures ANCOVA with standardised social anxiety as the covariate. We also repeated the same analysis but included standardised STAI-trait scores as the covariate. To account for multiple testing of 2 separate covariates we adopt an adjusted significance level of 0.05/2 for all of the covariate interactions. The descriptive statistics for the RTs for each of the eight trial types are shown in Table 4.1. Figure 4.2 shows the mean RTs for each of the 8 stimulus types.

Table 4.1: Mean RTs, 95% confidence intervals (95% CIs), and standard errors (SE) for each of the 8 stimulus types (listed by target emotion versus mouth versus discrimination task). All values are in msecs.

Happy/fear task				**Happy/anger task**			
Trial type	**Mean**	**95% CI**	**SE**	**Trial type**	**Mean**	**95% CI**	**SE**
Happy closed	660	638-681	11	**Happy closed**	658	636-679	11
Happy open	632	609-654	11	**Happy open**	633	612-654	11
Fear closed	658	637-680	11	**Anger closed**	656	634-678	11
Fear open	649	628-670	11	**Anger open**	643	621-666	11

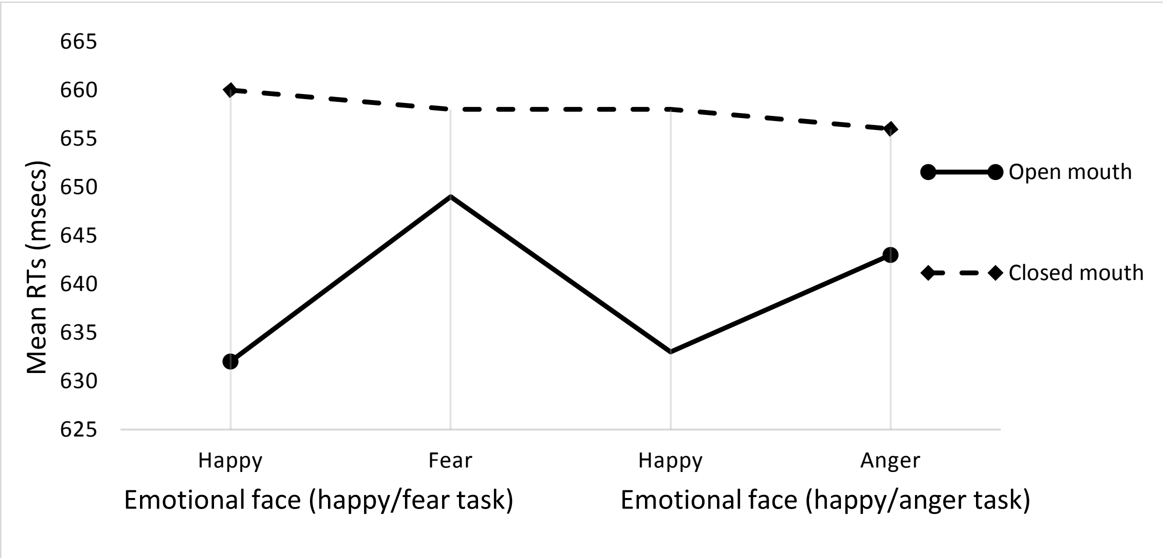

Figure 4.2: Mean RTs, for each of the 8 stimulus types (listed by target emotion versus mouth versus discrimination task). All values are in msecs.

4.4.3. Social anxiety RT analysis

The test of between-subjects effects showed that social anxiety was not significantly related to RTs averaged across the whole experiment (F[1,80]=0.3, p=0.605,

η^2=0.003). The key findings of the test of within-subjects effects were that the main effect of valence was significant (F[1,80]=7.5, p=0.008, η^2=0.086), and this also significantly interacted with social anxiety (F[1,80]=6.4, p=0.013, η^2=0.074). Therefore, there was a small but significant difference between RTs for averaged happy faces from both discrimination tasks (mean RT 645 msecs; 95% CI 625-666; SE 10), and RTs for averaged threat-related faces from both discrimination tasks (mean RT 652 msecs; 95% CI 631-672; SE 10). However, even though this effect was quite small the interaction shows that social anxiety correlated with the RT difference (RT threat-related faces minus RT happy faces). The correlation value was r= -0.27. This correlation is depicted in Figure 4.3, which shows that higher social anxiety was related to a reduced happy face recognition advantage. This effect relates to our key hypothesis suggesting that social anxiety will modulate emotion discrimination.

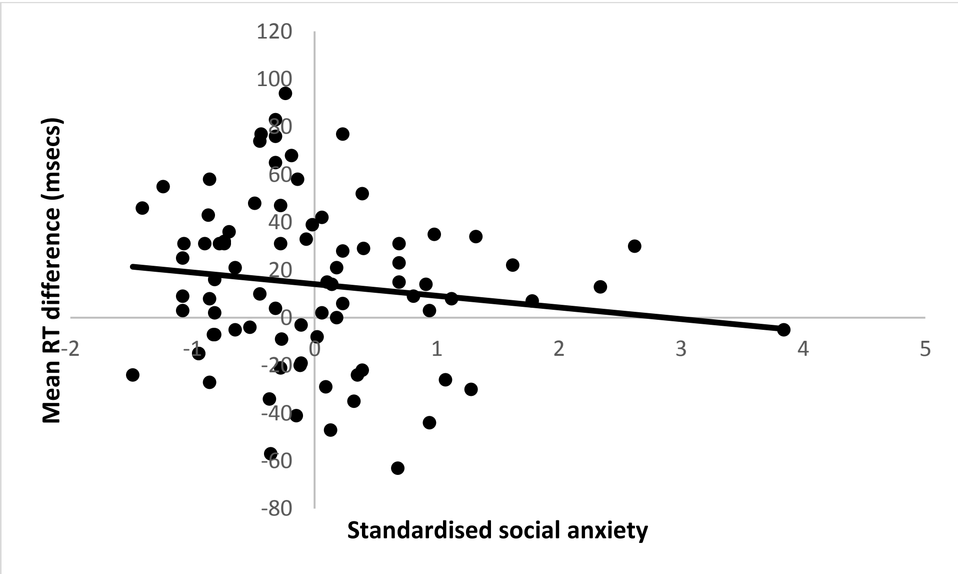

Figure 4.3: The negative correlation between social anxiety and the happy face recognition advantage. The correlation value is r = -0.27, p = 0.013.

The main effect of mouth salience was also significant (F[1,80]=91.9, p<0.001, η^2=0.535), but this did not significantly interact with social anxiety (F[1,80]=1.3, p=0.254, η^2=0.016). This shows that facial expressions with open mouths were on average responded to significantly faster (mean RT 639 msecs; 95% CI 618-660; SE

10) than facial expressions with closed mouths (mean RT 658 msecs; 95% CI 637-678; SE 10), but social anxiety was not significantly related to this RT difference (the correlation value was r= -0.13). Moreover, the main effect of discrimination task was not significant (F[1,80]=0.1, p=0.722, η^2=0.002), and did not significantly interact with social anxiety (F[1,80]=0.4, p=0.534, η^2=0.005). This shows that there were no RT differences between discrimination task (mean RT for the happy/fear task was 650 msecs; 95% CI 629-671; SE 11; and mean RT for the happy/angry task was 648 msecs; 95% CI 626-669; SE 11), and no differential RT effects of social anxiety between the two discrimination tasks.

The interaction between valence and mouth type was significant (F[1,80]=13.1, p=0.001, η^2=0.141), but this interaction did not significantly further interact with social anxiety (F[1,80]=0.3, p=0.587, η^2=0.004). Mean RTs for the happy faces and threat-related faces, relative to mouth type, are illustrated in Figure 4.4. This graph, coupled with the significant interaction, show that the RT advantage for the more salient open mouths, relative to closed mouths, was reduced when processing threat-related faces relative to happy faces. This relates to our key interest in how mouth salience affects emotional face discrimination. We return to explore this effect further below.

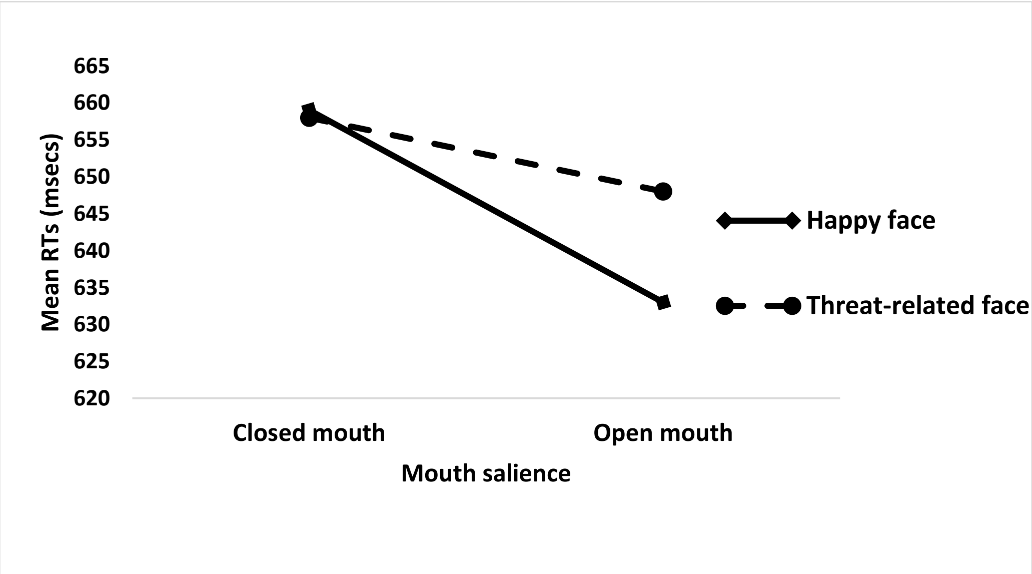

Figure 4.4: The RT interaction between the valence of the emotional faces (happy versus threat-related) and the salience of the mouths of the faces (open versus closed).

The interaction between valence and task was not significant ($F[1,80]=0.7$, $p=0.412$, $\eta^2=0.008$), and did not significantly interact with social anxiety ($F[1,80]=0.2$, $p=0.653$, $\eta^2=0.003$). Therefore RTs for happy faces were similar in both discrimination tasks (the mean RT for happy faces in the happy/fear task was 646 msecs; 95% CI 624-667; SE 11; the mean RT for happy faces in the happy/anger task was 645 msecs; 95% CI 624-667; SE 11), and RTs for threat-related faces in both discrimination tasks were similar (the mean RT for fearful faces in the happy/fear task was 654 msecs; 95% CI 632-675; SE 11; the mean RT for angry faces in the happy/anger task was 650 msecs; 95% CI 628-671; SE 11). These task similarities were true at all levels of social anxiety.

The interaction between mouth type and discrimination task was also not significant ($F[1,80]=0.006$, $p=0.939$, $\eta^2<0.001$), and did not significantly interact with social anxiety ($F[1,80]=0.1$, $p=0.779$, $\eta^2=0.001$). The 3-way interaction between valence, mouth type and discrimination task was also not significant ($F[1,80]=1.1$, $p=0.301$, $\eta^2=0.013$), and did not significantly interact with social anxiety ($F[1,80]<0.001$, $p=0.983$, $\eta^2<0.001$).

We now return to the aforementioned interaction between social anxiety and valence, and the interaction between valence and mouth type. As planned we explored the social anxiety by valence interaction using correlational analysis, in order to elucidate if any specific valence type was driving the interaction. In short, to explore our key hypotheses further we wished to determine whether RTs to just the happy faces, just the threat-related faces, or both types of faces were correlated with social anxiety. However, these analyses showed that social anxiety was not correlated with average RTs to happy faces (r= -0.03, p=0.826), nor average RTs to threat-related faces (r= -0.09, p=0.424).

We further explored the interaction between valence and mouth type using four one-way ANCOVAS, including standardised social anxiety as the covariate. Here we adopt an adjusted significance level of 0.025/4 (thus our accepted covariate significance level was p=0.006). The first one-way ANCOVA showed that happy faces with open mouths were responded to faster (mean RT 632 msecs; 95% CI 611-653; SE 11) than happy faces with closed mouths (mean RT 659 msecs; 95% CI

638-679; SE 10). This RT advantage was highly significant (F[1,80]=100.9, p<0.001, η^2=0.558), but did not further interact with social anxiety (F[1,80]=0.2, p=0.695, η^2=0.002). Thus, social anxiety was not significantly related to this RT difference. The correlation value was r = -0.04. The second one-way ANCOVA showed that threat-related faces with open mouths were responded to faster (mean RT 646 msecs; 96% CI 625-667; SE 11) than threat-related faces with closed mouths (mean RT 657 msecs; 95% CI 636-678; SE 10). This RT advantage was significant (F[1,80]=11.3, p=0.001, η^2=0.124), and again did not further interact with social anxiety (F[1,80]=1.2, p=0.285, η^2=0.014). Thus, social anxiety was not significantly related to this RT difference. The correlation value was r = -0.12.

Next, we considered the RT differences between responses to threat-related faces with salient open mouths and responses to happy faces with open mouths. The third one-way ANCOVA showed that threat-related faces with open mouths were responded to slower than happy faces with salient open mouths. This RT effect was significant (F[1,80]=14.9, p<0.001, η^2=0.157). Once again, this comparison did not significantly interact with social anxiety (F[1,80]=1.7, p=0.193, η^2=0.021). This interaction tests the correlation between social anxiety and the RT difference between responses to threat-related faces with open mouths and happy faces with open mouths. The correlation value was r= -0.15. Our fourth and final one-way ANCOVA showed that RTs for threat-related faces with closed mouths were not significantly different from RTs for happy faces with closed mouths (F[1,80]=0.2, p=0.643, η^2=0.003). However, critically for our key area of interest this non-significant comparison interacted with social anxiety at a very near significant level, judged against the adjusted p=0.006 significance level (F[1,80]=7.6, p=0.007, η^2=0.087). This interaction tests the correlation between social anxiety and the RT difference between responses to threat-related faces with closed mouths and happy faces with closed mouths (threat-related face RTs minus happy face RTs). The correlation value was r= -0.3. The last two one-way ANCOVAS illustrate how the reduced happy face recognition advantage in social anxiety may be driven more by the closed mouth trials, than the open mouth trials. In making this comment, one must bear in mind that the social anxiety by valence by mouth type interaction was not significant, as noted above. This interaction is the formal test that the social anxiety dependent RT disadvantage for happy faces (cf negative faces) is significantly greater for closed mouth rather than open mouth expressions.

Exploratory correlations (with unadjusted p-values) showed that social anxiety was not significantly correlated with average RTs for happy faces with closed mouths (r= -0.03, p=0.788), or average RTs for threat-related faces with closed mouths (r= -0.12, p=0.336). However, the sign of the correlations is in the direction that social anxiety relates to faster RTs for threat-related faces with closed mouths.

4.4.4. STAI-trait RT analysis

As planned, we repeated the main ANCOVA including STAI-trait scores as the covariate, as this was also a key area of interest for us. The test of between-subjects effects showed that STAI-trait scores did not correlate with RTs averaged across the whole experiment (F[1,80]=0.6, p=0.435, η^2=0.008). STAI-trait scores shared no significant covariate interactions with any of the within-subjects comparisons. The only effect worthy of reporting was a valence by discrimination task by STAI-trait score interaction (F[1,80]=4.5, p=0.036, η^2=0.053), but this was not quite formally significant at our adjusted initial covariate significance level of p=0.025. All other covariate interactions were even weaker (all Fs <0.9, all ps > 0.3). Given the large number of comparisons we do not analyse the trend towards a valence by discrimination task by STAI-trait score interaction any further.

4.4.5. Exploratory STAI-anxiety and STAI-depression RT analyses

We carried out our planned exploratory correlations using the STAI-anxiety and STAI-depression subscales of the STAI-trait measure, as this was another key interest of ours. The non-significant trend towards a valence by discrimination task by STAI-trait score interaction provided us with a clue as to where any STAI-anxiety effects may lie. We therefore analysed the effect of STAI-anxiety and STAI-depression upon each discrimination task separately. The zero-order correlation between STAI-anxiety and the RT difference score in the happy/fear condition was (r= -0.23, p=0.037), whereas the zero-order correlation between STAI-depression and this RT difference score was (r= -0.12, p=0.284). When controlling for depression the partial correlation between STAI-anxiety and the RT difference score in the happy/fear condition was weakened (r= -0.2, p=0.069). When controlling for STAI-anxiety the partial correlation between STAI-depression and this RT difference score was (r= 0.04, p=0.707). The zero-order correlation between STAI-anxiety and the RT difference score in the happy/anger condition was (r= 0.06, p=0.587), whereas the zero-order correlation between STAI-depression and this RT difference score was (r= 0.09, p=0.405). When controlling for STAI-depression the partial correlation between STAI-anxiety and the RT difference score in the happy/anger condition was (r<0.001, p=0.999). When controlling for STAI-anxiety the partial correlation between STAI-depression and the RT difference score in the happy/anger condition was (r=0.07, p=0.531).

4.4.6. Correlational RT analyses controlling for general RT

As with experiment 1, we suspected that the correlations between social anxiety and the specific RT effects in any single condition were likely to have been suppressed by general sources of RT variance shared across all conditions. Thus we calculated a general RT factor. Exploratory factor analyses clearly revealed a strong general RT factor across all conditions for both discrimination tasks. To estimate the general RT factor we used a maximum likelihood extraction of two factors using mean RTs from each participant for each of the 8 stimulus types. Factor 1 was clearly the general RT factor (all loadings > 0.91), which accounted for 86% of the variance). Factor 2 was small and accounted for 6% of the variance. The pattern of the loadings appeared to support the view that factor 2 was a discrimination task factor. In short, stimuli from the happy/fear discrimination task all loaded positively on factor 2, whereas stimuli from the happy/anger discrimination task all loaded negatively on factor 2. We used the general RT factor in a series of exploratory partial correlations to determine if social anxiety shared any suppressed RT correlations with any specific emotional facial expression. These correlations have not been adjusted for multiple testing and should therefore be treated with caution.

When controlling for the general RT factor, exploratory partial correlation showed that social anxiety shared a negative correlation with RTs to threat-related faces (averaged across discrimination task; r= -0.25, p=0.025). Therefore, as a person's level of social anxiety increased, their RTs to threat-related faces decreased. When controlling for the general RT factor, exploratory partial correlation showed that social anxiety shared a positive correlation with RTs to happy faces (averaged across discrimination task; r= 0.28, p=0.012). Therefore, as a person's level of social anxiety increased, their RTs to happy faces increased. In summary, participants who were higher in social anxiety responded faster to threat-related faces, and responded slower to happy faces, relative to participants lower in social anxiety. These correlations directly reflect our key hypotheses concerning how social anxiety will affect emotional face processing.

Further exploratory partial correlations showed that when controlling for the general RT effects social anxiety was correlated with RTs to threat-related faces with closed mouths (r= -0.3, p=0.008), but not open mouths (r= -0.07, p=0.525). Moreover, social anxiety was correlated with RTs to happy faces with closed mouths (r= 0.22, p=0.048), and similarly, although slightly less strongly, with RTs to happy faces with open mouths (r= 0.18, p=0.107).

Our final exploratory partial correlations showed that when controlling for the general RT factor STAI-anxiety was correlated with RTs to fearful faces (r= -0.23, p=0.035), but not happy faces (r= -0.02, p=0.897), in the happy/fear discrimination task. In addition, when controlling for the general RT factor STAI-depression was uncorrelated with RTs to fearful faces (r= -0.12, p=0.291), and happy faces (r< 0.001, p=0.999).

4.4.7. Exploratory attentional control analyses

We conducted further planned analyses concerning self-reported attentional control. Table 4.2 contains the correlations between the primary social anxiety and STAI-trait measures, the exploratory STAI-trait subscale measures, and the additional attentional control measures. These correlations are exploratory in nature, are intended to aid further hypothesis generation; and should be treated with caution as the p-values have not been adjusted for multiple testing.

Table 4.2: The correlations between social anxiety, STAI-trait, STAI-anxiety, STAI-depression, ACS-total, ACS-focusing and ACS-shifting.

	1	2	3	4	5	6	7
1: Social anxiety		0.55***	0.50***	0.51***	-0.20	-0.16	-0.18
2: STAI-trait			0.87***	0.95***	-0.40***	-0.35***	-0.34***
3: STAI-anxiety				0.65***	-0.31**	-0.31**	-0.22*
4: STAI-depression					-0.40***	-0.32**	-0.37***
5: ACS-total						0.87***	0.83***
6: ACS-focusing							0.46***
7: ACS-shifting							

*(*p<0.05, **p<0.01, ***p<0.001).*

We carried out further planned exploratory correlations between the attentional control subscales and the emotional face RT difference scores. Once again these correlations have not been adjusted for multiple testing and should be treated with caution. Attentional focusing was positively correlated with the average RT difference between happy faces and threat-related faces (r= 0.24, p=0.030). This correlation was driven primarily by a positive correlation with the RT difference between happy and fearful faces (r= 0.28, p=0.010), but not happy and angry faces (r= 0.09, p=0.406). In contrast, attentional shifting was not correlated with any of these RT difference scores (all rs < 0.13, all ps > 0.23). As both STAI-anxiety and attentional focusing were correlated with the RT difference between happy and fearful faces, in addition to being correlated with each other, we further probed these associations using regression models. Table 4.3 shows that the attentional focusing and STAI-anxiety correlations with the RT difference between happy and fearful faces was due to substantial shared components of attentional focusing and trait anxiety (as measured by the STAI-anxiety subscale). The attentional focusing regressions in step 2 of our analyses show that attentional focusing was not a reliable predictor of the happy/fear RT difference scores, when controlling for STAI-trait scores (the correlation value would be r=0.21, p=0.054 as shown in Table 4.3). Moreover, STAI-trait scores did not predict the happy/fear RT difference scores when controlling for attentional focusing (the correlation value would be r= -0.14, p=0.192 as also shown in Table 4.3).

Table 4.3: Regression analyses showing how attentional focusing and STAI-anxiety predict the RT difference between responses to happy and fearful faces.

	B	*SE B*	*beta*
Dependant variable: happy/fear RT diff			
Step 1 (R^2= 0.08)**	0.008	0.003	0.277**
ACS-focusing			
Step 2 (R^2= 0.10*)			
ACS-focusing	0.006	0.003	0.221
STAI-anxiety	-0.004	0.003	-0.149
Dependant variable: happy/fear RT diff			
Step 1 (R^2= 0.05*)			
STAI-anxiety	-0.006	0.003	-0.231*
Step 2 (R^2=0.10*)			
STAI-anxiety	-0.004	0.003	-0.149
ACS- focusing	0.006	0.003	0.221

(*p<0.05, **p<0.01; please note that the attentional focusing regressions in step 2 of our regression analyses could be considered borderline significant at p=0.054).

We carried out further exploratory correlations to verify whether attentional focusing predicted RTs for either happy faces or fearful faces in the happy/fear condition. When controlling for attentional shifting and general RT effects, attentional focusing was not significantly correlated with RTs to either the happy faces or fearful faces from the happy/fear discrimination condition (both *r*s < 0.13, *p*s>0.26).

We also wished to determine whether STAI-anxiety and STAI-depression share any unique relationships with attentional focusing and attentional shifting, with a view to clarifying the discriminant validity of the STAI-subscales. Table 4.4 illustrates our regression analyses showing the differential relationships between both attentional focusing and attentional shifting and the STAI-anxiety and STAI-depression subscales. We present this data in the same way as other recently published papers to aid a direct comparison. Table 4.4 shows that attentional shifting independently (and negatively) predicted depression (after controlling for anxiety) and not anxiety (after controlling for depression). In contrast, attentional focusing did not independently predict depression (after controlling for anxiety), nor did it significantly independently predict anxiety (after controlling for depression), although it is noteworthy that the sign of the latter partial correlation was negative.

Table 4.4: Regression analyses using the attentional focusing and attentional shifting subscales of the attentional control scale to predict STAI-anxiety and STAI-depression.

	B	***SE B***	***beta***
Dependant variable: STAI-anxiety			
Step 1 (R^2= 0.42*)**			
STAI-depression	0.43	0.05	0.65***
Step 2 (R^2= 0.45*)**			
STAI-depression	0.42	0.06	0.64***
ACS-focusing	-0.10	0.08	-0.14
ACS-shifting	0.06	0.07	0.08
Dependant variable: STAI-depression			
Step 1 (R^2= 0.42*)**			
STAI-anxiety	1.00	0.13	0.65***
Step 2 (R^2=0.49*)**			
STAI-anxiety	0.91	0.13	0.60***
ACS-focusing	-0.04	0.10	-0.04
ACS-shifting	-0.26	0.10	-0.22*

Note: This table follows the same format as Reinholdt-Dunne et al. (2013) and Judah et al. (2013) to facilitate a direct comparison with their regression analyses (*p<0.05, **p<0.01, ***p<0.001).

4.4.8. Accuracy analyses

The proportion correct data were first subjected to a 2 (valence; happy face versus threat-related face) x 2 (mouth salience; closed mouth versus open mouth) x 2 (discrimination task; happy/fear discrimination versus happy/anger discrimination) repeated-measures ANCOVA with standardised social anxiety as the covariate. Once again we also repeated the same analysis but included standardised STAI-trait scores as the covariate. To account for multiple testing of a covariate we again adopt an adjusted significance level of 0.05/2 for all of the covariate interactions. The descriptive statistics for the proportion correct for each of the eight trial types are shown in Table 4.5. Figure 4.5 shows the mean proportion correct, for each of the 8 stimulus types.

Table 4.5: Mean proportion correct (Prop/c), 95% confidence intervals (95% CIs), and standard errors (SE) for each of the 8 stimulus types (listed by target emotion versus mouth versus discrimination task).

Happy/fear task				Happy/anger task			
Trial type	**Prop/c**	**95% CI**	**SE**	**Trial type**	**Prop/c**	**95% CI**	**SE**
Happy closed	0.94	0.92-0.95	0.007	**Happy Closed**	0.95	0.94-0.96	0.005
Happy open	0.96	0.95-0.97	0.005	**Happy Open**	0.96	0.95-0.97	0.005
Fear closed	0.94	0.93-0.95	0.006	**Anger Closed**	0.95	0.94-0.96	0.006
Fear open	0.94	0.93-0.95	0.006	**Anger Open**	0.94	0.93-0.95	0.005

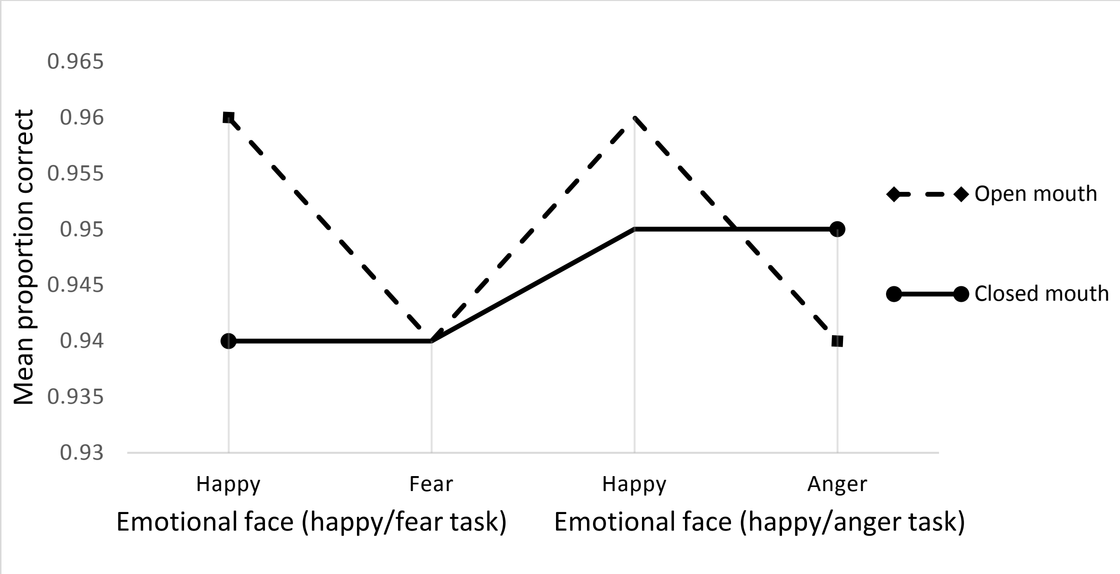

Figure 4.5: Mean proportion correct, for each of the 8 stimulus types (listed by target emotion versus mouth versus discrimination task).

4.4.9. Social anxiety accuracy analysis

The test of between-subjects effects showed that social anxiety was not significantly related to accuracy averaged across the whole experiment (F[1,80]=0.7, p=0.789, η^2=0.001). The key findings of the test of within-subjects effects were that the main effect of valence was significant (F[1,80]=9.0, p=0.004, η^2=0.101), but this did not significantly interact with social anxiety (F[1,80]=0.01, p=0.912, η^2<0.001). Therefore there was a small but significant difference between the proportion correct for happy faces averaged across the experiment (mean proportion correct 0.95; 95% CI 0.94-0.96; SE 0.004), and proportion correct for threat-related faces averaged across the experiment (mean proportion correct 0.94; 95% CI 0.93-0.95; SE 0.004), but social anxiety did not affect this difference in accuracy.

The main effect of mouth salience was also significant (F[1,80]=4.4, p=0.038, η^2=0.053), and this also did not significantly interact with social anxiety (F[1,80]=0.1, p=0.794, η^2=0.001). This shows that the proportion correct for facial expressions with open mouths (mean proportion correct 0.95; 95% CI 0.94-0.96; SE 0.004) was greater than the proportion correct for facial expressions with closed mouths (mean proportion correct 0.94; 95% CI 0.94-0.95; SE 0.004), but social anxiety did not affect this difference in accuracy.

Moreover, the main effect of discrimination task just reached significance (F[1,80]=4.1, p=0.045, η^2=0.049), and this effect also did not significantly interact with social anxiety (F[1,80]=2.6, p=0.114, η^2=0.031). This shows that there was a small accuracy difference between discrimination task, but no social anxiety related differences in accuracy between the two discrimination tasks. The proportion correct in the anger/happy task (mean proportion correct 0.95; 95% CI 0.95-0.96; SE 0.004) was greater than in the fear/happy task (mean proportion correct 0.94; 95% CI 0.94-0.96; SE 0.005).

The interaction between valence and mouth type was significant (F[1,80]=7.2, p=0.009, η^2=0.083), but this interaction did not significantly further interact with social anxiety (F[1,80]=0.3, p=0.586, η^2=0.004). The mean proportions correct for the happy faces and threat-related faces, subdivided according to mouth type, are illustrated in Figure 4.6.

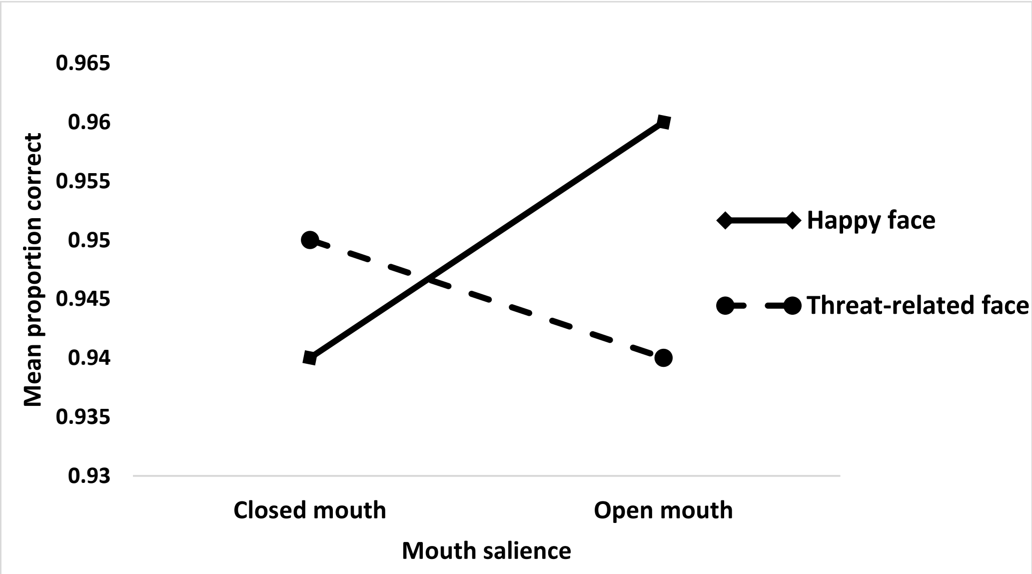

Figure 4.6: The accuracy interaction between the valence of the emotional faces (happy versus threat-related) and the salience of the mouths of the faces (open versus closed).

The interaction between valence and task was not significant (F[1,80]=0.3, p=0.855, η^2<0.001), and did not significantly interact with social anxiety (F[1,80]=0.01, p=0.923, η^2<0.001). Therefore accuracy levels for happy faces were similar in both discrimination tasks (the mean proportion correct in the happy/fear task was 0.95;

95% CI 0.94-0.96; SE 0.005; the mean proportion correct in the happy/anger task was 0.96; 95% CI 0.95-0.96; SE 0.004), and accuracy levels for threat-related faces in both discrimination tasks were similar (the mean proportion correct in the happy/fear task was 0.94; 95% CI 0.93-0.95; SE 0.005; the mean proportion correct in the happy/anger task was 0.95; 95% CI 0.94-0.96; SE 0.005). These similarities were true at all levels of social anxiety.

The interaction between mouth type and discrimination task was not quite significant ($F[1,80]=3.0$, $p=0.085$, $\eta^2=0.037$), and did not significantly further interact with social anxiety ($F[1,80]=0.8$, $p=0.372$, $\eta^2=0.010$). The 3-way interaction between valence, mouth type and discrimination task was also not significant ($F[1,80]=4.8$, $p=0.031$, $\eta^2=0.057$), and did not significantly interact with social anxiety ($F[1,80]=0.2$, $p=0.620$, $\eta^2=0.003$).

We further explored the previously reported accuracy interaction between valence and mouth type using four one-way ANCOVAS, including standardised social anxiety as the covariate. Here we adopt an adjusted significance level of 0.025/4 (thus our accepted covariate significance level was p=0.006). The first one-way ANCOVA showed that the proportion correct for happy faces with open mouths was greater (mean proportion correct 0.96; 95% CI 0.95-0.97; SE 0.004) than happy faces with closed mouths (mean proportion correct 0.94; 95% CI 0.93-0.95; SE 0.005). This open mouth accuracy advantage was highly significant ($F[1,80]=14.3$, $p<0.001$, $\eta^2=0.152$), but did not further interact with social anxiety ($F[1,80]=0.1$, $p=0.739$, $\eta^2=0.001$).The second one-way ANCOVA showed that the proportion correct for threat-related faces with open mouths (mean proportion correct 0.94; 95% CI 0.93-0.95; SE 0.005) was not significantly different than threat-related faces with closed mouths (mean proportion correct 0.95; 95% CI 0.94-0.96; SE 0.005; $F[1,80]=0.9$, $p=0.356$, $\eta^2=0.011$). This effect also did not interact with social anxiety ($F[1,80]=0.3$, $p=0.584$, $\eta^2=0.004$).

The third one-way ANCOVA showed that the proportion correct for happy faces with open mouths was greater than threat-related faces with open mouths. This open mouth accuracy advantage for happy faces relative to threat-related faces was highly significant ($F[1,80]=17.1$, $p<0.001$, $\eta^2=0.176$), and did not further interact with social anxiety ($F[1,80]=0.1$, $p=0.717$, $\eta^2=0.002$). The fourth one-way ANCOVA showed that the proportion correct for happy faces with closed mouths was less than threat-related faces with closed mouths. However, this accuracy difference was not significant (F[1,80]=0.2, p=0.879, η^2<0.001), and did not interact with social anxiety (F[1,80]=0.2, p=0.636, η^2=0.003).

4.4.10. STAI-trait accuracy analysis

As planned we repeated the main ANCOVA including STAI-trait scores as the covariate. The test of between-subjects effects showed that STAI-trait scores were not significantly related to accuracy levels averaged across the whole experiment (F[1,81]=0.01, p=0.925, η^2<0.001). The test of within-subjects effects showed that STAI-trait scores were not significantly related to any trial type and/or task interactions (all *F*s <1.8, all *P*s > 0.19). Accordingly, we did not conduct any further accuracy analyses concerning STAI-anxiety and STAI-depression.

4.5. Discussion

The key findings in this experiment were that overall RTs to the happy faces were faster than RTs to the threat-related faces. This finding is consistent with the results of experiment 1 and the general finding of a happy face recognition advantage, relative to negatively-valenced faces in the studies by Silvia et al. (2006), Cooper, Rowe and Penton-Voak (2008), Leppanen and Hietanen (2003), Leppanen and Hietanen (2004), Kirita and Endo (1995), and Feyereisen, Malet and Martin (1996), Werheid, Alpay, Jentzsch and Sommer (2005). Even though in the present study the happy face versus threat-related face RT difference was quite small, social anxiety was clearly related to a reduced difference in RTs between happy faces and threat-related faces. However, social anxiety did not appear to be correlated with average RTs to happy faces, nor average RT for threat-related faces. The finding that social anxiety relates to a reduced happy face recognition advantage is in alignment with the study by Silvia et al. (2006). In the present study happy faces were also responded to more accurately than threat-related faces but this happy face detection accuracy advantage was unaffected by social anxiety.

In the present study, facial expressions with salient open mouths were responded to faster and more accurately than facial expressions with less salient closed mouths. Social anxiety did not affect either the RT advantage, or the accuracy advantage for averaged facial expressions with open mouths. The RT advantage for the more salient open mouths, relative to closed mouths, was reduced when processing threat-related faces relative to happy faces. These analyses suggest that the salience of individual features enhances emotional expression recognition more during the processing of happy faces. These findings also lend some support the suggestions of Calvo and Nummenmaa (2008), who showed that observed facial mouth regions are important during situations requiring facial emotion detection. It is however interesting that in the present study this mouth salience effect was not further increased in social anxiety.

As planned we also explored the RT differences between responses to threat-related faces with salient open mouths and responses to happy faces with salient open mouths. Threat-related faces with open mouths were responded to slower than happy faces with open mouths. This RT effect was not significantly correlated with social anxiety, however the relationship was negative. RTs for threat-related faces with closed mouths were similar to RTs for happy faces with closed mouths. However, here we found an effect of social anxiety. Social anxiety was negatively related to the RT difference: threat-related face RT minus happy face RT. These analyses tentatively suggest that the reduced happy face recognition advantage in social anxiety was driven primarily by responses to faces with closed mouths, not responses to faces with open mouths. However, exploratory correlations suggested that in the present study, social anxiety was not significantly correlated with RTs to happy faces with closed mouths or threat-related faces with closed mouths, thus the social anxiety effect appeared to be manifested only in the RT difference computation. As discussed below general RT effects are subtracted out in the RT difference measures, but are present in the single condition RTs. Thus, if general RTs are a major source of variance in every condition, and are not related to social anxiety, then this will suppress the study’s ability to detect trait relationships with RTs in specific conditions.

The present results suggest that the processing of highly intense emotional faces with salient open mouths was similar at all levels of social anxiety. In contrast, the processing of moderately intense emotional faces with low-salient closed mouths was affected by social anxiety levels. This finding lends some support to the cognitive account of anxiety proposed by Mogg and Bradley (1998). Mogg and Bradley suggest that stimuli indicating a mild level of threat will be appraised as being more threat-relevant by those high in anxiety relative to those low in anxiety, as high anxiety is related to an oversensitive valence evaluation system. Similarly, Mathews and Mackintosh (1998) also proposed that strong threat cues will affect attention regardless of anxiety levels, but weak threat cues will only affect attention of those high in anxiety. In the present study the salient open mouths of the fearful and angry faces may have been processed as the same level of threat at all levels of social anxiety. In contrast, the non-salient closed mouths of the fearful and angry faces may have been processed as being more threat-related, by those high in social anxiety, relative to those low in social anxiety. The current study's findings, and these cognitive accounts of anxiety can also be accommodated with the emotional survival circuits framework theorised by LeDoux (2012). A hyper-sensitive threat evaluation system, and the resulting threat-related RT bias for less salient threat-related facial expressions, would likely reflect an increased sensitivity in the triggering of the emotional survival circuit. However, it is noteworthy that the study by Mogg et al. (2007) showed the opposite, as the effects of anxiety only appeared with high intensity fearful and angry faces not low intensity fearful and angry faces.

As with experiment 1, we suspected that the correlations between social anxiety and any specific RT effects were likely to have been suppressed by general sources of RT variance. We calculated a general RT factor using factor analysis. When controlling for this general RT factor, social anxiety shared a significant negative correlation with RTs to threat-related faces. Therefore, those higher in social anxiety responded faster to threat-related faces than those lower in social anxiety. Similarly, when controlling for this general RT factor, social anxiety shared a significant positive correlation with RTs to happy faces. Therefore, those higher in social anxiety responded to happy faces slower than those lower in social anxiety. Moreover, when controlling for these general RT effects, social anxiety was related to faster RTs to threat-related faces with closed mouths, but not open mouths. However, social anxiety was also related to slower RTs to happy faces with closed mouths, but not significantly with RTs to happy faces with open mouths. These correlations add further weight to our suggestion that the threat-related but low-salient closed mouths were processed as more threatening by those high in social anxiety, relative to those low in social anxiety.

It is noteworthy here that social anxiety was related to both faster RTs to threat-related faces and slower RTs to happy faces. This observation supports our explanation of the trait anxiety results in experiment 1. To reiterate, based upon the notion of emotional survival circuits in the brain (LeDoux, 2012), we suggested that those high in trait anxiety may have a more reactive survival circuit response to threat-related stimulation relative to adaptive reward stimulation, whereas those low in trait anxiety may have a more reactive survival circuit response to adaptive reward stimulation relative to threat-related stimulation. In experiment 1 trait anxiety was related to faster RTs to fearful faces, but the happy face RTs did not correlate with trait anxiety. The present study shows that this happy face correlation is indeed present (but with social anxiety), which increases the validity of our explanation.

As planned we repeated the main RT analysis, this time we included STAI-trait scores as the covariate instead of social anxiety scores. We found no reliable effects of the STAI-trait scores in this analysis. This shows that the STAI-trait scale is a much less reliable as a predictor of emotional face processing than the social anxiety scale. However, we anticipated that we may detect the effects of anxiety and emotional face processing by using the STAI-anxiety subscale.

We carried out planned exploratory correlations using the STAI-trait subscales. STAI-anxiety scores were related to a reduced RT difference score in the happy versus fear discrimination task, whereas STAI-depression scores were not. This lends some support for the discriminant validity of the STAI subscales proposed by Bieling et al. (1998). However, when controlling for STAI-depression scores the correlation between STAI-anxiety scores and this RT difference score was unreliable. Neither STAI-anxiety scores nor STAI-depression scores were related to the RT difference score in the happy versus anger discrimination task. When controlling for the general RT factor STAI-anxiety was related to faster RTs to fearful faces, but not happy faces, in the happy versus fear discrimination task. This finding is consistent with the results of experiment 1. In addition, STAI-depression was uncorrelated with RTs to fearful faces, and happy faces in this task. As planned we repeated the accuracy analyses using STAI-trait scores. STAI-trait scores were not significantly related to any trial type and/or task interactions. Accordingly, we did not conduct any further accuracy analyses concerning STAI-anxiety scores and STAI-depression scores.

The exploratory analyses using the STAI-anxiety scale do suggest that trait anxiety may be selectively related to the processing of fearful faces, whereas social anxiety seems related to the processing of both fearful and angry faces. It is noteworthy here that social anxiety, STAI-anxiety, and STAI-depression were all only moderately correlated with each other.

We also administered the attentional control scale (Derryberry & Reed, 2001, 2002) partly in order to further clarify the discriminant validity of the STAI-trait subscales, and partly to explore any possible behavioural effects relative to attentional control. Social anxiety was not significantly correlated with self-reported attentional control total scores, nor with attentional focusing scores, and nor with the attentional shifting scores. In contrast, STAI-trait, STAI-anxiety, and STAI-depression were all correlated with the attentional control total scores, the attentional focusing scores, and the attentional shifting scores. The finding that STAI-trait score correlated with the total attentional control scores is consistent with the studies by Reinholdt-Dunne et al. (2009) and Walsh, Balint, Smolira SJ, Fredericksen and Madsen (2009). However, we were primarily interested in the attentional control subscales. Exploratory correlations showed that attentional focusing was positively correlated with the RT difference between happy faces and threat-related faces. This correlation was due to a positive correlation between attentional focusing and the RT difference between happy and fearful faces, as opposed to the happy and angry faces. Thus as self-reported attentional focusing increased, so did the happy face recognition advantage. In contrast, attentional shifting was not correlated with any of these RT difference scores. Exploratory correlations showed that when controlling for both attentional shifting scores and general RT effects, attentional focusing was not related to RTs for either happy faces or fearful faces from the happy versus fear discrimination task.

STAI-anxiety and attentional focusing were inversely related, but both predicted the happy face recognition advantage. It therefore comes as no surprise that STAI-anxiety predicted a reduced happy face recognition advantage, whereas attentional focusing predicted an increased happy face recognition advantage. The attentional focusing and STAI-anxiety correlations with the RT difference between happy and fearful faces seemed to be due to some substantial shared cognitive resources between attentional focusing and trait anxiety (as measured by the STAI-anxiety subscale). Attentional focusing was not a reliable predictor of the happy/fear RT difference scores, when controlling for STAI-trait scores. Moreover, STAI-trait scores did not predict the happy/fear RT difference scores when controlling for attentional focusing.

Attentional shifting independently predicted STAI-depression but not STAI-anxiety. Attentional focusing did not independently predict STAI-depression, nor did it independently predict STAI-anxiety. This analysis shows that the discriminant validity of the depression subscale was much more reliable than the anxiety subscale. This finding is consistent with the suggestions that the discriminant validity of the anxiety subscale may be questionable (Bados et al., 2010). As discussed, the anxiety subscale was previously found to have lower convergent validity than the depression subscale (Bieling et al., 1998). In short, the present analysis only partially supports the findings of Judah et al. (2013) and Reinholdt-Dunne et al. (2013), who reported that attentional focusing much more reliably predicted STAI-anxiety than STAI-depression, and attentional shifting much more reliably predicted STAI-depression than STAI-anxiety.

The present study used photographs of real people posing emotional faces, as an ecologically valid test of emotion recognition. However in the real world the context provided by the events immediately preceding any experience of an emotional face may affect information processing. Lang, Bradley and Cuthbert (1998) propose that the evolutionary basis of emotion has a dual-factor motivationally-based organisation. Lang et al. propose that there are two brain systems that mediate adaptive responses to appetitive or aversive stimuli. Lang et al. propose that activation or arousal levels of each system can vary. Lang et al. conceptualise arousal as the intensity of activation (neural and/or metabolic) of each (or both) of the systems when activated. Accordingly, in this view arousal is not considered to have an independent substrate. This view is perhaps unsurprisingly highly compatible with RST (Gray & McNaughton, 2000), and its notion that the two slave systems; BAS and FFFS, predominantly processing appetitive and aversive stimuli. Lang et al. suggest that the brain's memory associations, representations and actions, which are associated with either active motivational system, are "primed" for activation. In other words, they have an increased likelihood of being used relative to other stored information or responses, and their potential strength of output is increased. Accordingly, memory associations, representations and actions that are associated with the inactive system have a lower likelihood of use. This emotional priming model suggests that any defensive reflex occurring to potential threat should be magnified if the organism is already processing an aversive stimulus as the defensive system is already active. This same reflex should be reduced if the organism is already reacting to an appetitive stimulus. This emotional priming account is also compatible with the theory of emotional survival circuits proposed by LeDoux (2012). In short, the survival circuit triggers could become more sensitive, if their activation was primed.

We suggest that a future study involving a partial replication of the present study, but also including the priming propositions of Lang et al. (1998), would usefully extend knowledge of this area. Hietanen and Astikainen (2013) used a priming paradigm to investigate how emotional facial expression recognition is affected by the context provided by prior emotional visual stimuli. Primes were either negatively-valenced or positively-valenced pictures whereas the target faces depicted either happy or sad faces. Four affective trial types were included in this paradigm; a happy face preceded by a positive prime; a happy face preceded by a negative prime; a sad face preceded by a positive prime; and a sad face preceded by a negative prime. Thus, there were two emotionally congruent pairs of targets and primes, and two emotionally incongruent pairs of targets and primes.

Hietanen and Astikainen (2013) found that happy faces were recognised more accurately and were responded to faster than sad faces. Happy faces were recognised more accurately when they followed positive primes as opposed to negative primes. Sad faces were recognised more accurately when they followed negative primes as opposed to positive primes. The priming effect for accuracy was stronger for sad faces than for happy faces. RTs for happy faces following positive primes were faster than for happy faces following negative primes. However, RTs for sad faces following negative primes only showed a trend towards being faster than RTs for sad faces following positive primes. The RT priming effect was stronger for happy faces than for sad faces. These findings lend some support to the emotional priming model proposed by Lang et al. (1998), and may be important when trying to understand how anxiety affects emotional face discrimination. We suggest that a further trait anxiety or social anxiety study (but including happy versus threat-related faces) should be conducted using this priming paradigm as anxiety may be affected by emotional priming effects. Moreover, a design such as this may provide evidence of how the survival circuits proposed by LeDoux (2012) are primed for activation, and also how this affects trait or social anxiety.

In a similar priming study, Werheid, Alpay, Jentzsch and Sommer (2005) used an emotional facial expression recognition task consisting of sequences of angry and happy faces. Half of the target stimuli were primed as the previous expression depicted the same emotion. The other half of the target stimuli were un-primed as the previous expression depicted the alternative expression to the target stimuli. RTs for target happy facial expressions were faster than RTs for target angry facial expressions. Moreover, overall RTs for target facial expressions were faster when they were primed relative to when they were un-primed. However, the critical finding of this study was that there was an interaction between this priming effect and the valence of the target facial expression. The priming effect was only present for happy facial expressions. Thus, happy faces were responded to faster when they were primed by a happy face, than when they were primed by an angry face. In contrast, RTs for angry facial expressions were not faster when they were primed (by a previous angry face) relative to when they were un-primed (by a previous happy face). It is possible that this happy face priming effect would be reduced in social anxiety. We suggest that future studies should try to test this.

We also suggest that a further study should be conducted to ascertain the neural basis of the social anxiety effects upon emotional face recognition. We suggest that the priming paradigms discussed could be ideal for this. For example, Hietanen and Astikainen (2013) showed using EEG recordings that the N170 ERP amplitude was greater during the processing of happy faces than sad faces, and larger over the right hemisphere than the left hemisphere. In a future study concerning social anxiety, it seems likely that this effect would be reduced. Moreover, the N170 amplitude in response to facial expressions was modulated by the affective congruency between the target emotional facial expression and the preceding affective picture prime. The N170 amplitude was greater for happy faces following positive primes, than for happy faces following negative primes. Furthermore, the N170 amplitude was also greater for sad faces following negative primes than for sad faces following positive primes. The priming effect for the N170 amplitude was the same for happy and sad faces. The latency of the N170 was shorter for happy faces than sad faces. The latency was shorter for positively primed happy faces than for negatively primed happy faces. There was no effect of prime type upon latency for sad faces. A future study that measures social anxiety may show that these neural priming effects for happy faces are reduced. Moreover, the addition of threat-related faces as opposed to sad faces might show that the neural priming effects are increased in social anxiety.

Werheid et al. (2005) also reported that priming related ERP effects were present independent of the valence of the facial expressions. An early priming effect present in the ERP data was expressed as attenuated amplitudes (present at 100-200 milliseconds) in frontal and occipital regions in response to target facial expressions that were primed. Werheid et al. reported that their dipole model located the probable sources of this effect as the inferior occipitotemporal cortex, and insular cortex. Werheid et al. suggest that the inferior occipitotemporal cortex activity may have been related to the detection of facial configurations that are specific to expressions, whereas the insular cortex activity may reflect affective processing. It is noteworthy that these early ERP effects appeared before the N170 ERP time window. These early ERPs did not show the same pattern as the N170. The N170 (post prime) was clearly present for all of the conditions, and was most clearly present at parieto-occipital regions. The peak N170 amplitude did not differ relative to the valance of the primes. We suggest that a further ERP study may show how this early but valence-unspecific priming effect is also modulated by social anxiety.

Werheid et al. (2005) also reported a late priming effect in the ERP data. The late positive potential (LPP) amplitudes (present at 500-600 milliseconds) were enhanced following target facial expressions that were unprimed. They also suggest that this LPP amplitude enhancement may reflect an attribution of greater relevance to changing emotional facial expressions. It is also possible that this neural activity would be further modulated by social anxiety. Werheid et al. interpreted these ERP findings together as suggesting that configurations of facial information related to emotion can be detected particularly early during the perception of a face, and that the LPP reflects the processing of the level of emotional arousal of the faces as opposed to the actual valence of the expression (i.e., happiness or anger in this case). Werheid et al. suggest that in the real world a change of a person's emotional expression (and thus their probable state of mind) may be more relevant to a viewer (and thus more arousing) than a repeated expression. The present study should be replicated (using primes) whilst recording EEG activity. This may further illustrate how social anxiety is related to differences in emotional facial expression discrimination, and explore whether it is also related to level of emotional arousal.

Further insights into this issue come from a different type of experiment. Li, Zinbarg, Boehm and Paller (2008) used an emotional valence judging task (using a Likert scale) that required participants to rate how negative or positive a face expression was. Target stimuli were preceded by subliminally presented fearful or happy primes. The primes influenced the valence ratings in the following face expression rating task. Li et al. reported that those high in trait anxiety showed enhanced subliminal priming effects from fearful primes (compared to happy primes) than those low in trait anxiety. High anxious participants also displayed an enhanced occipital P1 ERP during fearful trials as compared to happy trials, which was sourced to the bilateral extrastriate cortex. In summary, the studies carried out by Hietanen and Astikainen (2013), and Werheid et al. (2005), all showed that emotional priming affects information processing, whereas Li et al. (2008) showed that emotional priming affects those high in anxiety. Future research should examine this issue in more detail and in the context of discriminating threat related faces from happy faces.

4.6. Conclusion

In conclusion, this study has shown that social anxiety is reliably related to faster responses to threat-related faces, and slower responses to happy faces. However, this effect is only reliable when the facial expressions are shown with less salient closed mouths. Trait anxiety (measured by the anxiety subscale of the STAI) seems to be related specifically to the discrimination of fearful faces from happy faces, whereas social anxiety is related to the discrimination of both fearful and angry faces from happy faces. The interpretability of the overall scores of the STAI is made difficult as it might assess both anxiety and depression, and as such may measure general negative affect. However, the discriminant validity of the anxiety and depression STAI subscales is also something that requires further research. We suggest that future emotional face processing studies should use the social anxiety measure used in the present study as well as trait anxiety measures. Future goal conflict studies may benefit from using the anxiety subscale of the STAI.

Chapter 5

5. Experiment 4

5.1. Introduction

Experiment 1 showed that trait anxiety might relate to the reactivity of a conflict resolution system, and that this might be able to be assessed by using goal conflict tasks, that account for the sequential differences in performance referred to as congruency sequence effects (CSEs). Experiment 1 showed that the flanker task might be a useful tool to assess how trait anxiety relates to the CSE. In contrast, experiment 2 showed that trait anxiety did not relate to the CSE in the Stroop task. As discussed briefly in chapter 2, there are different mechanistic accounts that seek to explain the cognitive / information processing basis of the CSE. Before continuing with any discussion concerning any possible new design for a further experiment it is necessary to explain the key mechanistic accounts of the CSE. These are discussed in turn below.

5.1.1. The conflict monitoring account

As discussed in chapter 2, the CSE has been predominantly explained in the literature by what has become known as conflict monitoring theory (Botvinick, Braver, Carter, Barch, & Cohen; 2001). To reiterate, this account proposes that the stream of information being processed is being constantly monitored for any occurring conflict. Botvinick et al. in their conflict monitoring account of the CSE suggest that response conflict monitored during any current trial modulates cognitive control during the following trial. In tasks used to evaluate the CSE, trials are designated as either congruent (C) or incongruent (I); but the congruency of the preceding trial is indicated with lower case letters (so the set of possible trials can be denoted cC, iI, cI, iI). Performance during iI trials is improved relative to cI trials as cognitive control applied during the current incongruent trial is improved by the previously experienced conflict on the preceding incongruent trial. However, during cI trials performance is poorer than iI trials as cognitive control is not increased because the preceding trial was congruent and so the prior level of conflict was low.

As briefly discussed in chapter 2, this account has been questioned by Nieuwenhuis et al. (2006), who included 892 participants ranging from children to both younger and older adults in their study. The CSE was present only when the target stimulus (and the correct response) was repeated (a detailed description of how target and response repetition is implicated in these paradigms will be given below). This study suggested that basic response repetition priming effects drive the CSE. Moreover, Mayr, Awh, and Laurey (2003) also reported a CSE that was present only with target and response repetition. The findings obtained by Nieuwenhuis et al. and Mayr et al. are more in alignment with Hommels' (1998, 2004, 2007) event file theory. Hommel, Proctor & Vu (2004) have used event file theory to account for the sequential effects found in another conflict task referred to as the Simon task. This theoretical explanation of the CSE is referred to as the feature integration account.

5.1.2. The feature integration account

Hommel (2007) proposes that goal directed behaviour relies upon selectively attending to and recognising any goal relevant stimulus and then responding physically towards it in order to achieve the goal. This behaviour is facilitated by cells in the visual cortex coding colour, shape, motion, form and orientation of relevant stimuli, in addition to coding action features that are under a person's intentional control. Hommel (1998, 2004, 2007) postulates that information pertaining to any behavioural responses, along with their preceding stimuli, is integrated in episodic memory. Hommel refers to these neural based mnemonic representations as event files. Hommel proposes that these event files facilitate stimulus-response priming effects. Accordingly, these priming effects are able to cause impairments in goal directed behaviour in addition to improving goal directed behaviour, during tasks that rely upon motor responses to visually presented stimuli.

In a typical forced choice arrow flanker paradigm with two stimuli types and responses, trials involve either exact stimulus repetitions (e.g., <<<<< then <<<<< for cC trials; and >><>> then >><>> for iI trials), or exact alternations (e.g., <<<<< then >>>>> for cC trials; and <<><< then >><>> for iI trials). However, cI and iC trials involve partial stimulus repetitions (e.g., >>>>> then >><>> for cI trials; and

>><>> then <<<<< for iC trials). For clarity, the sequences of stimuli that occur in flanker tasks are also depicted in Table 5.1

Table 5.1: The sequences of stimuli that occur in a typical two choice arrow flanker task.

Trial type	Repetition type	Previous trial	Current trial
cC	Exact stimulus repetition	<<<<<	<<<<<
cC	Exact stimulus repetition	>>>>>	>>>>>
iI	Exact stimulus repetition	<<><<	<<><<
iI	Exact stimulus repetition	>><>>	>><>>
cC	Exact stimulus alternation	<<<<<	>>>>>
cC	Exact stimulus alternation	>>>>>	<<<<<
iI	Exact stimulus alternation	<<><<	>><>>
iI	Exact stimulus alternation	>><>>	<<><<
iC	Partial stimulus repetition	<<><<	<<<<<
iC	Partial stimulus repetition	>><>>	>>>>>
iC	Partial stimulus repetition	<<><<	>>>>>
iC	Partial stimulus repetition	>><>>	<<<<<
cI	Partial stimulus repetition	<<<<<	<<><<
cI	Partial stimulus repetition	>>>>>	>><>>
cI	Partial stimulus repetition	>>>>>	>><>>
cI	Partial stimulus repetition	<<<<<	>><>>

The feature integration account (Hommel et al., 2004) relies upon the assumption that the stimulus and response features of any previously experienced trial will have been temporarily bound together to form a common episodic memory trace. Therefore, the presence of any of these features during the following trial will automatically co-activate the remaining features of the bound memory trace. Thus, from this perspective, the reason that trials with complete stimulus repetitions and complete stimulus alternations are responded to faster is because no previous feature binding needs to be undone. In other words, a complete stimulus and response repetition will require effortless repeated co-activation of features in the event file. This situation would reflect the target and response repetition priming effect discussed above. A complete stimulus and response alternation would also be processed relatively effortlessly, as no feature binding needs to be undone. In contrast, trials with partial repetitions require the feature binding to be undone before any (correct) response can be made. In iC and cI transitions, one feature changes in the second trial, whilst the other features remain the same as in the first trial. The undoing of previously bound features in the event file, thus slows responses to the following trial. In other words, the feature integration perspective suggests that the partial stimulus repetitions will facilitate the retrieval of episodic memory traces of the previous trial's stimulus and response representations. These representations would partially conflict with the stimuli present in the current trial. According to the feature integration account this would slow RTs to cI and iC trials relative to iI and cC trials, thus producing the CSE. In contrast to conflict monitoring theory, the feature integration account does not involve cognitive control mechanisms, it involves memory mechanisms.

5.1.3. Delineating cognitive control and episodic memory effects upon the CSE

The feature integration account has provoked a multitude of attempts to dissociate the different contributions to the CSE made by higher level cognitions that mediate cognitive control, and lower level cognitions that rely upon episodic memory. Several goal conflict studies show that the CSE is abolished when feature repetitions are not present (e.g., Chen & Melara, 2009; Mayr et al., 2003; Nieuwenhuis et al., 2006; Fernandez-Duque & Knight, 2008). In contrast, several other studies have found that a CSE is present when there is no feature repetition (e.g., Kerns et al., 2004; Kunde & Wuhr, 2006; Ullsperger, Bylsma, & Botvinick, 2005; Clayson & Larson, 2012, 2011a, 2011b). Paradigms using a design that does not include any feature integration to start with have also been used. For example, Duthoo and Notebaert (2012) used an eight colour vocal Stroop task where feature repetition was not possible and found that the CSE was still present. Feature repetition is not possible in a Stroop design that uses eight colours because feature repetitions can be completely excluded at the design stage.

The finding of a CSE when there are no feature repetitions present does not suggest that the feature integration account should be abandoned. It is possible that both feature integration and conflict monitoring may contribute to the CSE (Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Davelaar and Stevens, 2009; Egner, 2007). Indeed, Notebaert, Gevers, Verbruggen, and Liefooghe (2006) illustrated this by varying the response to stimulus interval (RSI) in a Stroop task. Bottom-up priming effects that can be explained as feature integration effects were detected at a very short RSI (50 milliseconds), whereas top-down conflict monitoring effects required longer to affect behaviour (at an RSI of 200 milliseconds). However, it is noteworthy that the feature integration account and the conflict monitoring account explain the CSE during iI trials rather differently. The feature integration account explains the effect as a facilitatory effect driven by stimuli repetitions or alternations, whereas the conflict monitoring account explains the effect as resulting from conflict resolution.

In an extensive review of the CSE, Duthoo et al. (2014) drew attention to the fact that the available neuroimaging evidence seems to support the conflict monitoring account as opposed to the feature integration account. For example, Botvinick et al (2001) suggest that the anterior cingulate (ACC) is specifically implicated in conflict detection (Jones, Cho, Nystrom, Cohen, & Braver, 2002), whereas any subsequent adjustments in the control of behaviour are mediated by the dorsolateral prefrontal cortex (DLPFC; Egner & Hirsch, 2005). Duthoo et al. also suggested that fMRI evidence showing strong DLPFC activation during iI trials supports the conflict monitoring account, and that the feature integration account cannot explain why the CSE is not found when the DLPFC cannot function. For example, transcranial magnetic stimulation (TMS) over the DLPFC abolishes the CSE (Sturmer, Redlich, Irlbacher, & Brandt, 2007). Moreover, surgical removal of the DLPFC (in patients undergoing stereotactic cingulotomy for treatment-refractory obsessive-compulsive disorder) also abolishes the CSE (Sheth et al., 2012).

Davelaar and Stevens (2009) suggest that Hommel's (1998, 2004, 2007) theory of episodic memory event files explains the observed priming effects caused by feature repetitions in the flanker task. However, they postulate that conflict monitored in any previous trial will modulate the size of the priming effect in any current trial. Davelaar and Stevens therefore propose that both priming and conflict monitoring affect the CSE. This suggestion is based upon the finding that the effect is larger for iI trials (when the full stimuli array repeats), than it is for cC trials (when the full stimuli array repeats). In short, the observed response conflict in a current incongruent trial increases the priming effect for the following incongruent trial, more than low conflict congruent trials preceding low conflict congruent trials are able to do. In other words, currently congruent trials cannot increase cognitive control for following congruent trials as they have no attention-increasing conflict. Davelaar and Stevens postulate that the observed level of response conflict in trials therefore modulates the strength of the association between any stimulus and response. Observed correct motor responses increase the association between the stimulus and motor response, whilst observed incorrect responses will decrease this stimulus/response association. This stimulus/response association increasing effect is therefore greater for high conflict incongruent trials than it is for low conflict congruent trials. However, in a later study Davelaar (2013) showed that the repetition of flankers alone is sufficient to produce a CSE. Davelaar illustrated that it is not necessary for participants to make a response or even perceive a target stimulus on a preceding trial to obtain a CSE in a current trial.

5.1.4. The negative priming account

Another account of the CSE suggests that negative priming is implicated (Ullsperger et al., 2005; Bugg, 2008). Negative priming refers to the idea that an iI trial with a complete non-repetition transition will slow responses (e.g., <<><< followed by >><>>). This would be due to the target in a previous trial becoming the distractor in the following trial. However, whereas Bugg found slower RTs for the complete non-repetition transition trials relative to a neutral baseline condition, Davelaar and Stevens (2009) did not. In addition, Bugg also found slower RTs for the iC partial repetition transition where flankers repeat but target and response do not (e.g., >><>> followed by >>>>>). Davelaar (2013) suggested that if negative priming were implicated in the iI trials with a complete non-repetition transition, then the iC partial repetition transition (where flankers repeat but target and response do not transition) should produce positive priming. Davelaar suggested that this pattern is not observable in the literature that focuses upon two-choice flanker tasks, and that there is no evidence for the existence of negative priming in flanker tasks that include both congruent and incongruent trials. It is also interesting to note that Mayr and Awh (2009) showed using a six colour-word Stroop task that distractor to target transitions for iI trials did not produce slower RTs than non-repetition iI trials; thus, again, there was no evidence of negative priming. In contrast, target to distractor repetitions for iI trials produced faster RTs and were more accurate than non-repetition iI trials. So, from this evidence, one can conclude that negative priming should not be an issue in a two-choice emotional flanker task of the kind we used in experiment 1.

5.1.5. The contingency learning account in proportion congruent designs

As discussed in chapter 3, Schmidt, Crump, Cheesman and Besner (2007) and Schmidt and Besner (2008) propose that participants implicitly learn the correlations (contingencies) between the words and responses in Stroop tasks using proportion congruent manipulations (e.g., when there are more congruent trials than incongruent trials participants learn that the word in red ink is more often the word "red" than an incongruent word). This contingency learning account has been applied to CSE research when the proportions of congruent and incongruent trials are unequal. Schmidt (2013) claimed that contingency biases when congruent trials are predominant can artificially enhance the magnitude of the CSE. One could suggest that this was possible in experiment 1 of the present thesis. However, it is noteworthy that in experiment 1 (where congruent trials outnumbered incongruent trials) RTs for iI trials were similar to RTs for cC trials. Thus we suggest that contingency learning did not enhance the CSE in our emotional face flanker task in experiment 1.

5.1.6. Precluding contingency learning and feature integration

Several studies have used designs that precluded the possibility of both contingency learning and feature integration. For example, Schmidt and Weissman (2014) showed that a CSE can occur without the presence of any feature integration or the possibility of any contingency learning effects when using prime probe tasks. Larson, Clayson, Kirwan and Weissman (2016) also used a prime probe task and found a robust CSE. These prime probe tasks use stimuli that are similar to those used in flanker tasks. In these tasks distractor arrays of arrows or words are shown initially (i.e., a prime stimulus that does not require a response). Unlike flanker tasks these distractors then disappear before the lone target arrow or word is presented, where a response is required from the participant. The prime probe tasks are thus quite different from the conflict tasks usually used to study the CSE. However, it is noteworthy here that Duthoo, Abrahamse, Braem, Boehler and Notebaert (2014) created versions of the picture-word Stroop task, and colour-word Stroop task, in addition to the flanker task that control for feature integration and any possibility of contingency learning. CSEs were present in all three of the tasks.

Kim and Cho (2014) used a different design that alleviates any possibility of feature integration and contingency learning. This task required participants to alternate between two flanker tasks in a trial by trial fashion. Experiment 1 of their study required responding with key presses by using four fingers of one hand (two fingers for each task), whereas experiment 2 of their study required participants to respond with their index and middle fingers of both hands (one hand for each task). Kim and Cho reported that a CSE was present only in their experiment 1. In short, the CSE was only present when the response mode was single-handed for both tasks, not dual-handed with one hand per task. They suggest that these results support the notion that the CSE is produced by top-down cognitive control resources coping with response conflict. However, it is entirely possible that both conflict monitoring and thus (conflict adaptation) as well as episodic memory processes can influence the CSE in different situations. Bugg (2014) suggested that conflict adaptation may be a last resort, and as such is a process that participants may only rely upon if environmental cues are not reliable.

5.1.7. The repetition expectancy account

The repetition expectancy account of the CSE originally proposed by Gratton, Coles and Donchin (1992) does not concern objective probabilistic judgments, but relates to subjective expectancies. Gratton et al. reasoned that expectations of either congruent or incongruent stimuli repeating would facilitate adjustments in attentional focus. Incongruent trials would lead to a focused attentional state, whereas congruent trials would lead to a broadened attentional state (which they referred to as "parallel"). Thus, if two consecutive trials are of the same congruency (iI or cC) then the second trial in that sequence will be expected (in terms of congruency) and thus processed faster as the attentional state would be adjusted appropriately. The converse happens when the second trial in the sequence has the alternate congruency to the preceding trial (iC or cI), and the attentional state has been inappropriately adjusted, making RTs slower[3].

There are a few studies that have tried to isolate repetition expectancy based processing in conflict tasks. Duthoo and Notebaert (2012) used a Stroop task with a learning phase that had two conditions (manipulating the proportions of trial types to create either high congruency repetition expectancy or low congruency repetition expectancy). This was followed by a test phase. The idea here was if repetition expectancy has an effect it should transfer to the test phase where the proportions of trial types were kept equal, and be illustrated by an increased CSE in the high

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[3] It is noteworthy here that one cannot be sure that Gratton et al. use the term expectancy here in the sense that participants have an explicit expectancy of the up and coming trials congruency type. They may simply mean that there is a beneficial congruency matching effect that occurs on some sequential trials. In other words, if a congruent trial puts a participant in one cognitive state then it will be easier for them to respond quickly if they are required to respond to another congruent trial next (and thus are already in the "right" cognitive state). The same effect would occur for incongruent trials, except that they would be placed in an alternative cognitive state. These effects could/would happen without any need for any active (explicit) expectancy. This account could thus be interpreted as meaning that participants rely upon implicit attentional expectancies. In other words, the word expectancy may be being somewhat misused in this account.

expectancy condition. This was not found to occur. However, Duthoo, Abrahamse, Braem and Notebaert (2013) tested the repetition expectancy account more explicitly with a Stroop task by asking their participants if they expected an easy (congruent) or hard (incongruent) trial before they responded. Four experiments showed that participants exhibited a repetition bias, as they expected the congruency level of any trial to repeat above what would be predicted by chance. Moreover, a robust CSE was found only when participants had predicted a repetition of congruency type. Duthoo et al. suggested that expectancies might influence control in addition to conflict based adjustments, but only if the expectancies are being explicitly registered or manipulated.

Correa, Rao and Nobre (2009) used EEG and showed that the N2 ERP deflection was reduced when it followed a cue that signalled increased conflict. The N2 is proposed to reflect conflict related brain activity, which is proposed to be generated in the ACC (Mathalon, Whitfield, & Ford, 2003). Correa et al. suggested that the anticipation of conflict may speed up the detection of conflict and the subsequent resolution of this conflict. Aarts and Roelofs (2011) used a Stroop-like task with probabilistic cues and showed that anticipated conflict or anticipated lack of conflict facilitates sequential adjustments in a similar fashion to actually experienced conflict or lack of conflict in a previous trial. They also reported that this manipulation modulated ACC activity in a similar fashion to studies that used experienced conflict (e.g., Kerns, 2006; Kerns et al., 2004). Thus it seems as if the repetition expectancy account is the hardest to delineate from the conflict monitoring account.

5.1.8. Plotting the CSE from the perspective of each of the three main theoretical accounts.

The three main theoretical accounts of the CSE that feature in the literature are the conflict monitoring (conflict adaptation) perspective, the feature integration perspective, and the repetition expectancy perspective. An analysis of the CSE from each of these three perspectives would amount to the same thing statistically. However, the data are usually plotted slightly differently for the conflict monitoring/adaptation perspective, than for the feature integration perspective and the repetition expectancy perspective. In contrast, the data are usually plotted in the same way for the feature integration perspective and the repetition expectancy perspective. In short, it is important to understand that the data in any congruency sequence effect paradigm can be plotted in several ways, and that the variables included in the required ANOVA can be labelled in several different ways. Figures 5.1, 5.2, and 5.3 illustrate the three ways of plotting the data, the three ways of labelling the variables, and thus taken together these figures also illustrate the relationship between the three ways of analysing and interpreting the CSE.

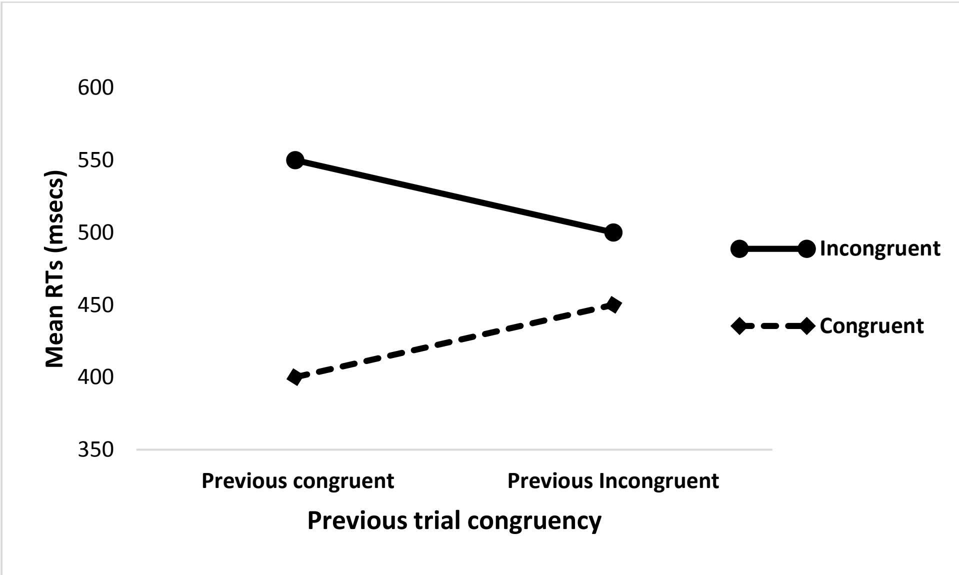

Figure 5.1: A hypothetical CSE plotted from the conflict monitoring/adaptation perspective, as advocated by conflict monitoring theory. Here the data is plotted as current trial type of congruency (solid lines vs. dotted lines) for different levels of previous trial type congruency on the x-axis. This plot is thus laid out in a way that specifically reinforces the suggestion that monitored conflict in a previous trial affects performance in any current trial.

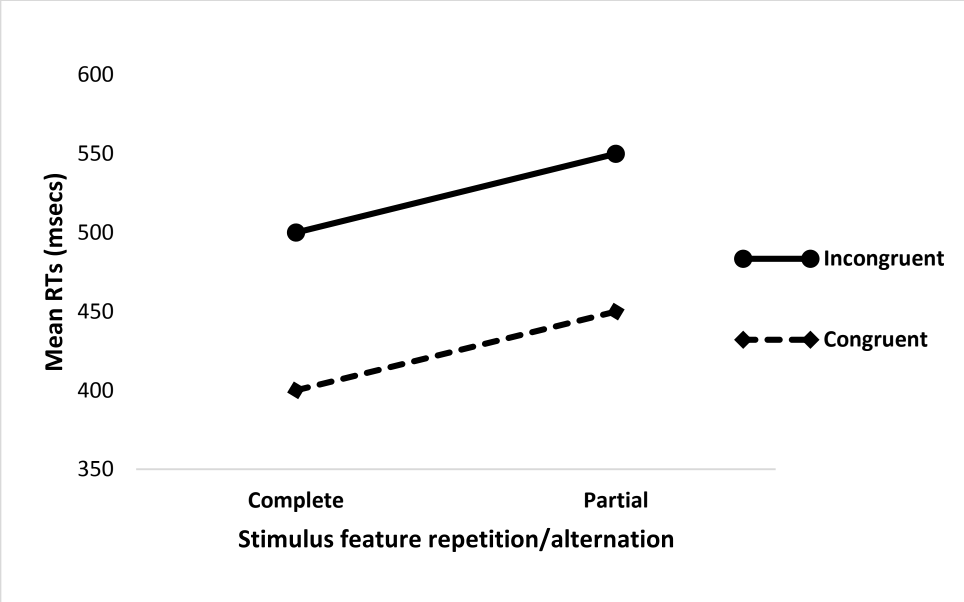

Figure 5.2: A hypothetical CSE plotted from a feature integration perspective. Here the data is plotted as current trial type of congruency (solid vs. dotted lines) for different amounts of feature overlap with the previous trial plotted on the x-axis. Thus, the previous trial has either complete feature overlap or partial feature overlap with the current trial. Thus, the feature integration account reconceptualises the current trial congruency versus previous trial congruency effect, as a current trial congruency by stimulus feature transition effect.

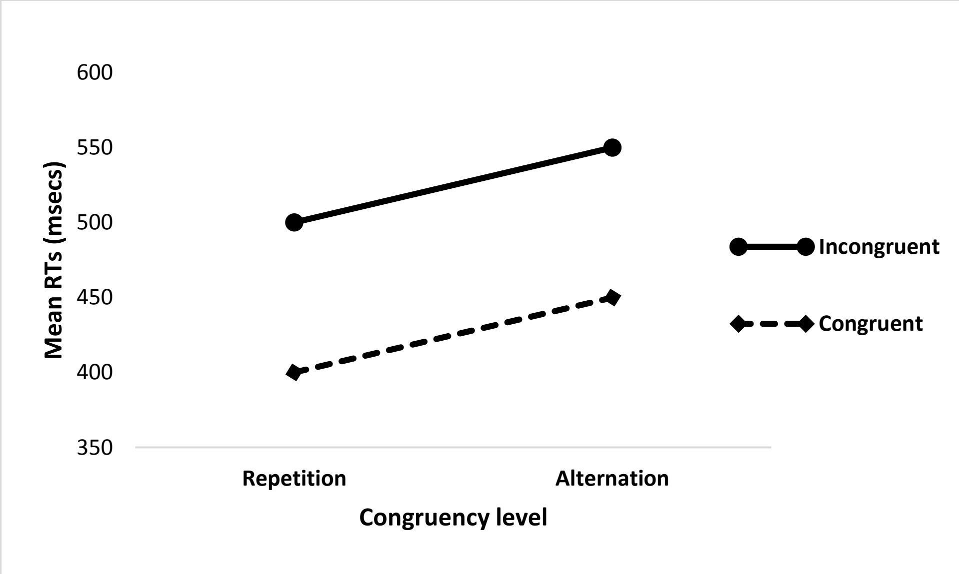

Figure 5.3: A hypothetical CSE plotted from a repetition expectancy perspective. Here the data is plotted as current trial type of congruency (solid lines vs. dotted lines) for repetition or alternation of congruency on the previous trial plotted on the x-axis. Although the proposed cognitive mechanisms differ, the plot for the repetition expectancy perspective is the same as for the feature integration perspective. Moreover, the plots for both of these two perspectives differ from the plot for the conflict monitoring/adaptation perspective.

5.2. Purpose of experiment 4

Here we intended to design a new, more ecologically valid, emotional face flanker paradigm that enables us to research goal conflict resolution by investigating the CSE. Moreover, we intended to control for contingency learning, negative priming, and as far as possible any feature integration effects. It seems that precisely delineating the effects of conflict monitoring and repetition expectancy upon the CSE is not very easy. However, we suggest that even though the data is plotted differently for these two accounts, and the theoretical cognitive mechanisms differ, they are actually still quite similar. The impact of any anxiety effect found upon the CSE would be similar regardless of which of these two perspectives one preferred. As discussed in chapter 2, in real life settings an (in)congruency repetition advantage may manifest as the increased speed of detection of repeated conflicting (or non-conflicting) facial emotions in the social environment. In contrast, an (in)congruency repetition disadvantage may manifest as a reduced speed of detection of repeated conflicting (or non-conflicting) facial emotions in the social environment. This would be true regardless of whether the CSE was driven by conflict adaptation, subjective expectancies (or even episodic memory). Thus we suggest that the CSE is still a viable method of researching how anxiety relates to conflict resolution. In short, here we wished to achieve three things. Firstly, we wished to design and test a new emotional CSE paradigm with an increased level of ecological validity. Secondly, we wished to use it to investigate whether a reliable anxiety related effect of emotional conflict resolution exists. Thirdly, we wished to determine whether fearful faces and happy faces differentially affect the magnitude of the CSE.

Experiment 1 used a design with unequal proportions of congruent and incongruent trials, which theoretically could have enhanced the magnitude of the CSE. However, above we suggested that contingency learning was not the driving force behind the CSE in experiment 1 as RTs for iI trials were similar to RTs for cC trials. However, to be sure of this in the present study, we used equal proportions of congruent and incongruent trials. As discussed above, there is no evidence for negative priming in binary flanker tasks. However, to be sure this cannot affect the CSE we used a design with stimuli consisting of six persons' identities included in each task. Moreover, we designed our sequences of stimuli such that the identity of the person depicting a target emotion was never the same identity as that of the flanker faces appearing in the previous trial, we suggest that negative priming should definitely not be possible. We can also account for possible feature integration effects because the identity of the person depicting a target emotion is never the same identity as that of the flanker faces in the previous trial. In addition, we can also account for differences in performance that may occur relative to whether the hand used by the participant to make a response repeats (i.e., the response repetition priming effect), or does not repeat, at the stage of data analysis.

Thus, the purpose of this 4th experiment is to ascertain how trait anxiety relates to the CSE, but also to use a design that enables us to better understand the mechanism driving the CSE, and any anxiety effect upon the CSE. As stated above, we also wished to increase ecological validity relative to the task we designed for experiment

1. In experiment 1 the flanker stimuli were of the same identity to the target stimuli. This was the case as, when developing the original version of the task, we wished to remain as true to the conventional flanker task design as possible. In the real world faces on the periphery of any target face would be of a different person's identity. In the present experiment we also included this alteration in our design. Thus, this alteration serves the dual purpose of controlling for the design and interpretation issues described above, and also increasing ecological validity.

Specifically, we predicted that higher trait anxiety would be related to an increased CSE. More specifically, we predicted that higher trait anxiety would relate to an increased (in)congruency repetition advantage. We made this prediction based upon the results of experiment 1, and the results of Larson, Clawson, Clayson and Baldwin (2013). We also intended to conduct analyses designed to determine whether fearful faces and happy faces differentially affect the magnitude of the CSE. We make no specific predictions here as there is no literature available to base them on. We also intended to delineate trials with and without target and response repetition, in order to determine where the CSE occurs. As discussed above, the literature is inconsistent concerning this issue, so we cannot make a precise prediction here.

As noted above, here we control for contingency learning, negative priming, and as far as possible any feature integration effects. However, as we are not attempting to delineate the effects of conflict adaptation and repetition expectancy here, we still plot the data, and analyse the CSE from the relatively atheoretical perspective that we adopted in experiment 1.

5.3. Method

5.3.1. Participants

Participants with no reported history of neurological disorder (N = 87, 61 female) were recruited from Goldsmiths, University of London, and had a mean age of 24.3 (SD = 6). 73 of these participants were right handed. 21 participants were psychology 1st year undergraduates recruited via a research participation scheme who took part in return for course credit. The rest were paid £10 and recruited via advertisements placed around the campus, and were therefore students and staff from other departments. All participants gave informed written consent in accordance with standard ethical guidelines. This study was approved by the Goldsmiths Psychology Department ethics committee (approval received 24/10/2012).

Based upon the 0.32 correlation between trait anxiety and the RT difference between responses to happy and fearful faces in experiment 1 of this thesis, 74 participants should allow 80% power for a two-tailed test at p=0.05, for a correlation of 0.32 in this experiment. We can also make a sample size and power prediction based upon the 0.4 correlation between anxiety and the CSE reported in the study by Larson et al. (2013), which also suggest that 46 participants would be sufficient. However, experiment 1 in this thesis showed a weaker 0.24 correlation between anxiety and the CSE. To obtain this size of correlation 133 participants would be required to allow 80% power for a two-tailed test at p=0.05. However, we can make a one-tailed prediction here based upon experiment 1, so 103 participants would provide 80% power here. We therefore aimed for 100 participants approximately. Our final sample of 87 participants is slightly smaller than the required amount based on a 0.24 correlation, but the availability of participants was somewhat reduced towards the end of our testing period. 87 participants gave us a power of 73% for a 0.24 correlation.

5.3.2. Psychometric measures.

Trait anxiety was initially assessed with the STAI trait anxiety scale of the State-Trait Anxiety Inventory (STAI, Spielberger et al., 1983; referred to as STAI-trait hereafter). We also used the previously proposed anxiety and depression subscales of the STAI, as described by Bieling, Antony & Swinson (1998). The STAI-anxiety subscale consists of STAI-trait items 22, 28, 29, 31, 37, 38, & 40. The STAI-depression subscale consists of STAI-trait items 21, 23-27, 30, 32-36, & 39.

5.3.3. Stimuli

The emotional faces used were obtained from a standardised face stimuli set developed for research (NimStim; Tottenham et al., 2009). The individual face pictures were 20mm high x 16 mm wide and were formed into grids of 9 faces, thus the overall grid dimensions were 60mm high and 48 mm wide (when presented using MATLAB version R2006a on a 15.5 inch laptop screen). The laptop was running Windows XP, and we used the Psychophysics Toolbox version 3 for precision RT measurement. As with experiment 4, three face stimulus sets containing different people's faces in each were used. Each of the three face sets included happy and fearful facial expressions (with versions of each expression included that had both open mouths and closed mouths) posed by six different models from the NimStim set. Thus, in each set, images of each of the six models were used, with both closed and open mouths (for both facial expressions). Figure 5.4 shows examples of the grids of emotional faces used to create the congruent and incongruent trials described below.

Figure 5.4: Examples of the grids of emotional faces used to create the different trial types. Clockwise from top left; incongruent happy trial; incongruent happy trial; incongruent fear trial; congruent happy trial; congruent fear trial; congruent fear trial.

5.3.4. Procedure

Participants were told that they would be required to complete a facial emotion recognition task. Participants were asked to sit as close to the screen as was comfortable for their eyes (typical viewing distance was approximately 70 cm). The task instructions were presented on the screen. To start each task the first screen instructed participants that they would have to judge the emotional expression showing on photos of faces. Participants were then shown examples of the various stimulus combinations they might see and reminded to concentrate on the central face and ignore any others. They were told to rest their index fingers over the responses keys (z and /) and to respond as fast as possible while maintaining high accuracy levels. They were verbally told that a high pitched tone following a response indicates a correct response, whereas a low pitched tone following a response indicates an incorrect response.

The experimental stimuli were displayed until a response key was pressed. Unbeknown to the participants, at the beginning of each task, there were twelve congruent trials and twelve incongruent trials included as practice trials; these were discarded and not analysed. The main experimental stimuli that followed consisted of 120 incongruent trials and 120 congruent trials. The emotional stimuli also consisted of 120 happy face trials and 120 fearful face trials. Thus, there were 60 happy incongruent trials and 60 happy congruent trials (and 60 fearful incongruent trials and 60 fearful congruent trials). Half of each of these sets of 60 stimuli types had open mouths whereas half had closed mouths. The modified flanker task was designed primarily to elicit RT effects as opposed to errors. The trial type sequence was created using a programme in Matlab that used its random number generator function to create a sequence with very specific requirements (see below). The sequence used was the same for all participants. We kept the sequence the same for all participants as this is an individual differences study, and we wanted as few uncontrolled variables as possible to vary across participants. We specified in the programme, which created the sequence, that at no point was a person’s identity from a previous trial (target or flanker) to be used in the following trial (target or flanker). This was to help control for feature integration and negative priming (as discussed above). The task lasted for approximately ten minutes. The left/right finger response key mappings were also counterbalanced.

5.3.5: Data analysis

In our primary analysis, RTs will be analysed using ANCOVA with factors of trial type, emotion, previous trial type (i.e. (in)congruency repetition/alternation), and previous emotion (emotion repetition vs. emotion alternation), with standardised trait anxiety included as the covariate.

The effect of trial type will allow us to test if the different types of peripheral distracting faces (congruent vs. incongruent) affect the discrimination of the central target faces. The effect of the covariate here will show if anxiety modulates (correlates with) the overall trial type effect. The effect of emotion will reveal whether RTs to central fearful faces differ from RTs to central happy faces, and the covariate interaction with this will test whether trait anxiety modulates (correlates with) this emotion effect. The effect of emotion upon the effect of trial type will allow us to test whether the size of the distraction (trial type) effects differ significantly when happy or fearful faces are the target emotion. The anxiety by emotion by trial type interaction will test whether trait anxiety modulates (correlates with) the emotion by trial type interaction effect.

The CSE is the previous trial type effect, which we have referred to as the (in)congruency repetition/alternation effect. This effect is the RT difference between trials when the level of (in)congruency repeats relative to when it alternates. The effect of emotion upon the (in)congruency repetition/alternation effect tests if the CSE differs between trials with happy central target faces vs. trials with fear targets. The critical covariate effect here is the covariate interaction with the (in)congruency repetition/alternation effect. This will reveal if anxiety modulates (correlates with) the size of the CSE. These effects therefore test our hypotheses that anxiety will relate to a difference in how conflict resolution is achieved (as indexed by the CSE).

The effect of previous emotion tests the RT difference between trials when the target emotion (i.e., happy vs. fear) repeats relative to when it alternates. This emotion repetition vs. emotion alternation effect can also be described as whether the correct response on the previous trial was repeated or not. Such effects are sometimes described in the literature as target and response repetition effects.

The test of previous emotion (emotion repetition vs. emotion alternation) upon the effect of emotion tests whether the emotion RT difference differs significantly when the emotion repeats between the previous and current trial, and when it alternates. More critically, the test of previous emotion upon the effect of (in)congruency repetition/alternation tests whether the CSE differs significantly between trials on which the previous emotion is repeated on the current trial, compared with trials on which the previous emotion alternates to the other emotion on the current trial. The anxiety by previous emotion by current emotion effect thus tests if trait anxiety modulates (correlates with) the size of the previous emotion by current emotion interaction.

The further 3 and 4-way interactions test if either target emotion or trial type modulate other effects within this design. The covariate interactions with these complex higher order interactions test whether those effects are further modulated by trait anxiety.

We also conducted follow-up tests where required and also some planned comparisons of the trial type versus (in)congruency repetition/alternation interaction in each emotion condition, and each emotion repetition/alternation condition. In effect, we sorted the trial type and (in)congruency repetition/alternation comparisons by target emotion and by target and response repetition/alternation.

We also planned to conduct further analyses concerning how the STAI subscales relates to relate to any RT effects that relate to trait anxiety as measured by the total scores of the STAI. For completeness, the main analyses were then repeated with the accuracy data.

5.4. Results

5.4.1. Psychometric measures

In this sample, participants' total STAI scores (STAI-trait scores) ranged from 23 to 69 (mean: 43, SD: 9).

5.4.2. Reaction time analyses

Including all participants the experiment contained 20880 responses in total. 19534 of these were correct responses. Correct responses ranged from 1 msec to 6751 msecs. RT outliers for correct responses were removed if RTs < 200 msecs and RTs > 1250 msecs. Of these 1530 were where RT > 1250msecs, and 2 were where RT < 0.200 msecs. Thus, 1532 correct responses were removed. Thus, 7.84 % of correct responses were excluded.

1532 / 19534 * 100

We will denote 4 key types of goal conflict trial within this analysis thus: incongruent trials preceded by incongruent trials (iI); incongruent trials preceded by congruent trials (cI); congruent trials preceded by congruent trials (cC); and congruent trials preceded by incongruent trials (iC).We will also denote 4 key types of emotion trial within this analysis thus: fearful trials preceded by fearful trials (fF); fearful trials preceded by happy trials (hF); happy trials preceded by happy trials (hH); and happy trials preceded by fearful trials (fH). However, the nature of our analysis requires combining the goal conflict and emotion variables, as each of the goal conflict variable appears under each of the emotion variables. Thus, this creates 16 variables 4 x 4 (sequential conflict trials x sequential emotion trials). Accordingly, the 16 trials types are denoted by both the goal conflict and emotion denotations. For example, fFiI would denote a trial where an incongruent fear trial follows and incongruent fear trial. Similarly, hFcI would denote a trial where an incongruent fear trial follows a congruent happy trial.

The RT data were subjected to a 2 (current trial type; congruent versus incongruent) x 2 (emotion; fearful face versus happy face) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) x 2 (previous emotion type; emotional face repetition versus alternation) repeated-measures ANCOVA with the standardised scores of the STAI-trait measure as the covariate. STAI-trait scores are referred to as trait anxiety in this analysis. Responses faster than 200 msecs and slower than 1250 msecs were not included. We also planned to conduct several further comparisons designed to examine the CSE in each of four specific cognitive situations; 1: fearful faces with target/response repetition; 2: fearful faces without target/response repetition; 3: happy faces with target response repetition; 4: happy faces without target response repetition.

The test of between-subjects effects was not significant (F[1,85]=0.6, p=0.448, η^2=0.007), thus anxiety was unrelated to RTs averaged across the paradigm. The mean RTs for each trial type, 95% confidence intervals, and standard errors of the mean are shown in Table 5.2. Figure 5.5 shows the mean RTs for each of the 16 trial types.

Table 5.2: Mean RTs, 95% confidence intervals (95% CIs), and standard errors (SE) for each of the 16 stimulus types. All values are in msecs. As described above, in the trial type denotations the first 2 letters describe the emotion presented on the previous trial (lower case) and the current trial (upper case). Then the next 2 letters describe the congruency type again for the previous trial (lower case) and the current trial (upper case).

Fearful face trials				**Happy face trials**			
Trial type	**Mean**	**95% CI**	**SE**	**Trial type**	**Mean**	**95% CI**	**SE**
fFcC	778	729-827	25	**hHcC**	727	689-765	19
hFcC	809	757-861	26	**fHcC**	775	732-819	22
fFiC	791	747-835	22	**hHiC**	722	686-759	18
hFiC	773	731-815	21	**fHiC**	766	726-807	20
fFiI	815	765-864	25	**hHiI**	725	685-765	20
hFiI	798	754-841	22	**fHiI**	769	727-810	21
fFcI	781	738-824	22	**hHcI**	745	707-783	19
hFcI	781	738-823	21	**fHcI**	792	747-836	22

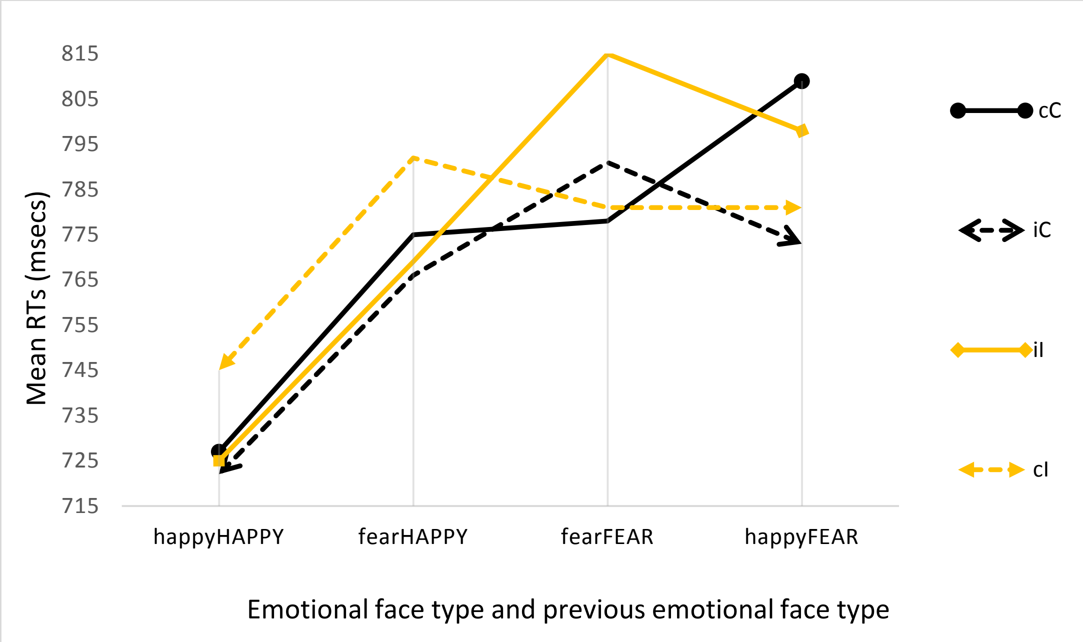

Figure 5.5: Mean RTs for each of the 16 trial types separated by current trial congruency, previous trial congruency, emotion, and previous emotion.

The test of within subjects effects showed that the main effect of trial type was not significant ($F[1,85]=3.4$, $p=0.067$, $\eta^2=0.039$). Thus, averaged congruent trials (mean RT 769 msecs; 95% CI 729-809; SE 20) were not responded to significantly faster than averaged incongruent trials (mean RT 776 msecs; 95% CI 737-815; SE 20). The main effect of trial type did not significantly interact with trait anxiety ($F[1,85]=1.6$, $p=0.206$, $\eta^2=0.019$). This interaction finding shows that there was no significant correlation between trait anxiety and the RT difference between congruent and incongruent trials. This effect relates to our key interest in whether trait anxiety relates to distraction.

The main effect of emotional face type was highly significant ($F[1,85]=41.5$, $p<0.001$, $\eta^2=0.328$), as averaged happy faces (mean RT 754 msecs: 95% CI 717-792; SE 19) were responded to faster than averaged fearful faces (mean RT 791 msecs; 95% CI 749-834; SE 21). However, the main effect of emotional face type did not significantly interact with trait anxiety ($F[1,85]=0.4$, $p=0.544$, $\eta^2=0.004$). Therefore, trait anxiety was not significantly correlated with the RT difference between responses to happy faces and responses to fearful faces. This effect relates to our key interest in whether trait anxiety relates to emotional face discrimination.

The main effect of (in)congruency repetition/alternation was not significant (F[1,85]=1.6, p=0.212, η^2=0.018). This shows that the CSE was not significant when averaged across emotion types and across congruent and incongruent trials. In other words averaged (in)congruency repetition trials (mean RT 774 msecs; 95% CI 733-816; SE 21) were not responded to significantly faster than averaged (in)congruency alternation trials (mean RT 769 msecs; 95% CI 731-807; SE 19). Critically, this effect also did not significantly interact with trait anxiety (F[1,85]=0.4, p=0.536, η^2=0.005). Thus, trait anxiety was uncorrelated with the RT difference between averaged (in)congruency repetition trials and averaged (in)congruency alternation trials. This effect relates to our key interest in whether trait anxiety relates to conflict resolution as measured by the CSE.

The main effect of emotional face repetition/alternation was highly significant (F[1,85]=23.2, p<0.001, η^2=0.214). This shows that averaged RTs to faces that followed a face depicting the same emotion (mean RT 760 msecs; 95% CI 722-799; SE 19) were significantly faster than averaged RTs to faces that followed a face depicting the alternative emotion (mean RT 783 msecs; 95% CI 742-824; SE 21). This main effect of emotional face repetition/alternation did not interact with trait anxiety (F[1,85]=0.7, p=0.419, η^2=0.008). Thus, anxiety was not correlated with the RT difference between emotional face repetition trials and emotional face alternation trials.

The trial type x emotion interaction was not significant (F[1,85]=0.2, p=0.656, η^2=0.002). This shows that the effect of trial type (i.e., the congruency effect) upon RTs did not significantly differ depending upon what the target emotional face was. However, the trial type x emotion x trait anxiety interaction was significant (F[1,85]=5.3, p=0.024, η^2=0.059). This shows that trait anxiety was related to a difference in the effect of trial type (or congruency effect) between the two emotion conditions. The correlation value between trait anxiety and the RT difference between the fearful trial congruency effect and the happy trial congruency effect is -0.23, p=0.029. This correlation is depicted in Figure 5.6. This effect relates to our key interest in whether trait anxiety relates to distraction, thus we return to this issue later.

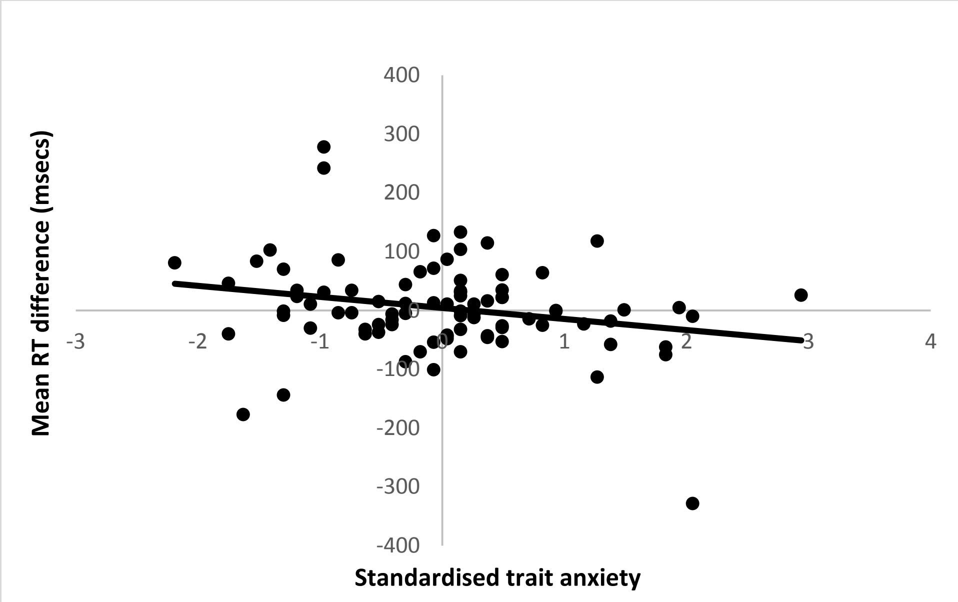

Figure 5.6: The correlation between standardised trait anxiety and the RT difference between the congruency effect for trials with fearful target faces and the congruency effect for trials with happy target faces. The correlation value is -0.23.

The trial type x (in)congruency repetition/alternation interaction was not significant (F[1,85]=0.8, p=0.368, η^2=0.010). This shows that there was no difference in the effect of (in)congruency repetition and alternation depending upon whether congruent or incongruent trials were involved. Moreover, the trial type x (in)congruency repetition/alternation interaction did not further interact with anxiety (F[1,85]=0.3, p=0.581, η^2=0.004).

By contrast, the emotion x (in)congruency repetition/alternation interaction was robustly significant (F[1,85]=7.3, p=0.008, η^2=0.079). This interaction suggests that the effect of (in)congruency repetition/alternation may be present more strongly in one of the emotion conditions than the other. This effect is depicted by Figure 5.7. We return for further statistical analysis of this effect later.

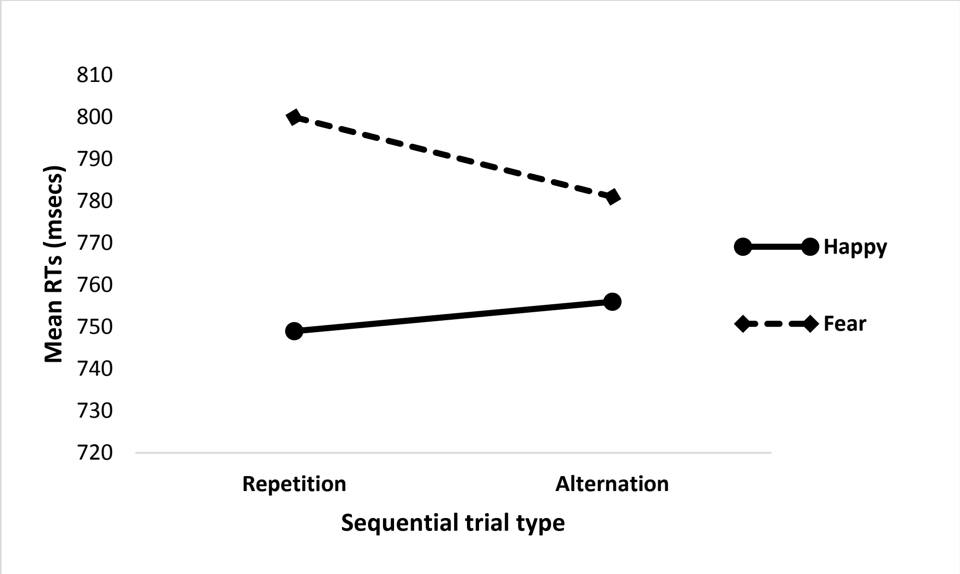

Figure 5.7: The RT interaction between the effect of (in)congruency repetition/alternation and the effect of target emotional face type.

The emotion x (in)congruency repetition/alternation interaction did not significantly further interact with trait anxiety (F[1,85]=2.6, p=0.113, η^2=0.029). Thus trait anxiety was not significantly correlated with any relative difference in the size of the (in)congruency repetition/alternation effect that may occur as a function of emotional target face type. This effect relates to our key interest in whether trait anxiety relates to conflict resolution and emotion.

The trial type x emotion x (in)congruency repetition/alternation interaction was also robustly significant (F[1,85]=7.4, p=0.008, η^2=0.081). Thus the effect of emotion on the (in)congruency repetition/alternation effect varies significantly depending whether the trials are congruent or incongruent. This interaction is explained by Figures 5.8 and 5.9.

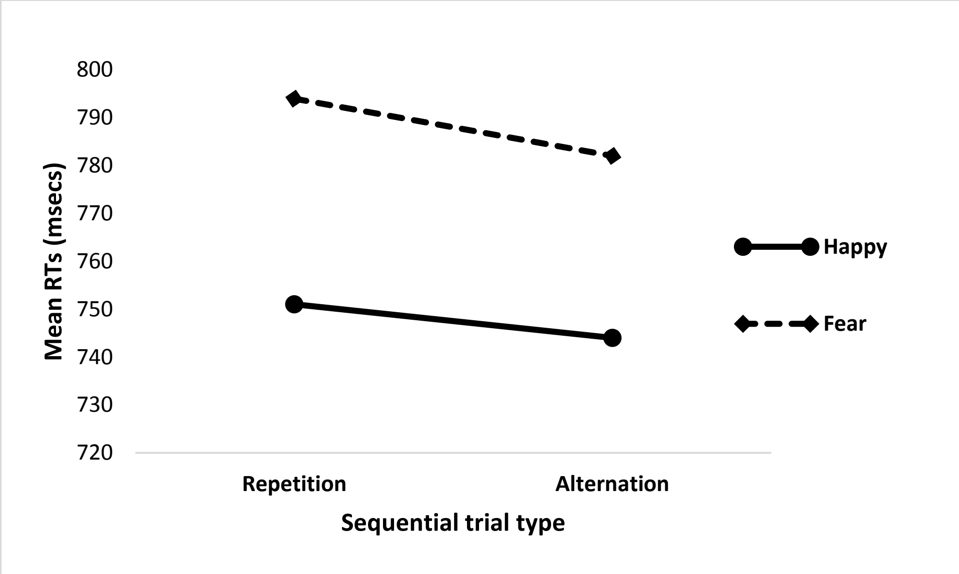

Figure 5.8: The RT interaction between the effect of congruency repetition and alternation, and the effect of emotional face type for the congruent trials.

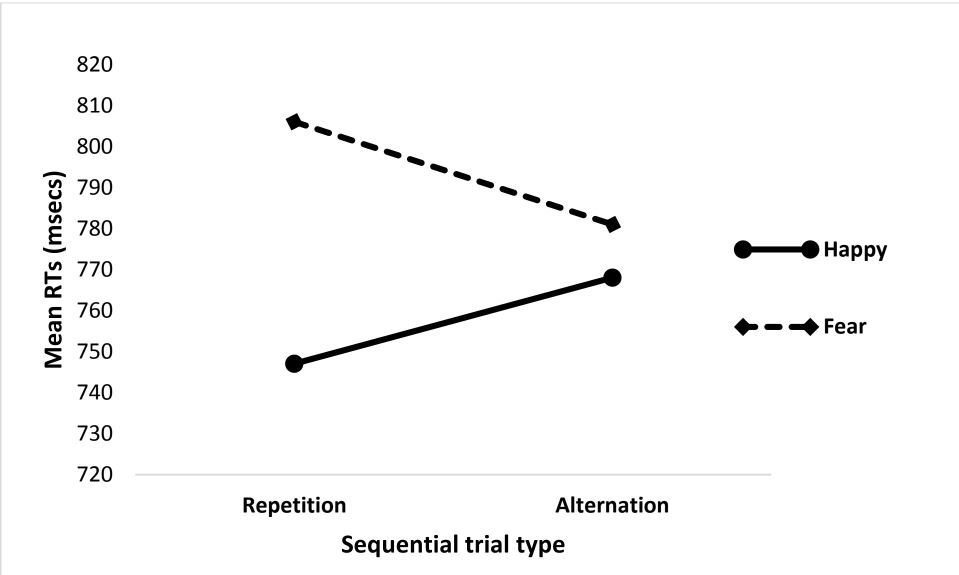

Figure 5.9: The interaction between the effect of congruency repetition and alternation, and the effect of emotional face type for the incongruent trials.

We return for further statistical analysis of this effect later. However, trait anxiety was not related to this effect, as the trial type x emotion x (in)congruency repetition/alternation x anxiety interaction was not significant ($F[1,85]=0.3$, $p=0.616$,

η^2=0.003). This effect relates to our key interest in whether trait anxiety relates to conflict resolution and emotion.

The trial type x emotional face repetition/alternation interaction was not significant (F[1,85]=0.6, p=0.444, η^2=0.007). This comparison shows that the effect of trial type upon RTs was not affected by whether the emotional face type depicted the same emotion as the previous trial, or depicted a different emotion to the previous trial. The trial type x emotional face repetition/alternation interaction did not further significantly interact with trait anxiety (F[1,85]=0.02, p=0.902, η^2<0.001). This shows that trait anxiety was not related to any sequential effect of emotion upon the effect of trial type.

The emotion x emotional face repetition/alternation interaction was robustly significant (F[1,85]=18.8, p<0.001, η^2=0.181). This shows that the difference in RTs for responses when the emotional face type repeats relative to when the emotional face type alternates is greater in one of the two emotion conditions. Figure 5.10 shows that an emotional face repetition advantage was present for the happy faces but not the fearful faces. We return for further statistical analysis of this effect later. The emotion x emotional face repetition/alternation x trait anxiety interaction was not significant (F[1,85]=0.1, p=0.725, η^2=0.001). Thus this effect of emotion upon the emotional face repetition/alternation effect was not further modulated by trait anxiety. Moreover, the trial type x emotion x emotion repetition/alternation interaction was not significant (F[1,85]=0.6, p=0.435, η^2=0.007), and this interaction did not further interact with trait anxiety (F[1,85]=0.02, p=0.895, η^2<0.001).

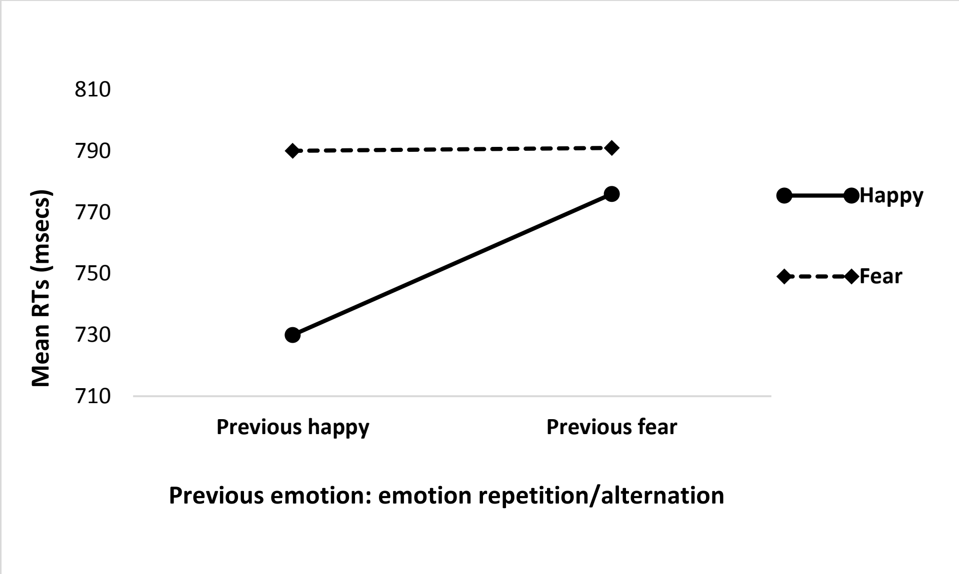

Figure 5.10: Mean RTs for the happy target faces, and fearful target faces, as a function of the previous emotional face type.

The (in)congruency repetition/alternation x emotional face repetition/alternation interaction was not significant (F[1,85]=0.8, p=0.383, η^2=0.009). This shows that averaged across emotion type, and trial type, the CSE did not differ between responses to repeated emotional faces and alternated emotional faces. Thus, overall the CSE appeared to be unaffected by whether the emotion repeated or not. Moreover, this null effect did not further significantly interact with trait anxiety (F[1,85]=1.0, p=0.320, η^2=0.012). This effect relates to our key interest in whether trait anxiety relates to conflict resolution and emotion.

The trial type x (in)congruency repetition/alternation x emotional face repetition/alternation interaction was significant (F[1,85]=5.4, p=0.022, η^2=0.060). Given the large number of effects in this 4-way design we might treat this relatively weak effect with caution. It might be a Type I error. If it is real, then it suggests that there was an effect of emotional target and response repetition/alternation that is modulated by the effect of (in)congruency repetition/alternation, but this effect differs between trial types. This is illustrated by Figures 5.11 and 5.12. We return for further statistical analyses of this effect later. However, this interaction did not further interact with trait anxiety (F[1,85]=0.3, p=0.577, η^2=0.004).

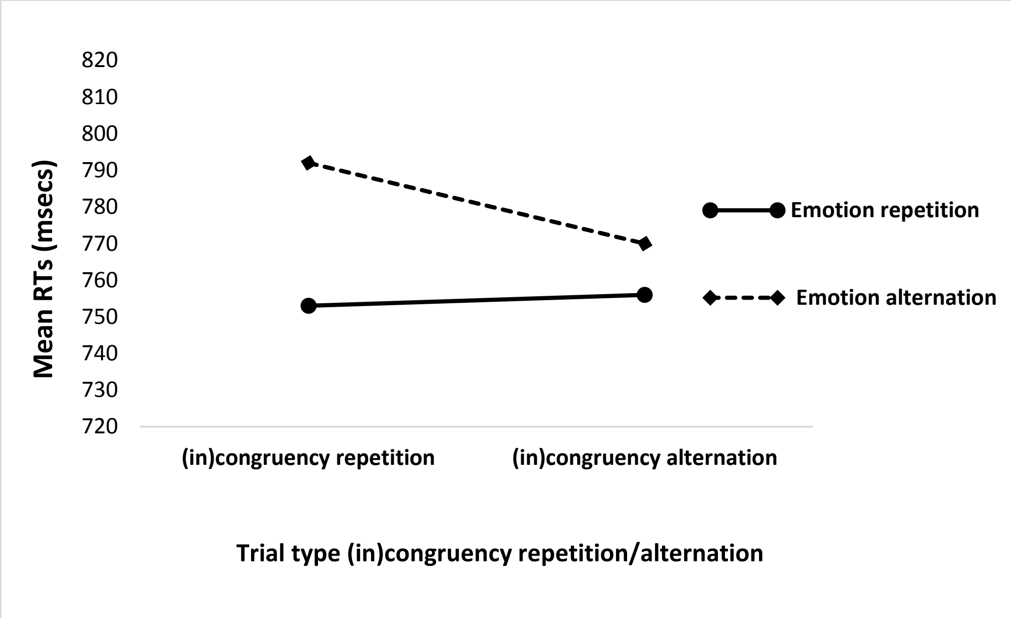

Figure 5.11: The interaction between the (in)congruency repetition/alternation effect and the emotional target and response repetition/alternation effect for congruent trials. The reader is reminded here that the variables in this interaction are averaged across the two emotional face types.

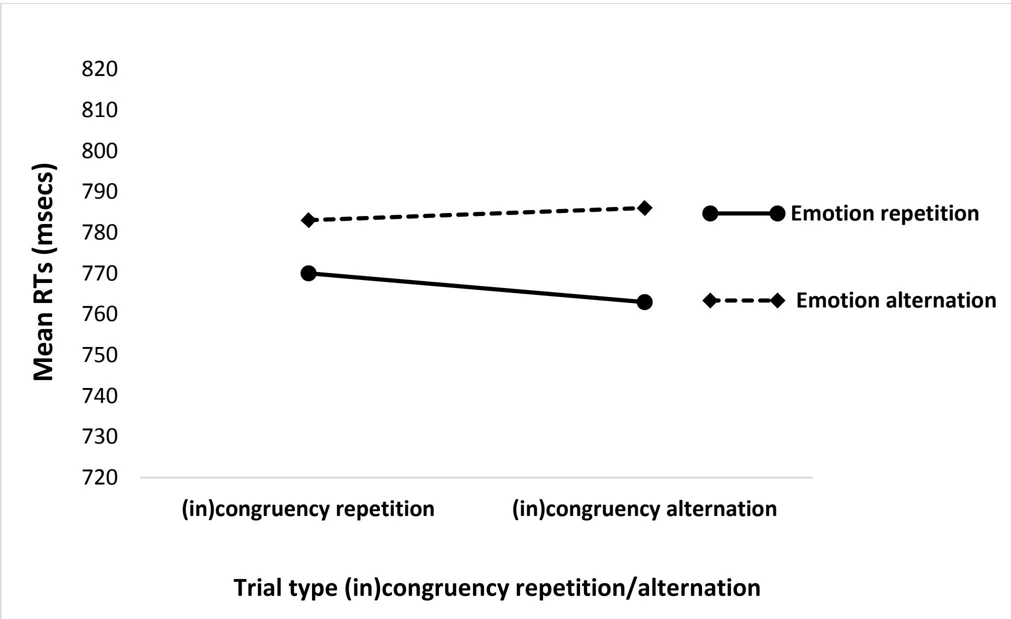

Figure 5.12: The interaction between the (in)congruency repetition/alternation effect and the emotional target and response repetition/alternation effect for incongruent trials. The reader is reminded here that the variables in this interaction are averaged across the two emotional face types.

The emotion x (in)congruency repetition/alternation x emotional face repetition/alternation interaction was not significant (*F*[1,85]=0.6, *p*=0.444, η^2=0.007), nor was the emotion x (in)congruency repetition/alternation x emotional face repetition/alternation x trait anxiety interaction (*F*[1,85]=0.3, *p*=0.586, η^2=0.004). Similarly the trial type x emotion x (in)congruency repetition/alternation x emotion repetition/alternation interaction was not significant (*F*[1,85]=2.3, *p*=0.130, η^2=0.027), nor was the trial type x emotion x (in)congruency repetition/alternation x emotion repetition/alternation x trait anxiety interaction (*F*[1,85]=2.4, *p*=0.128, η^2=0.027).

5.4.3. Probing the RT interaction effects

There were some significant interactions in the previous analysis that require further analyses. The trial type x emotion x trait anxiety interaction suggests that the effect of trial type (i.e., the congruency effect) is modulated by anxiety but the modulation is different across the two emotion conditions. To verify which condition this was we conducted two more ANCOVAS (including standardised trait anxiety as the covariate). Here we adopt an adjusted significance level of 0.05/2. A one-way ANCOVA conducted upon trial type (congruent versus incongruent) in the fearful face condition showed that although the trial type effect was not significant (*F*[1,85]=0.6, *p*=0.442, η^2=0.007), trait anxiety showed a trend towards interacting with the trial type effect (*F*[1,85]=4.8, *p*=0.031, η^2=0.054). This interaction tests the correlation between trait anxiety and the RT difference between congruent and incongruent trials when fearful faces were the target emotion. The correlation value was *r*=0.23. Therefore those higher in anxiety showed a greater RT congruency effect relative to those lower in anxiety. A second one-way ANCOVA conducted upon trial type (congruent versus incongruent) in the happy face condition showed that the effect of trial type was not significant (*F*[1,85]=3.2, *p*=0.077, η^2=0.036), and nor was the trial type versus trait anxiety interaction (*F*[1,85]=0.7, *p*=0.419, η^2=0.008). Thus, anxiety was not correlated with the RT difference between congruent and incongruent trials when happy faces were the target emotion. The correlation value was *r*= -0.09. Figure 5.13 shows the two separate correlations between trait anxiety and the congruency effect for trials with target happy faces, and the congruency effect for trials with target fearful faces**.** These two correlations relate to our key interest in whether trait anxiety relates to distraction.

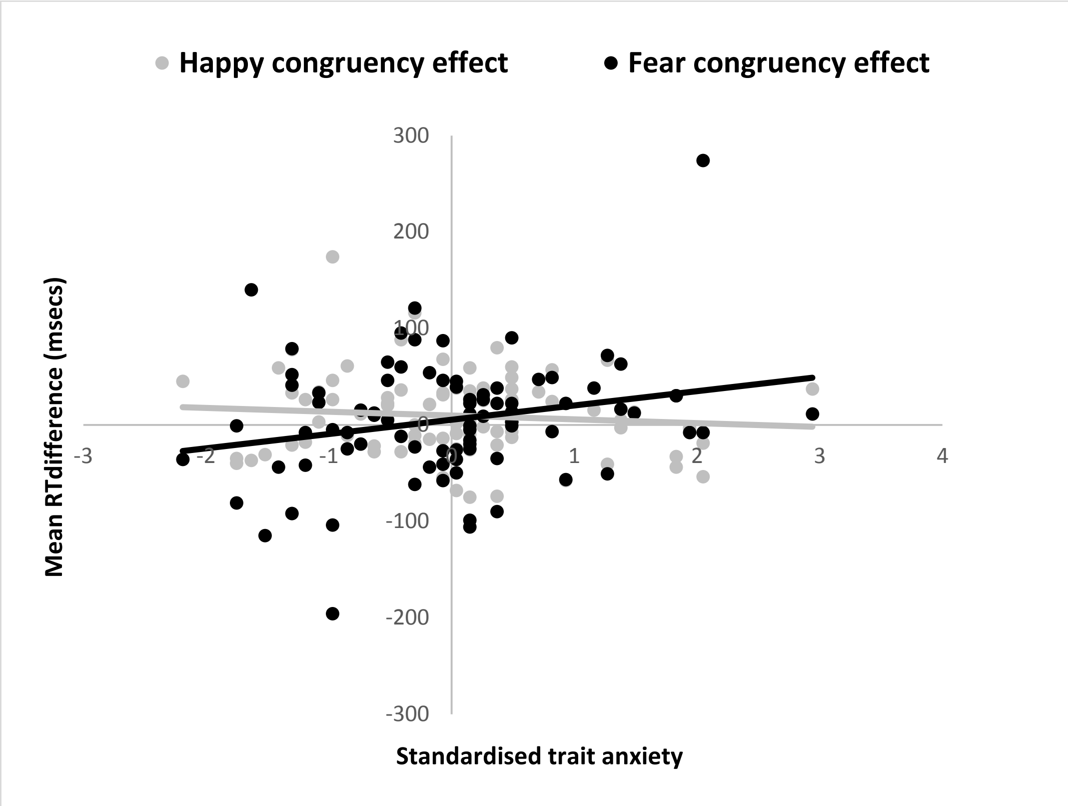

Figure 5.13: The two separate correlations between standardised trait anxiety and the congruency effect for trials with target happy faces, and the congruency effect for trials with target fearful faces. The correlation values are r= -0.09, and r=0.23, respectively.

As the trend towards an anxiety interaction with the trial type congruency effect for fear trials could have been driven by high anxious participants responding slower on incongruent trials and/or faster on congruent trials we ran two more correlations to clarify this issue. Here we adopt an adjusted significance level of 0.025/2. Trait anxiety was not significantly correlated with RTs to incongruent fear trials (r= -0.05, p=0.673), or with RTs to congruent trials (r= -0.11, p=0.298).

Next, we focused upon the emotion versus previous emotion interaction. Figure 5.10 depicted above suggests that the emotional response priming effect is present for happy faces but not fearful faces. In order to explore this statistically we conducted two more one-way ANCOVAS (including standardised trait anxiety as the covariate) whilst also adopting an adjusted significance level of 0.05/2. The first one-way ANCOVA showed that there was no significant RT difference between fearful trials that followed a fearful trial and fearful trials that followed a happy trial (F[1,85]=0.2, p=0.879, η^2<0.001). Moreover, trait anxiety did not significantly interact with this comparison (F[1,85]=0.6, p=0.801, η^2=0.001). Thus, trait anxiety was not correlated with any RT difference between these trials. The second one-way ANCOVA showed that there was a significant RT difference between happy trials that followed a happy trial and happy trials that followed a fearful trial (F[1,85]=44.4, p<0.001, η^2=0.343). Once again, trait anxiety did not significantly interact with this comparison (F[1,85]=0.7, p=0.412, η^2=0.008). Thus, trait anxiety was not correlated with any RT difference between these trials.

There were also two more complex interactions that were significant in our initial ANCOVA; first there is a trial type x emotion x (in)congruency repetition/alternation interaction, depicted above in Figures 5.6 and 5.7. Second, there is a trial type x (in)congruency repetition/alternation x emotional face repetition/alternation interaction, depicted above in Figures 5.9 and 5.10. Rather than carry out individual follow-up analyses for these interactions we carried out our planned (and thus more meaningful) comparisons of the trial type versus (in)congruency repetition/alternation interaction in each emotion condition, and emotion repetition/alternation condition. In effect, we sorted the trial type and (in)congruency repetition/alternation comparisons by target emotion and target and response repetition/alternation. Thus we conducted four ANCOVAS on the CSE (i.e., fear trials without target and response repetition; fear trials with target and response repetition; happy trials without target and response repetition; happy trials with target and response repetition). Here we adopt an adjusted significance level of 0.05/4.

The first analysis focused upon a 2 (trial type; congruent versus incongruent) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) ANCOVA in the fearful face condition (when target emotion and response do not repeat), including standardised trait anxiety as the covariate. The critical finding here was that the (in)congruency repetition/alternation effect was robustly significant (F[1,85]=9.2, p=0.003, η^2=0.098). However, the (in)congruency repetition/alternation effect did not significantly interact with trait anxiety (F[1,85]=0.1, p=0.730, η^2=0.001). Figure 5.14 shows that the CSE for fearful trials when the previous emotion was a happy face is in reverse to what is usually found. In short, (in)congruency alternation trials were responded to faster than (in)congruency repetition trials. The trial type x (in)congruency repetition/alternation interaction was not significant (F[1,85]=1.4, p=0.234, η^2=0.017), and nor was the trial type x (in)congruency repetition/alternation x trait anxiety interaction (F[1,85]=1.4, p=0.243, η^2=0.016). The test of between-subjects effects showed that trait anxiety was uncorrelated with RTs averaged across these trial types (F[1,85]=0.6, p=0.459, η^2=0.006).

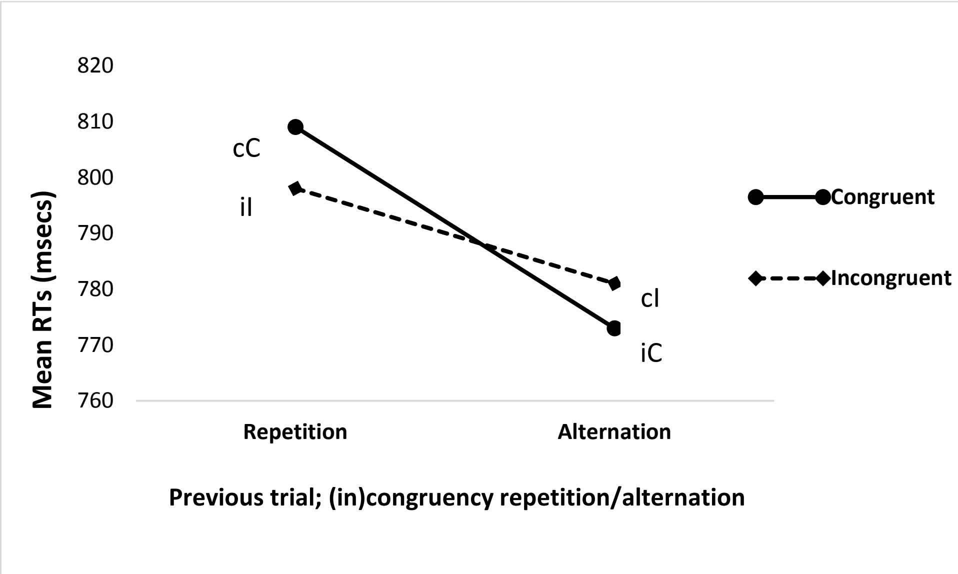

Figure 5.14: The significant reversed (in)congruency repetition/alternation effect in RTs for fearful trials without emotional target and response repetition.

The second analysis focused upon a 2 (trial type; congruent versus incongruent) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) ANCOVA in the fearful face condition (when target emotion and response do repeat), including standardised trait anxiety as the covariate. The critical finding here was that the (in)congruency repetition/alternation effect shown in Figure 5.15 was not significant (F[1,85]=0.9, p=0.332, η^2=0.011). The (in)congruency repetition/alternation effect did not significantly interact with trait anxiety (F[1,85]=2.7, p=0.102, η^2=0.031). The trial type x (in)congruency repetition/alternation interaction was not significant at the adjusted significance level (F[1,85]=5.3, p=0.024, η^2=0.058), and nor was the trial type x (in)congruency repetition/alternation x trait anxiety interaction (F[1,85]=0.9, p=0.338, η^2=0.011). The test of between-subjects effects showed that trait anxiety was uncorrelated with RTs averaged across these trial types (F[1,85]=0.7, p=0.410, η^2=0.008).

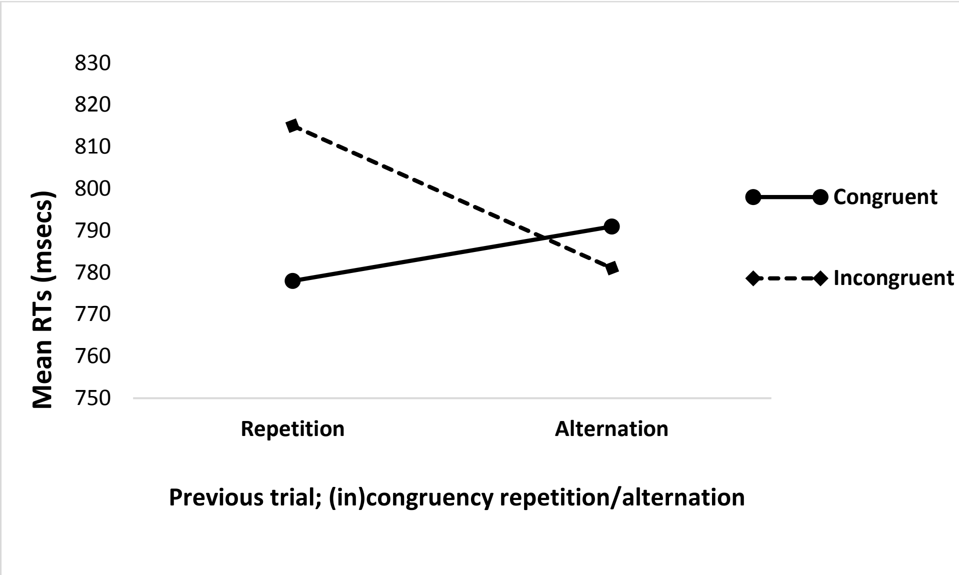

Figure 5.15: The non-significant (in)congruency repetition/alternation effect in RTs for fearful trials with emotional target and response repetition.

The third analysis focused upon a 2 (trial type; congruent versus incongruent) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) ANCOVA in the happy face condition (when target emotion and response do not repeat), including standardised trait anxiety as the covariate. The critical finding here was that the (in)congruency repetition/alternation effect shown in Figure 5.16 was not significant (F[1,85]=0.6, p=0.450, η^2=0.007). The (in)congruency repetition/alternation effect did not significantly interact with trait anxiety (F[1,85]=0.5, p=0.467, η^2=0.006). The trial type x (in)congruency repetition/alternation interaction was not significant at the adjusted significance level (F[1,85]=4.4, p=0.038, η^2=0.049), and nor was the trial type x (in)congruency repetition/alternation x trait anxiety interaction (F[1,85]=1.5, p=0.230, η^2=0.017).

The test of between-subjects effects showed that trait anxiety was uncorrelated with RTs averaged across these trial types (F[1,85]=0.3, p=0.607, η^2=0.003).

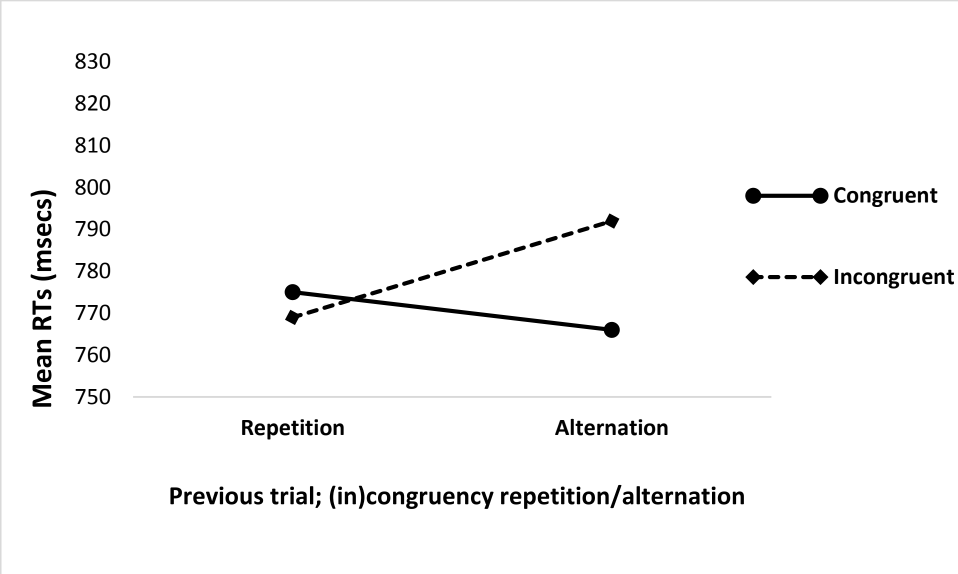

Figure 5.16: The non-significant (in)congruency repetition/alternation effect in RTs for happy trials with no emotional target and response repetition.

The fourth analysis focused upon a 2 (trial type; congruent versus incongruent) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) ANCOVA in the happy face condition (when target emotion and response do repeat), including standardised trait anxiety as the covariate. The critical finding here was that the (in)congruency repetition/alternation effect shown in Figure 5.17 was not significant (F[1,85]=0.8, p=0.386, η^2=0.009). The (in)congruency repetition/alternation effect did not significantly interact with trait anxiety (F[1,85]=0.1, p=0.733, η^2=0.001). The trial type x (in)congruency repetition/alternation interaction was not significant (F[1,85]=2.8, p=0.098, η^2=0.032), and nor was the trial type x (in)congruency repetition/alternation x trait anxiety interaction (F[1,85]=0.1, p=0.911, η^2<0.001). The test of between-subjects effects showed that trait anxiety was uncorrelated with RTs averaged across these trial types (F[1,85]=0.8, p=0.368, η^2=0.010).

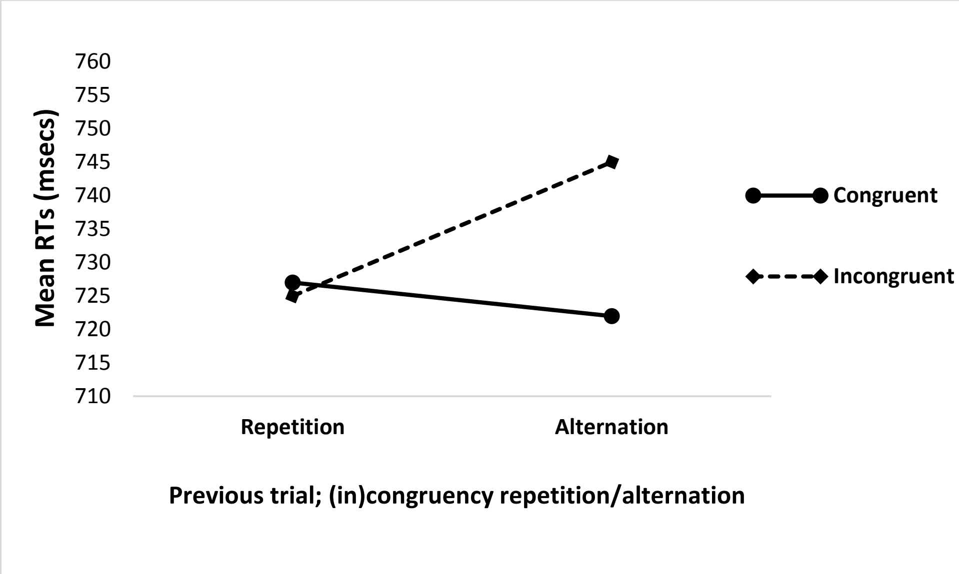

Figure 5.17: The non-significant (in)congruency repetition/alternation effect in RTs for happy trials with emotional target and response repetition.

To follow, we followed up the reversed CSE interaction found for fearful trials when target and response did not repeat, in order to verify if both incongruent and congruent trials were implicated. Here we use two one-way ANCOVAs with standardised trait anxiety included as the covariate. Here we adopt a further adjusted significance level of 0.0125/2. The first ANCOVA compared hFiI trials with hFcI trials, and showed that hFcI trials were not responded to significantly faster than hFiI trials (F[1,85]=2.9, p=0.092, η^2=0.033). Trait anxiety did not significantly interact with this RT difference (F[1,85]=1.4, p=0.238, η^2=0.016). Thus, trait anxiety was not significantly correlated with the RT difference between these trials. The correlation value was r=0.13. The second ANCOVA compared hFcC trials with hFiC trials, and showed that hFiC trials were responded to faster than hFcC trials (F[1,85]=7.6, p=0.007, η^2=0.082). This comparison was very near significant as the adjusted significance level of p=0.006. This means that the reversed CSE was found primarily in the congruent trials. Once again, trait anxiety did not significantly interact with this RT difference (F[1,85]=0.2, p=0.643, η^2=0.003). Thus, trait anxiety was uncorrelated with the RT difference between these trials. The correlation value was r= -0.05.

5.4.4. Latent correlations: Controlling for general RT effects.

As with experiment 1, we suspected that the correlations between trait anxiety and the specific RT effects in any single condition were likely to have been suppressed by general sources of RT variance shared across all conditions. Thus, we calculated a general RT factor. Exploratory factor analyses clearly revealed a strong general RT factor across all conditions. To estimate the general RT factor we used a maximum likelihood extraction of two factors using mean RTs from each participant for each of the 16 stimulus types. Factor 1 was clearly the general RT factor (all loadings > 0.83), which accounted for 78% of the variance). Factor 2 was much smaller, and accounted for 6% of the variance. We used the general RT factor in a series of exploratory partial correlations to determine if trait anxiety shared any latent RT correlations with any specific effect. These correlations have not been adjusted for multiple testing and should therefore be treated with caution. When controlling for these general RT effects trait anxiety was still not significantly correlated with the happy face recognition advantage (r= -0.04, p=0.726), and not significantly correlated with the reversed CSE for fear trials (when target and response did not repeat; r= -0.06, p=0.556), nor was trait anxiety significantly correlated with the CSE when we combined fear trials with and without target and response repetition (r= -0.14, p=0.216). However, the correlation between trait anxiety and the congruency effect for fear trials remained stable (r= 0.22, p=0.039). When controlling for general RTs trait anxiety was correlated with RTs to congruent fear trials at a trend level (r= -0.21, p=0.052), but not with RTs to incongruent trials (r= 0.05, p=0.624). Thus, the anxiety effect upon the congruency effect for fear trials appears to be driven by high anxious participants responding to congruent trials faster than low anxious participants. Finally, we also confirmed that when controlling for general RTs, trait anxiety was still not significantly correlated with the RT difference between hFiI trials and hFcI trials (r= 0.14, p=0.209), and also not significantly correlated with the RT difference between hFcC trials and hFiC trials (r= -0.03, p=0.799).

5.4.5. Exploratory RT correlations with the STAI-anxiety and STAI-depression measures.

STAI-anxiety and STAI-depression correlated positively and moderately (r=0.65, p<0.001). We wished to explore the relationship between these measures and some selected RT effects. Once again these analyses are exploratory in nature, are not adjusted for multiple testing, and as such should be treated with caution. We wished to verify whether the STAI-anxiety subscale related to any of the main emotional goal conflict effects of interest any more strongly than the total STAI-trait scores did. We also wished to verify whether STAI-depression related to any of these effects.

STAI-anxiety correlated with the interference effect for fear trials (r= 0.21, p=0.057) at a trend level (the correlation value was r= 0.21, p=0.052, when controlling for the general RT factor), as did STAI-depression (r= 0.22, p=0.045; the correlation value was r= 0.20, p=0.067 when controlling for the general RT factor). However, partial correlation showed that when controlling for STAI-depression, STAI-anxiety was no longer correlated with the interference effect for fear trials (r= 0.087, p=0.423). When controlling for STAI-anxiety, STAI-depression was uncorrelated with the interference effect for fear trials (r= 0.11, p=0.306). Therefore we suggest that the STAI-trait correlation with the interference effect for fear trials was driven by the shared variance of STAI-anxiety and STAI-depression. This analysis relates to our key interest in whether trait anxiety relates to distraction.

Similarly to the total scores of the STAI-trait (r= 0.04, p=0.730), STAI-anxiety was not significantly correlated with the reversed RT (in)congruency repetition/alternation effect for fear trials when target and response did not repeat (r= 0.11, p=0.295). The correlation value was (r= 0.13, p=0.253), when controlling for the general RT factor. As one would expect, STAI-depression was also uncorrelated with the reversed RT (in)congruency repetition/alternation effect for fear trials when target and response did not repeat (r= -0.02, p=0.857). The correlation value was (r= 0.01, p=0.901), when controlling for the general RT factor.

Next, we wished to verify whether when controlling for general RTs STAI-anxiety and/or STAI-depression were specifically correlated with the RT difference score for hFiI trials and hFcI trials, and also the RT difference score for hFcC trials and hFiC trials. When controlling for general RTs STAI-anxiety was correlated with the RT difference between hFiI trials and hFcI trials (*r*= 0.22, *p*=0.040), but not the RT difference between hFcC trials and hFiC trials (*r*= -0.02, *p*=0.873). Moreover, when controlling for both general RTs and STAI-depression, STAI-anxiety was correlated with the RT difference between hFiI trials and hFcI trials (*r*=0.24, *p*=0.026). This effect relates to our key interest in whether trait anxiety relates to conflict resolution and emotion as indexed by the emotional CSE.

When controlling for general RTs STAI-depression was not correlated with the RT difference between hFiI trials and hFcI trials (*r*= 0.06, *p*=0.592), nor with the RT difference between hFcC trials and hFiC trials (*r*= -0.03, *p*=0.778). Moreover, when controlling for both general RTs and STAI-anxiety, STAI-depression was still not significantly correlated with the RT difference between hFiI trials and hFcI trials (*r*= -0.12, *p*=0.293).

Finally, we determined that STAI-anxiety was not significantly correlated with RTs to hFiI trials (*r*= -0.07, *p*=0.536), or hFcI trials (*r*= -0.04, *p*=0.742). However, when controlling for general RTs STAI-anxiety was correlated with hFiI trials (*r*= 0.21, *p*=0.051), but not hFcI trials (*r*= -0.06, *p*=0.579). Moreover, the correlation between STAI-anxiety and the hFiI trials was similar when controlling for both general RTs and STAI-depression (*r*= 0.22, *p*=0.043). This effect relates to our key interest in whether trait anxiety relates to conflict resolution and emotion as indexed by the emotional CSE.

5.4.6. Proportion correct analysis

The proportion correct data were subjected to a 2 (current trial type; congruent versus incongruent) x 2 (emotion; fearful face versus happy face) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) x 2 (previous emotion type; emotional face repetition versus alternation) repeated-measures ANCOVA with the standardised scores of the STAI-trait measure as the covariate. STAI-trait scores are referred to as trait anxiety in this analysis. Once again responses faster than 200 msecs and slower than 1250 msecs were not included. Again, we also planned to conduct several further comparisons designed to examine the CSE in each of four specific cognitive situations; 1: fearful faces with target/response repetition; 2: fearful faces without target/response repetition; 3: happy faces with target response repetition; 4: happy faces without target response repetition.

The test of between-subjects effects was not significant (F[1,85]=0.9, p=0.352, η^2=0.010),thus anxiety was unrelated to proportion correct averaged across the paradigm. The mean proportion correct for each trial type, 95% confidence intervals, and standard errors of the mean are shown in Table 5.3. Figure 18 shows the mean proportion correct for each of the 16 trial types.

Table 5.3: Mean proportion correct, 95% confidence intervals (95% CIs), and standard errors (SE) for each of the 16 stimulus types. As described above, in the trial type denotations the first 2 letters describe the emotion presented on the previous trial (lower case) and the current trial (upper case). Then the next 2 letters describe the congruency type again for the previous trial (lower case) and the current trial (upper case).

Fearful face trials				**Happy face trials**			
Trial type	**Mean**	**95% CI**	**SE**	**Trial type**	**Mean**	**95% CI**	**SE**
fFcC	0.95	0.93-0.96	0.008	**hHcC**	0.94	0.93-0.95	0.007
hFcC	0.92	0.90-0.94	0.010	**fHcC**	0.94	0.93-0.96	0.008
fFiC	0.92	0.90-0.94	0.009	**hHiC**	0.95	0.93-0.96	0.008
hFiC	0.93	0.91-0.94	0.008	**fHiC**	0.94	0.93-0.95	0.007
fFiI	0.92	0.90-0.94	0.010	**hHiI**	0.96	0.95-0.97	0.006
hFiI	0.93	0.92-0.95	0.008	**fHiI**	0.92	0.90-0.94	0.010
fFcI	0.94	0.92-0.96	0.010	**hHcI**	0.96	0.94-0.97	0.008
hFcI	0.93	0.91-0.94	0.008	**fHcI**	0.93	0.92-0.95	0.007

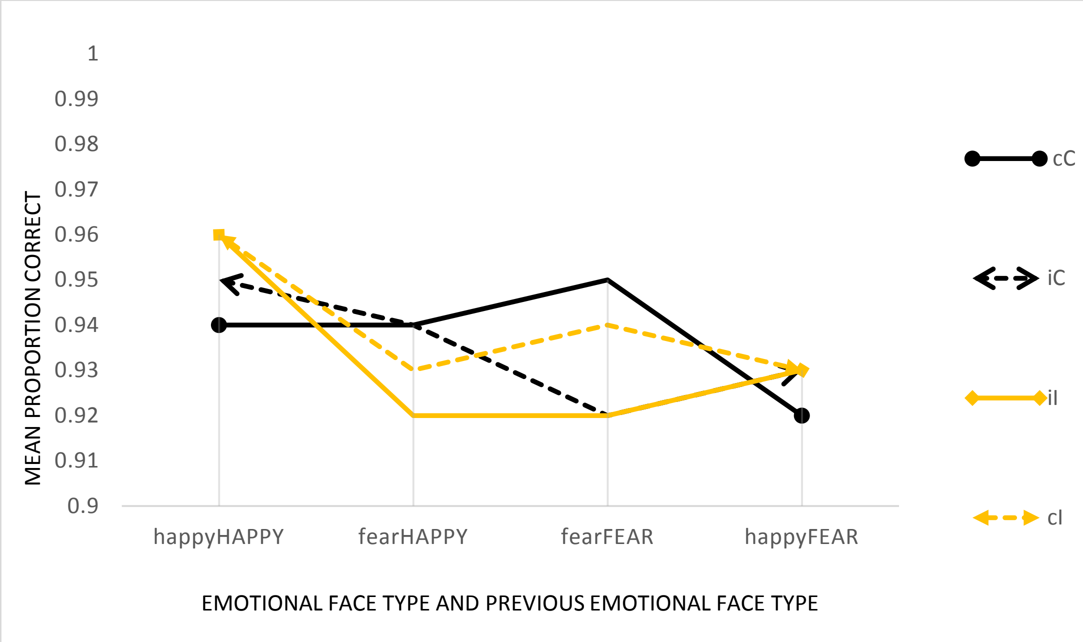

Figure 5.18: Mean proportion correct for each of the 16 trial types separated by current trial congruency, previous trial congruency, emotion, and previous emotion.

The test of within subjects effects showed that the main effect of trial type was not significant (F[1,85]=0.01, p=0.910, η^2<0.001). Thus, averaged congruent trials (mean proportion correct 0.94; 95% CI 0.93-0.95; SE 0.005) were not responded to more accurately than averaged incongruent trials (mean proportion correct 0.94; 95% CI 0.93-0.94; SE 0.005). The main effect of trial type did not significantly interact with trait anxiety (F[1,85]=1.1, p=0.294, η^2=0.013). This interaction shows that there was no significant correlation between trait anxiety and the accuracy difference between congruent and incongruent trials.

The main effect of emotional face type was significant (F[1,85]=6.5, p=0.013, η^2=0.071), as averaged happy faces (mean proportion correct = 0.94; 95% CI 0.93-0.95; SE 0.005) were responded to significantly more accurately than averaged fearful faces (mean proportion correct = 0.93; 95% CI 0.92-0.94; SE 0.006). This effect is in alignment with the RT analysis which showed that happy faces were responded to faster than fearful faces. Moreover, in the proportion correct analysis the main effect of emotional face type did not significantly interact with trait anxiety (F[1,85]=3.3, p=0.075, η^2=0.037), which is also in alignment with the RT analysis.

Therefore, trait anxiety was not correlated with the accuracy difference between responses to happy faces and responses to fearful faces.

The main effect of (in)congruency repetition/alternation was not significant (F[1,85]=0.2, p=0.648, η^2=0.002), as repetition trials (mean proportion correct 0.93; 95% CI 0.92-0.94; SE 0.005) were not responded to significantly more accurately than alternation trials (mean proportion correct 0.94; 95% CI 0.93-0.995; SE 0.005). This shows that the CSE was not significant when averaged across all other features of the design. Critically, this effect also did not significantly interact with trait anxiety (F[1,85]=0.001, p=0.970, η^2<0.001). Thus, trait anxiety was uncorrelated with any average accuracy difference between (in)congruency repetition trials and (in)congruency alternation trials.

The main effect of emotional face repetition/alternation was significant (F[1,85]=6.5, p=0.013, η^2=0.071). This shows that averaged proportion correct for faces that followed a face depicting the same emotion (mean proportion correct 0.94; 95% CI 0.93-0.95; SE 0.005) were more accurate than averaged proportion correct for faces that followed a face depicting the alternative emotion (mean proportion correct 0.93; 95% CI 0.92-0.94; SE 0.005). This accuracy effect is in alignment with the RT analysis reported above which showed that emotion repetition trials were responded to significantly faster than emotion alternation trials. In the proportion correct analysis the main effect of emotional face repetition/alternation did not interact with trait anxiety (F[1,85]=0.2, p=0.667, η^2=0.002). Thus, anxiety was not correlated with any accuracy difference between emotional face repetition trials and emotional face alternation trials.

The trial type x emotion interaction was not significant (F[1,85]=0.002, p=0.964, η^2<0.001). This shows that the effect of trial type upon accuracy did not significantly differ depending upon what he target emotional face was. The trial type x emotion x trait anxiety interaction was also not significant (F[1,85]=0.02, p=0.876, η^2<0.001). This shows that trait anxiety was not related to any difference in the effect on accuracy of trial type between the two emotion conditions. This is in contrast to the RT analysis, which showed that trait anxiety was related to a difference in the effect of trial type between the two emotion conditions

The trial type x (in)congruency repetition/alternation interaction was not significant (F[1,85]=2.9, p=0.093, η^2=0.033). This shows that there was no difference in the effect of (in)congruency repetition and (in)congruency alternation depending upon which trial type was responded to. Moreover, the trial type x (in)congruency repetition/alternation interaction did not further interact with anxiety (F[1,85]=1.3, p=0.252, η^2=0.015).

The emotion x (in)congruency repetition/alternation interaction was not significant (F[1,85]=0.4, p=0.524, η^2=0.005). This shows that the effect of (in)congruency repetition/alternation did not differ significantly as a function of the emotion conditions. This null effect in accuracy is in contrast to the RT analysis which was robustly significant. In the proportion correct analysis the emotion x (in)congruency repetition/alternation interaction did not significantly further interact with trait anxiety (F[1,85]=1.2, p=0.277, η^2=0.014). Thus trait anxiety was not related to any difference in the (in)congruency repetition/alternation effect that may occur relative to emotional target face type.

The trial type x emotion x (in)congruency repetition/alternation interaction was also not significant (F[1,85]=1.1, p=0.308, η^2=0.012). Therefore the effect of trial type did not differ depending upon how emotional target face type affects the (in)congruency repetition/alternation effect. This null effect in accuracy is again in contrast to the RT analysis which was robustly significant. In the proportion correct analysis, trait anxiety was not related to this effect, as the trial type x emotion x (in)congruency repetition/alternation x anxiety interaction was not significant (F[1,85]=0.4, p=0.529, η^2=0.005). The trial type x emotional face repetition/alternation interaction was not significant (F[1,85]=1.4, p=0.246, η^2=0.016). This comparison shows that the effect of trial type upon accuracy was not affected by whether the emotional face type depicted the same emotion as the previous trial, or depicted a different emotion to the previous trial. The trial type x emotional face repetition/alternation interaction did not further significantly interact with trait anxiety (F[1,85]=0.5, p=0.462, η^2=0.006). This shows that trait anxiety was not related to any sequential effect of emotion upon the effect of trial type.

The emotion x emotional face repetition/alternation interaction was not significant (F[1,85]=3.1, p=0.083, η^2=0.035). This shows that the difference in accuracy for responses when the emotional face type repeats relative to when the emotional face type alternates is not significantly affected by which emotion type is involved. This is in contrast to the RT analysis, where this effect was robustly significant. In the proportion correct analysis the emotion x emotional face repetition/alternation x trait anxiety interaction was also not significant (F[1,85]=1.4, p=0.238, η^2=0.016). Thus any possible effect of emotion upon the emotional face repetition/alternation effect was not modulated by trait anxiety. However, the trial type x emotion x emotion repetition/alternation interaction was highly significant (F[1,85]=9.4, p=0.003, η^2=0.099). This effect is illustrate by Figures 5.19 and 5.20. We return for further statistical analyses of this effect later. This interaction did not further interact with trait anxiety (F[1,85]=1.3, p=0.258, η^2=0.015).

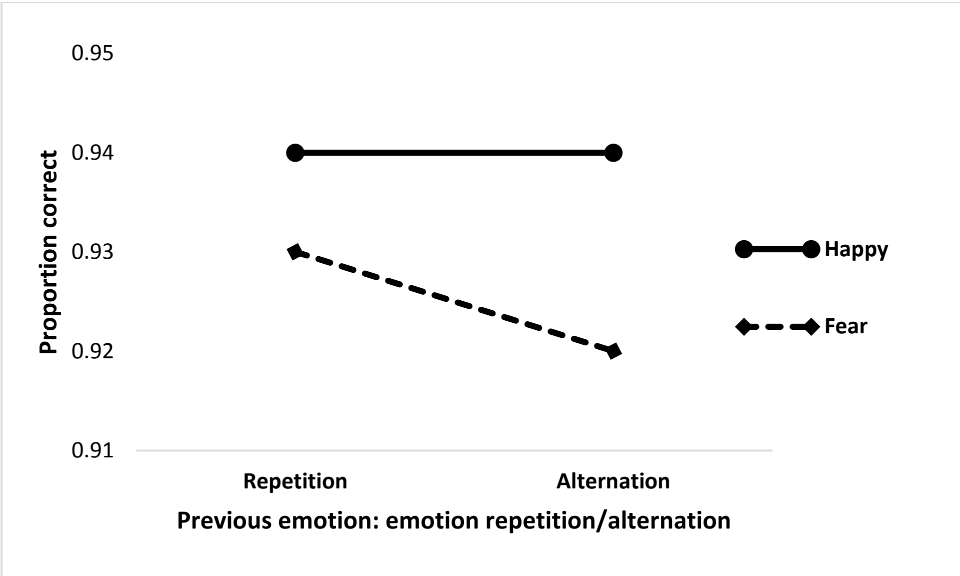

Figure 5.19: The accuracy interaction between emotional expression type and previous emotional expression type for congruent trials.

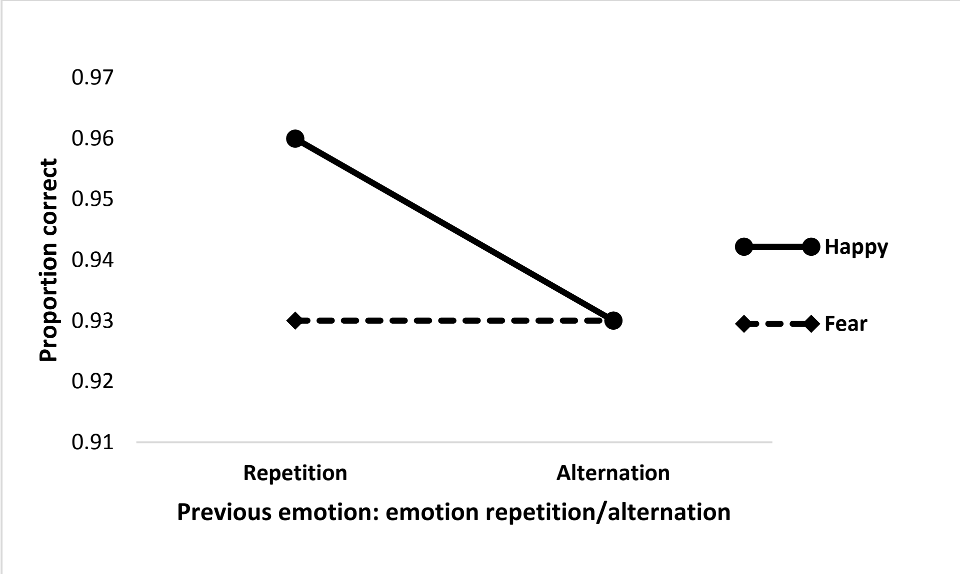

Figure 5.20: The accuracy interaction between emotional expression type and previous emotional expression type for incongruent trials.

The (in)congruency repetition/alternation x emotional face repetition/alternation interaction was not significant (F[1,85]=0.2, p=0.656, η^2=0.002). Moreover, this null interaction effect did not further significantly interact with trait anxiety (F[1,85]=3.4, p=0.069, η^2=0.038). The trial type x (in)congruency repetition/alternation x emotional face repetition/alternation interaction was not significant (F[1,85]=2.1, p=0.151, η^2=0.024). This is in contrast to the RT analysis, where this effect was significant. This proportion correct interaction did not further interact with trait anxiety (F[1,85]=0.8, p=0.367, η^2=0.010). The emotion x (in)congruency repetition/alternation x emotional face repetition/alternation interaction was not significant (F[1,85]=0.03, p=0.861, η^2<0.001), nor was the emotion x (in)congruency repetition/alternation x emotional face repetition/alternation x trait anxiety interaction (F[1,85]=0.7, p=0.412, η^2=0.008). However, the trial type x emotion x (in)congruency repetition/alternation x emotion repetition/alternation interaction was robustly significant (F[1,85]=8.7, p=0.004, η^2=0.092). We return to this issue later (4-way interactions are hard to depict so there is no figure here). It is again noteworthy here that this effect was not significant in the RT analysis. In the proportion correct analysis the trial type x emotion x (in)congruency repetition/alternation x emotion repetition/alternation x trait anxiety interaction was not significant (F[1,85]=0.07, p=0.793, η^2=0.001).

5.4.7. Probing the proportion correct interaction effects

There were two interactions in the accuracy analysis that were significant in our initial ANCOVA: a trial type x emotion x emotion repetition/alternation interaction; and a trial type x emotion x (in)congruency repetition/alternation x emotion repetition/alternation interaction.

Rather than carry out excessive individual follow-up analyses for these interactions we carried out the planned comparisons of the trial type versus (in)congruency repetition/alternation interaction in each emotion condition, and emotion repetition/alternation condition. In effect, as with the RT analysis we sorted the trial type and (in)congruency repetition/alternation comparisons by target emotion and target and response repetition/alternation. Thus we conducted four ANCOVAS evaluating the CSE (i.e., separate CSE analyses for: fear trials without target and response repetition; fear trials with target and response repetition; happy trials without target and response repetition; happy trials with target and response repetition). Here we again adopt an adjusted significance level of 0.05/4.

The first analysis focused upon a 2 (trial type; congruent versus incongruent) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) ANCOVA in the fearful face condition when target emotion and response do not repeat, including standardised trait anxiety as the covariate. The critical finding here was that the CSE shown in Figure 5.21 (i.e. the (in)congruency repetition/alternation effect) was not significant ($F[1,85]=0.05$, $p=0.817$, $\eta^2=0.001$). Moreover, the (in)congruency repetition/alternation effect did not significantly interact with trait anxiety ($F[1,85]=0.9$, $p=0.355$, $\eta^2=0.010$). The trial type x (in)congruency repetition/alternation interaction was not significant ($F[1,85]=1.2$, $p=0.284$, $\eta^2=0.014$), suggesting that there was not significant variation in the CSE size for congruent vs. incongruent trials. Finally, the trial type x (in)congruency repetition/alternation x trait anxiety interaction was not significant ($F[1,85]=0.02$, $p=0.896$, $\eta^2<0.001$). However, it is noteworthy here that the test of between-subjects effects showed that trait anxiety was related to accuracy levels averaged across these four trial types, at a trend level ($F[1,85]=4.5$, $p=0.037$, $\eta^2=0.050$). The correlation value was r=0.22, thus anxiety was marginally related to increased accuracy for fear trials when emotional target and response did not repeat.

Figure 5.21: The non-significant (in)congruency repetition/alternation effect present in the proportion correct for trials with fearful target faces, when the target and response did not repeat.

The second analysis focused upon a 2 (trial type; congruent versus incongruent) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) ANCOVA in the fearful face condition (when target emotion and response do repeat), including standardised trait anxiety as the covariate. The critical finding here was that the CSE shown in Figure 5.22 (i.e., the (in)congruency repetition/alternation effect) was not significant (F[1,85]=0.1, p=0.708, η^2=0.002). The (in)congruency repetition/alternation effect did not significantly interact with trait anxiety (F[1,85]<0.001, p=0.100, η^2<0.001). The trial type x (in)congruency repetition/alternation interaction was robustly significant at the adjusted significance level (F[1,85]=9.8, p=0.002, η^2=0.103). This means that the CSE was significantly different for congruent and incongruent trials. The trial type x (in)congruency repetition/alternation x trait anxiety interaction was not significant (F[1,85]=1.7, p=0.200, η^2=0.019). The test of between-subjects effects showed that trait anxiety was not related to accuracy levels averaged across these four trial types (F[1,85]=0.7, p=0.394, η^2=0.009).

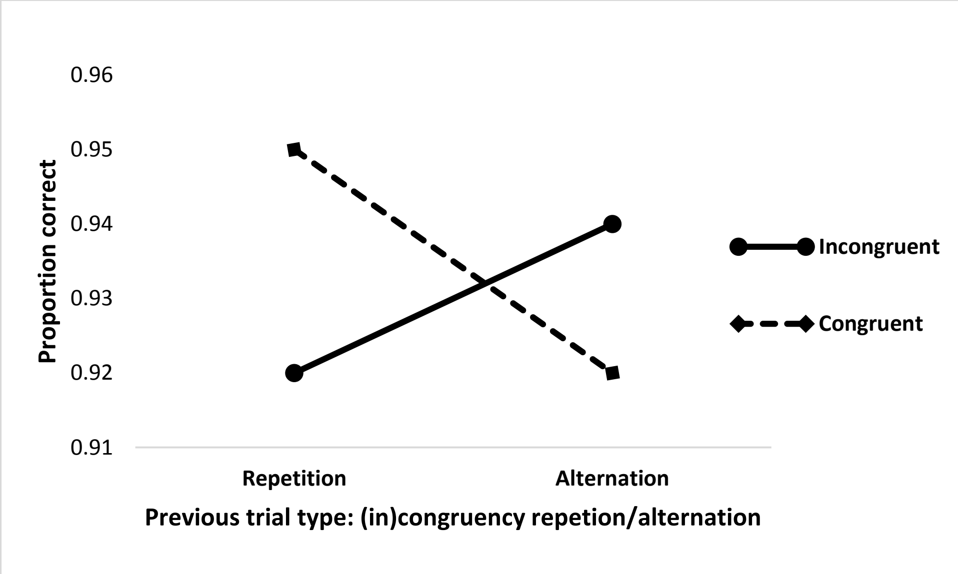

Figure 5.22: The non-significant (in)congruency repetition/alternation effect present in the proportion correct for trials with fearful target faces, when the target and response did repeat.

The third analysis focused upon a 2 (trial type; congruent versus incongruent) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) ANCOVA in the happy face condition (when target emotion and response do not repeat), including standardised trait anxiety as the covariate. The critical finding here was that the CSE shown in Figure 5.23 (i.e., the (in)congruency repetition/alternation effect) was not significant (F[1,85]=0.5, p=0.479, η^2=0.006). The (in)congruency repetition/alternation effect did not significantly interact with trait anxiety (F[1,85]=0.8, p=0.380, η^2=0.009). The trial type x (in)congruency repetition/alternation interaction was not significant at the adjusted significance level (F[1,85]=1.2, p=0.274, η^2=0.014), and nor was the trial type x (in)congruency repetition/alternation x trait anxiety interaction (F[1,85]=0.03, p=0.874, η^2<0.001). The main effect of trial type did not reach significance (F[1,85]=4.7, p=0.032, η^2=0.053) and this effect did not interact with trait anxiety (F[1,85]=2.0, p=0.160, η^2=0.023). The test of between-subjects effects showed that trait anxiety was not related to accuracy levels averaged across these four trial types (F[1,85]=0.07, p=0.782, η^2=0.001).

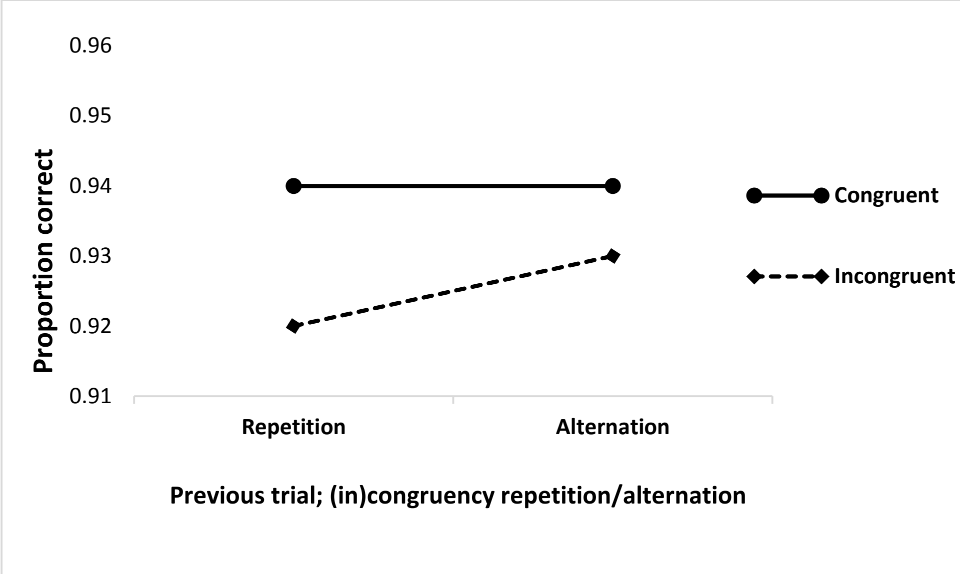

Figure 5.23: The non-significant (in)congruency repetition/alternation effect present in the proportion correct for trials with happy target faces, when the target and response did not repeat.

The fourth analysis focused upon a 2 (trial type; congruent versus incongruent) x 2 (previous trial type; (in)congruency repetition versus (in)congruency alternation) ANCOVA in the happy face condition (when target emotion and response do repeat), including standardised trait anxiety as the covariate. The critical finding here was that the CSE shown in Figure 5.24 (i.e., the (in)congruency repetition/alternation effect) was not significant (F[1,85]=0.2, p=0.682, η^2=0.002). Moreover, the (in)congruency repetition/alternation effect did not significantly interact with trait anxiety F[1,85]=3.8, p=0.054, η^2=0.043). Trait anxiety shared a weak correlation (that was non-significant cf the adjusted critical p-level) with the accuracy difference between (in)congruency repetition and (in)congruency alternation trials when happy faces repeated. The correlation value was r=0.21. The trial type x (in)congruency repetition/alternation interaction was not significant (F[1,85]=0.1, p=0.750, η^2=0.001), and nor was the trial type x (in)congruency repetition/alternation x trait anxiety interaction (F[1,85]=0.5, p=0.471, η^2=0.006). It is noteworthy here that the main effect of trial type approached significance against the adjusted significance level (F[1,85]=6.2, p=0.015, η^2=0.068) as congruent trials (proportion correct = 0.94) were responded to less accurately than incongruent trials (proportion correct = 0.96), but this effect did not interact with trait anxiety (F[1,85]=0.4, p=0.523,

η^2=0.005). The test of between-subjects effects showed that trait anxiety was not related to accuracy levels averaged across these four trial types (F[1,85]=0.03, p=0.859, η^2<0.001).

Figure 5.24: The non-significant (in)congruency repetition/alternation effect present in the proportion correct for trials with happy target faces, when the target and response did repeat.

We further probed the two proportion correct interactions reported above. The adjusted p-level is 0.0125/2 for these follow-up tests. The trial type x (in)congruency repetition/alternation interaction in the fearful face condition when target emotion and response did repeat was driven by the CSE being more robustly present for congruent trials (F[1,85]=7.2, p=0.009, η^2=0.078), than for incongruent trials (F[1,85]=4.2, p=0.044, η^2=0.047). This is also illustrated in Table 5.3 which shows that fFcC trials were responded to more accurately than fFiC trials. In contrast, fFiI trials were responded to less accurately than fFcI trials. This shows that congruent trials where the congruency level repeats were responded to more accurate than when it alternates. In contrast, the opposite pattern is present for incongruent trials (although the effect would not approach significance after accounting for multiple testing). Neither comparison was significantly affected by trait anxiety (both Fs < 1.0, both ps > 0.3).

As noted above, the (in)congruency repetition/alternation interaction with trait anxiety in the happy face condition when target emotion and response did repeat was driven by trait anxiety showing a trend towards a correlation with the accuracy difference between (in)congruency repetition and (in)congruency alternation trials. We further probed this effect in an attempt to verify which trial type was driving the effect. However, trait anxiety was not significantly correlated with (in)congruency repetition trials (r= -0.11, p=0.304), or (in)congruency alternation trials (r= 0.12, p=0.281).

5.5. Discussion

We created a novel, and more ecologically-valid, emotional face flanker task that allowed for an analysis of emotion recognition, emotional distraction, and emotional conflict resolution. Thus, this task assesses the non-sequential and sequential effects of both emotional face processing and emotional goal conflict processing. Congruent trials where the emotional expression depicted by the target face was the same as the emotional expression depicted by the flanker faces were not responded to significantly faster or more accurately than incongruent trials where the target face and flanker faces depicted different emotions (when averaged across target emotion type, goal conflict sequence type, and emotion sequence type). There was no significant correlation between trait anxiety and any RT difference or accuracy difference between these congruent and incongruent trials. The finding that trait anxiety is unrelated to the congruency effects is in alignment with the results of experiment 1 and the results of the neutral arrow flanker task experiment carried out by Larson, Clawson, Clayson and Baldwin (2013).

Overall happy faces, averaged across trial type, goal conflict sequence type, and emotion sequence type, were responded to faster and more accurately than fearful faces averaged across these trial types. This finding is in alignment with the findings of experiment 1. The finding of an overall processing advantage for happy facial expressions also supports the findings of several emotional facial expression recognition studies (Silvia, Allan, Beauchamp, Maschauer, & Workman., 2006; Cooper, Rowe, & penton-Voak, 2008; Hietanen & Astikainen, 2013; Leppanen &

Hietanen, 2004; Leppanen & Hietanen, 2003; Kirita & Endo, 1995; Feyereisen, Malet, & Martin, 1996; Werheid, Alpay, Jentzsch, & Sommer; 2005). In the present study trait anxiety did not appear to significantly affect either the RT difference or the accuracy difference between responses to happy faces and responses to fearful faces averaged across trial types. This finding is in contrast to experiment 1 where trait anxiety was related to the RT difference between happy and fearful face trials[4].

The effect of trial type upon RTs and accuracy did not significantly differ depending upon what the target emotional face was. However, trait anxiety was related to a RT difference, but not any accuracy difference, in the effect of trial type between the two emotion conditions (i.e., a RT congruency effect which is greater in one emotion condition than the other). In the fearful face condition those higher in anxiety showed a greater RT congruency effect relative to those lower in trait anxiety, although the effect was marginal. This effect of trait anxiety was not present in the happy face condition. Moreover, this effect of trait anxiety upon the fearful face congruency effect was not present in experiment 1. In the present experiment, when controlling for sources of general RT variance trait anxiety was negatively correlated with RTs to congruent fear trials at a trend level, but not with RTs to incongruent trials. Those high in trait anxiety responded to congruent fear trials faster than those low in anxiety. This effect of trait anxiety upon RTs to the congruent grids of fearful faces does still suggest that trait anxiety affects the speed of the detection of threat related stimuli, even when there is no distraction caused by the presence of different emotions in the display.

The present experiment assessed both the sequential effects of emotion recognition, and the sequential effects of goal conflict resolution. There were some robust

[4] NOTE: It is noteworthy that in the present experiment the effect of anxiety upon the accuracy difference between happy and fearful faces could be considered a weak trend ($p = 0.075$). Moreover, when the analysis is carried out non-sequentially (i.e., a basic trial type x emotion analysis), the anxiety interaction with the emotion effect upon accuracy is actually significant ($p = 0.045$). The correlation value here was $r = -0.22$, thus higher trait anxiety was marginally related to a reduced difference in accuracy between happy and fearful faces. This was driven by a non-significant anxiety related increase in accuracy for fear trials ($r = 0.18$, $p = 0.093$), not happy trials ($r = -0.02$, $p = 0.842$).

sequential effects concerning the speed of emotion recognition. An emotional face repetition RT advantage was present for the happy faces but not the fearful faces. In contrast, an emotional face repetition accuracy advantage was present for both happy faces and fearful faces. These effects of emotional face repetition were not altered by participants' levels of trait anxiety. The finding of a happy face repetition effect (or possible priming effect) in the RTs is somewhat in alignment with the findings of the studies conducted by Hietanen and Astikainen (2013) and Werheid, Alpay, Jentzsch and Sommer (2005). Hietanen and Astikainen found that happy faces were recognised more accurately when they followed positive picture primes as opposed to negative picture primes. However, in their study RTs for sad faces following negative picture primes only showed a trend towards being faster than RTs for sad faces following positive picture primes. Werheid et al. also found that happy faces were responded to faster when they were primed by a happy face, than when they were primed by an angry face. However, in their study RTs for angry facial expressions were not faster when they were primed by an angry face relative to when they were un-primed (by a previous happy face). However, in the present study we cannot be definitely sure that the repetition advantage for happy faces was due to an emotional priming effect. It is possible that the effect was due to a basic featural processing advantage provided by the mouth region of the happy faces being more salient than the mouth region of the fearful faces, as the stimuli were quite small.

The sequential effect of goal conflict resolution as measured by the CSE was not significant for both RTs and accuracy when averaged across emotion types and across trials where target and response repeat and where target and response alternate. Critically, trait anxiety was uncorrelated with any RT or accuracy difference between averaged (in)congruency repetition trials and averaged (in)congruency alternation trials. This finding is in contrast to the results found for the between-valence condition (happy faces versus fearful faces) of experiment 1. Moreover, in the present experiment there was no difference in the effect of (in)congruency repetition and (in)congruency alternation depending upon which trial type was responded to. This finding is consistent with experiment 1.

The critical finding in the present experiment was that the CSE for RTs (but not accuracy) appeared to be present only in trials where fearful faces were the target face, not where happy faces were the target face. When we probed this effect further we found that the effect was even more specific. It was only reliably present in the fearful face condition when target emotion and response did not repeat (i.e., the (in)congruency repetition/alternation effect was robustly significant). It is noteworthy here that the CSE for fearful trials when target emotion and response did not repeat (i.e., the previous emotion was a happy face) was in reverse to what is usually found in conventional flanker tasks (e.g., Davelaar, 2013; Davelaar & Stevens, 2009; Gratton et al., 1992; Larson et al., 2013; Nieuwenhuis et al., 2006), and was thus the opposite pattern to what was found in experiment 1.

In summary, in the current experiment when fearful faces were the target face (and the previous trial contained a happy target face) congruent trials (where fearful flanker faces surround the target fearful face) were responded to faster if the previous trial was incongruent (where happy flanker faces surround the fearful target face) compared to when the previous trial was also congruent (where fearful flanker faces surround the target fearful face). Moreover, when fearful faces were the target face (and the previous trial contained a happy target face) incongruent trials (where happy flanker faces surround the fearful target face) were responded to faster if the previous trial was congruent (where fearful flanker faces surround the target fearful face) compared to when the previous trial was also incongruent (where happy flanker faces surround the fearful target face). In short, for fearful trials with no target and response repetition (in)congruency alternation trials were responded to faster than (in)congruency repetition trials. In contrast, in the fearful face condition when target and response did repeat, overall the (in)congruency repetition/alternation effect was not significant.[5] Trait anxiety did not affect the CSE in either of these conditions. The CSE was not significant in either the happy face condition when target emotion and response did not repeat, nor in the happy face condition when target emotion and response did repeat. Trait anxiety was not related to the CSE in either of these two conditions. Thus, the lack of a trait anxiety interaction with the CSE is in contrast to the results of the between-valence condition of experiment 1 in (happy faces versus fearful faces), and in contrast to the results of Larson et al. (2013).

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[5] NOTE: We conducted an extra exploratory analysis (not reported in the main results) which verified that fFcI trials were responded to faster than fFiI trials, but the effect is not robust and does not withstand the necessary Bonferroni adjustment.

We followed up the reversed CSE interaction found for fearful trials when target and response did not repeat, in order to explore whether both incongruent and congruent trials were implicated. We found that the effect was mostly driven by the congruent trials. The analysis showed that incongruent trials that followed congruent trials were not responded to faster than incongruent trials that followed incongruent trials. Trait anxiety was uncorrelated with the RT difference between these trials. Moreover, congruent trials that followed incongruent trials were responded to faster than congruent trials that followed congruent trials. This comparison was much more robust (but just missed a very strict Bonferroni adjusted significance cut-off). Trait anxiety was uncorrelated with the RT difference between these trials.

There was also an interesting effect in the accuracy data for the fearful face condition when target emotion and response were repeated. For congruent trials (in)congruency alternation trials were responded to more accurately than (in)congruency repetition trials. In contrast, the opposite pattern was present for incongruent trials as (in)congruency repetition trials were responded to more accurately than (in)congruency alternation trials. However, it is noteworthy that the effect on the incongruent trials did not withstand a strict Bonferroni adjustment. Neither of these CSEs were significantly affected by trait anxiety

There were however two marginal effects of trait anxiety upon levels of accuracy. Trait anxiety was marginally related to an overall increased level of accuracy for fear trials when emotional target and response did not repeat (i.e., trials where trials requiring responding to a target fearful face were preceded by a trial requiring responding to a target happy face). In the happy face condition when target and response did repeat (i.e., trials where trials requiring responding to a target happy face were preceded by a trial requiring responding to a target happy face) the overall CSE related to trait anxiety at a trend level. Thus there was a weak effect of trait anxiety upon the accuracy of emotion processing.

To summarise the anxiety effects thus far, trait anxiety was related to a marginally increased RT congruency effect when fearful faces were the target emotion. Exploratory analyses suggested that this effect was driven by high anxious participants responding to congruent fear trials faster than their low anxious counterparts. Trait anxiety was unrelated to the happy face recognition advantage, or any of the CSEs found in the RTs. The only other effects of anxiety found in the analysis thus far were therefore the marginal accuracy effects described directly above. Accordingly, we also wished to verify whether the STAI-anxiety and/or STAI-depression subscale related to any of the main emotional goal conflict effects of interest any more strongly than the total STAI-trait scores did.

Both STAI-anxiety and STAI-depression related to an increased congruency effect for fear trials at a trend level. However, partial correlation showed that when controlling for STAI-depression, STAI-anxiety was no longer correlated with the congruency effect for fear trials. Similarly when controlling for STAI-anxiety, STAI-depression was uncorrelated with the congruency effect for fear trials. Therefore we suggest that the STAI-trait correlation with the congruency effect for fear trials was possibly driven by the shared variance of these anxiety and depression measures (assuming that the names for these STAI subscales are valid).

Similarly to the total scores of the STAI-trait, STAI-anxiety was uncorrelated with the reversed RT (in)congruency repetition/alternation effect for fear trials when target and response did not repeat. However, when controlling for general RTs STAI-anxiety was positively correlated with the RT difference between hFiI trials and hFcI at a trend level, but not the RT difference between hFcC trials and hFiC trials. Moreover, when controlling for both general RTs and STAI-depression, STAI-anxiety remained correlated with the RT effect. In contrast, STAI-depression was not correlated with either of these RT difference effects when controlling for general RTs or STAI-anxiety. Critically, we determined that when controlling for general RTs STAI-anxiety was positively correlated with RTs for hFiI trials at a trend level, but not RTs for hFcI trials. Moreover, the correlation between STAI-anxiety and the hFiI trials remained when controlling for both general RTs and STAI-depression. Thus, anxiety was weakly related to a slowing in responses to incongruent fearful trials (when target and response did not repeat).

There were two important but unpredicted effects found in the present study that require some considerable explanation. Firstly the CSE for RTs was absent for happy trials but present for fear trials. Secondly, the CSE for RTs present for fear trials was in reverse to what is reliably reported in the literature. Even more specifically, the reversed CSE was only reliably present for fearful trials with no target and response repetition. Therefore, in this subset of trials (in)congruency alternation trials were responded to faster than (in)congruency repetition trials. It is tempting to suggest that the happy face repetition / priming effect in some way overpowered the CSE for happy trials. However, this seems unlikely as although the CSE was absent for trials with target and response repetition, it was also absent for those without target and response repetition. Thus, it is entirely possible that the happy faces (or the detection of appetitive emotion) abolished the CSE. Moreover, it is entirely possible that the appetitive happy faces activated the same brain system (or emotional survival circuit) that would be active for reward processing.

We are aware of three studies that investigated the CSE and how it is affected by reward processing. Two studies by van Steenbergen, Band and Hommel (2012; 2009) used a neutral arrow flanker task to investigate the CSE. Participants received arbitrary feedback indicating monetary loss or gain in-between trials. Reward (monetary gain) reduced the CSE (that was manifested in the usual direction: (in)congruency repetition trials responded to faster than (in)congruency alternation trials), relative to monetary loss. However, Braem, Verguts, Roggeman and Notebaert (2012) used a colour naming flanker task and showed that reward (for 25% of trials) increased the CSE relative to no reward trials. The studies by van Steenbergen et al. differed from the study by Braem et al. as they had a monetary loss condition whereas Braem et al. had a no reward condition. It seems as if the effects of reward may vary depending upon the context provided by situations of potential loss or no reward. Nevertheless, in the present study it is possible that the loss of any significant CSE in the happy face condition was in some way due to the happy faces activating reward based brain systems. However, this cannot explain the reversal of the CSE in the fearful face condition.

The CSE was reliably present only for fear trials when target and response did not repeat. Thus, we cannot rule out the explanation that there was something specific about these fearful trial types that facilitated the CSE. Moreover, it is noteworthy that the CSE for incongruent trials when target and response did repeat was marginally present. Accordingly, the complete lack of a CSE for congruent trials when target and response did repeat could have also been lost due to target and response repetition. These selective RT effects for the fear trials are difficult to interpret. However, it does seem that the effect of processing the differing emotional faces might have further affected cognitive control processes being carried out by a network of interconnected brain regions differently. The medial frontal cortex (MFC) and ACC are activated by stimuli that are emotionally negative, but they are also involved in anxiety (Etkin, Egner, & Kalisch, 2011). Both the ACC and the mid-cingulate cortex (MCC) may be implicated in both emotion and cognitive control (Shackman et al., 2011). It is possible that upon perception of the appetitive happy faces that the cognitive control functions of the ACC, MCC and/or MFC were interrupted by a dopaminergic reward signal, which resulted in an abolished CSE for happy face trials. Moreover, it is possible that for fearful face trials the threat-related aversive emotion affected ACC, MCC and/or MFC function differently, and this then reversed the CSE (with the effect being more robust when target and response repetition were not present). It is possible that the reversed CSE was due to the interaction of neural resources in the ACC, MCC, and MFC when processing the threat related target fearful faces, whilst simultaneously providing cognitive control (i.e., monitoring conflict, selective attention and/or response inhibition).

It is also noteworthy that in the accuracy data for the fearful face condition when target emotion and response were repeated, congruent (in)congruency alternation trials (fFiC trials) were responded to more accurately than congruent (in)congruency repetition trials (fFcC trials), which shows a reversed CSE in accuracy was present for these trials. In contrast, the opposite pattern was present for incongruent trials as (in)congruency repetition trials (fFiI trials) were responded to more accurately than (in)congruency alternation trials (fFcI trials). These two findings suggest that attention to repeated target fearful faces was affected by the sequential effects of conflict. It seems possible that for congruent trials attention to the target fearful faces was more focused for trials that followed emotionally conflicting incongruent trials, relative to trials that followed no conflict congruent trials. Moreover, it also seems possible that for incongruent trials attention to the target fearful faces was more focused for trials that followed emotionally conflicting incongruent trials, relative to those that followed no conflict congruent trials. Thus, we suggest that these effects upon accuracy may also be due to some effects of emotion upon the activity of the ACC, MCC, and/or MFC when cognitive control is required.

Neuroimaging evidence suggests that the ACC has bi-directional connections to the insula cortex, which is involved with subjective feelings and uncertainty (Singer, Critchley, & Preuschoff, 2009). Anxiety is related to uncertainty and anticipation concerning possible future threat-related situations (Grupe & Nitschke, 2013**).** It is possible that in the present study the ACC, MCC, and MFC did affect the cognitive control of emotion by high anxious participants slightly differently than low anxious participants. In the present study trait anxiety was weakly related to some performance differences when processing the fearful faces. Anxiety was weakly related to an overall increased level of accuracy for fear trials when emotional target and response did not repeat. Moreover, high anxious participants responded to congruent fear trials faster than their low anxious counterparts. It is also noteworthy that STAI-anxiety was positively but not robustly correlated with the RT difference between hFiI trials and hFcI trials. Thus there was some indication that anxiety related to the cognitive control of threat-related emotion.

5.6. Conclusion

To conclude, overall the CSEs found in the present experiment offer no support to any of the theoretical accounts of the CSE discussed earlier. Critically, none of the accounts predict a reversed CSE in RTs after accounting for target and response repetition. However, we changed the design of the task considerably in order to account for various possible confounds to any interpretation of the data, and also to increase ecological validity. We are not aware of any other study that has used a design such as ours. It is possible that the task design used a combination of variables that affected ACC, MCC, and/or MFC performance slightly differently than other published conflict paradigms do. We suggest that further anxiety and emotional CSE experiments may have to sacrifice a certain amount of ecological validity in order to detect any reliable anxiety effect. Our analysis using the total STAI scores did not reveal that anxiety related to any CSE effect in RTs, although there was a weak effect of anxiety in the accuracy data. However, critically there was an effect of anxiety, measured by the STAI-anxiety subscale, upon the reversed CSE present in RTs. STAI-anxiety was weakly related to a slowing in responses to repeated incongruent fearful trials (when target and response did not repeat). Thus, increased anxiety was related to slower responses to trials with a fearful target face surrounded by happy faces, when they were preceded by a trial with a target happy face surrounded by fearful faces. Although this effect can be considered marginal at best, it does suggest that trait anxiety might be related to a difference in how emotional conflict resolution is achieved.

Chapter 6

6. Experiment 5

6.1. Introduction

Bieling, Antony and Swinson (1998) suggested that the STAI (Spielberger et al., 1983) may measure more than one underlying factor (as discussed in chapter 4). To briefly reiterate, Bieling et al. suggested that the STAI measures an umbrella factor of negative affect, but it also separately measures anxiety (referred to as STAI-anxiety hereafter) and depression (referred to as STAI-depression hereafter). If the factorial structure of the STAI proposed by Bieling et al. is accurate it may have some important implications concerning how future research is interpreted. Indeed, it may also suggest that much published work on trait anxiety should be reanalysed, whilst accounting for the distinction made between the two proposed anxiety and depression subscales. Accordingly, in experiment 3 (chapter 4) and experiment 4 (chapter 5) we have already conducted and reported some exploratory analyses designed to determine if the STAI-anxiety and STAI-depression subscales offer any reliable level of discriminant validity. STAI-anxiety and STAI-depression were moderately correlated in experiments 3 and 4, but it is still not clear if they measure different constructs or not.

Experiment 3 (chapter 4) showed that STAI-anxiety and STAI-depression related to emotional facial expression recognition differently from one and another. STAI-anxiety was related to a reduced happy face recognition advantage present in RTs when discriminating happy faces from fearful faces. STAI-depression was not related to any emotional face discrimination effects. These results appear to lend some support to the discriminant validity of the STAI subscales proposed by Bieling et al. (1998). However, it is noteworthy in experiment 3 that when controlling for STAI-depression the correlation between STAI-anxiety and the reduced happy face recognition advantage was unreliable. Experiment 4 (chapter 5) showed that high STAI-anxiety was weakly related to a reduced reversed CSE present in the RTs, whereas STAI-depression was not. Thus, this tentatively suggests that STAI-anxiety but not STAI-depression may be related to variations in how emotional conflict resolution is achieved. Based upon these findings we reanalysed the data from experiments 1 and 2, but this time we used the STAI-anxiety and STAI-depression scales as the individual difference measures. These analyses are contained in appendix A and appendix B. These analyses showed that the key behavioural effects did not relate to either the proposed STAI-anxiety scale or STAI-depression scale more than the other. Thus, the behavioural effects may relate to both anxiety and depression, or an umbrella factor of negative affect. However, experiment 3 (chapter 4) showed that psychometric measures such as the attentional control scale may be of utility when assessing the discriminant validity of the STAI subscales. Moreover, there are a number of published studies that use other psychometric constructs to tease apart measures of anxiety and depression in general.

The reinforcement sensitivity theory (RST, Gray & McNaughton, 2000) constructs of behavioural inhibition system (BIS) sensitivity and behavioural activation system (BAS) sensitivity are often measured using the so-called BIS/BAS scales (Carver & White, 1994). Multiple past studies have shown that high BIS is related to both high anxiety and high depression, but BAS is not related to either anxiety or depression (Johnson, Turner, & Iwata, 2003; Jorm et al., 1999; Muris, Meesters, De Kanter, & Timmerman, 2005). In contrast, both anxiety and depression have been shown to relate to high BIS and low BAS (Coplan, Wilson, Frohlick, & Zelenski, 2006). In a further contrast, multiple past studies have also shown that high BIS is related to high anxiety and high depression, and also that high BAS is related to low depression but not low anxiety (e.g., Beevers & Meyer, 2002; Campbell-Sills, Liverent, & Brown, 2004; Hundt, Nelson-Gray, Kimbrel, Mitchell, & Kwapil, 2007; Kimbrel, Nelson-Gray, & Mitchell, 2007; Segarra et al., 2007). Accordingly one can suggest that generally studies indicate that increased BIS scale scores relate in some way to the comorbidity of depression and anxiety, whereas low BAS might relate to depression although this relationship is not always found. Takahashi, Roberts, Yamagata and Kijima (2015) investigated whether these inconsistencies concerning the reported relationships between both BIS and BAS, and anxiety and depression might be due to the shared variance of anxiety with depression.

Takahashi et al. (2015) showed that higher state anxiety (controlling for depression) was related to higher BIS scale scores, whereas higher depression (controlling for state anxiety) was related to higher BIS scale scores and lower BAS. Thus, whereas BIS was related to both anxiety and depression, BAS was uniquely related to depression. Takahashi et al. suggest that BIS might be one of the constructs underlying the comorbidity of anxiety and depression, whereas BAS uniquely predicts depression. They suggest that BAS may be a useful measure in differentiating between the internalising disorders of anxiety and depression. They continue by suggesting that low BAS activity reflects low reward seeking activity which may lead to increased depression.

Takahashi et al. (2015) used a non-clinical sample, however, there are two clinical studies that are also particularly relevant here. Kasch, Rottenberg, Arnow and Gotlib (2002) showed that clinically depressed patients reported lower BAS scores and higher BIS scores than normal controls. They also showed that for these patients lower BAS scores were related to increased levels of current depression, and a worse outcome after eight months. In a similar study, Mellick, Sharp and Alfano (2014) used a design with three groups; clinically depressed, high risk of clinical depression, and normal controls. Clinical levels of depression were related to higher BIS scores than normal controls but not the high risk group (the BIS scores of the high risk and normal controls were similar). No differences in BAS scores were found for the three groups.

BIS and BAS are not the only constructs that can be used to tease apart anxiety and depression. As discussed in more detail in chapter 4, Olafsson et al. (2011) reported that attentional shifting significantly predicted depression (after controlling for anxiety). Moreover, Olafsson et al. also reported that attentional focusing significantly predicted anxiety (after controlling for depression). Whereas Olafsson et al. did not use the STAI subscales, there are two more studies that actually used the STAI-anxiety and STAI-depression subscales to investigate this same issue. Judah, Grant, Mills and Lechner (2013) and Reinholdt-Dunne, Mogg and Bradley (2013) also reported that attentional focusing predicts STAI-anxiety whereas attentional shifting predicts STAI-depression. Thus, different attentional mechanisms that can be measured by questionnaire may also help discriminate between the constructs of STAI-anxiety and STAI-depression.

In summary, it seems likely that anxiety and depression will relate to some other psychometric personality constructs differently from one and another. It is important for clinicians to be able to tease apart the symptoms of anxiety and depression in patients. Anxiety and depression share a strong comorbidity and are highly correlated (Kessler, Chiu, Demler, & Walters, 2005). This comorbidity is related to serious and prolonged psychiatric problems (Aina & Susman, 2006). It seems likely that the constructs of BIS, BAS, attentional shifting, and attentional focusing might be useful in discriminating between anxiety and depression. More specifically, based upon the studies discussed above, increased BIS activity (or whatever is actually captured by BIS scale scores) might in some way contribute to the comorbidity of both anxiety and depression, but low BAS activity might specifically contribute to depression. Moreover, a reduced ability to shift ones attention may relate specifically to depression, whereas a reduced ability to focus ones attention may relate specifically to anxiety.

There is however some controversy that concerns the construct validity of Carver and White's (1994) BIS scale. This controversy has arisen from studies using factor analysis to assess the reliability of the measure. Cogswell, Alloy, van Dulmen and Fresco (2006) found that two items included in the BIS scale were problematic. Moreover, it is also noteworthy that Johnson, Turner and Iwata (2003) showed that these two items represented a separate factor from the other BIS items[6]. However, it is noteworthy that a later study by Heym, Ferguson and Lawrence (2008) has actually shown that three items from the original BIS scale form a separate factor from the four remaining items. Heym et al. refer to the three item factor as representing fear and the activity of the FFFS component of RST, whereas the four items represent anxiety and the BIS component of RST. This controversy was not addressed in any of the studies discussed above. Thus, this could have obscured the interpretation of how BIS scores relate to anxiety and depression.

6.2. Purpose of experiment

We intended to use the self-report measures of BIS, BAS and attentional control discussed above to further investigate the discriminant validity of the STAI-anxiety and STAI-depression subscales defined by Bieling et al. (1998). Here we also

[6] It is noteworthy here that in their study concerning the relationships between BIS, BAS, anxiety, and depression, they still included the whole BIS scale when calculating their participants BIS scores.

confirm if the separate BIS-fear and BIS-anxiety subscales of the original BIS scale, as proposed by Heym et al. (2008), affect the reported relationship between BIS scores and STAI-anxiety and STAI-depression. As the regression analyses in experiment 3 (chapter 4) concerning the relationship between the STAI subscales and the attentional control subscales were carried out on one experimental sample of 90 participants we intended to repeat the analyses but this time pooling the data from experiment 1 (chapter 2) and experiment 3 (chapter 4). This will provide a larger sample and more power to explore the depression and attentional shifting correlation. We also intended to use self-report measures of trait anger and interpersonal fear to help discriminate between the constructs of STAI-anxiety and STAI-depression.

Based upon the literature discussed above we can make some predictions concerning how BIS relates to STAI-anxiety and STAI-depression. We can predict that high anxiety will relate to higher total BIS scores based upon the results of many published studies (Beevers & Meyer, 2002; Campbell-Sills et al., 2004; Coplan et al., 2006; Hundt et al., 2007; Johnson et al., 2003; Jorm et al., 1999; Kimbrel, et al., 2007; Muriseta et al., 2005; Segarra et al., 2007; Takahashi et al., 2015). We can also predict that high depression will relate to higher total BIS scores, based upon the results of many published studies (Beevers & Meyer, 2002; Campbell-Sills et al., 2004; Coplan et al., 2006; Hundt et al., 2007; Kasch et al., 2002; Kimbrel et al., 2007; Mellick et al., 2014; Segarra et al., 2007; Takahashi et al., 2015). We aim to confirm if the BIS correlations will remain stable after separating the items that load onto the BIS-fear scale from those that load onto the BIS-anxiety scale.

We can also tentatively predict that low BAS might relate to higher depression but be unrelated to anxiety based upon several published studies (Beevers & Meyer, 2002; Campbell-Sills et al., 2004; Hundt et al., 2007; Kimbrel et al., 2007; Segarra et al., 2007). However, the reason this prediction must be considered tentative is some other published studies have not found this relationship. To reiterate, BAS has sometimes been shown to be unrelated to either anxiety or depression (Johnson et al., 2003; Jorm et al., 1999; Muris et al., 2005). Moreover, we are aware of one study that does not support our predictions, as both anxiety and depression were reportedly related to high BIS and low BAS (Coplan et al., 2006). Nevertheless, we intend to investigate whether the BAS scale offers any help in determining the discriminant validity of the two STAI subscales.

Based upon the studies by Judah et al. (2013), Olafsson et al. (2011), and Reinholdt-Dunne et al. (2013) that used the attentional control scale (Derryberry & Reed, 2001, 2002), we can predict that attentional shifting would predict STAI-depression (when controlling for attentional focusing). We can also predict that attentional focusing would predict STAI-anxiety (when controlling for attentional shifting) based upon these three studies. Although the STAI-anxiety and attentional focusing relationship was not significant in chapter 4, we assumed that this was due to the limited sample size, whereas in the present analysis we double the size of the sample.

We also intended to run an exploratory correlational analysis using these measures to verify if some other psychometric relationships reported in the literature are present in the sample. For example, we can predict that that trait anger will be related to higher BAS scores as it is related to increased BAS activity (Carver & Harmon-Jones, 2009), as anger is an approach related behaviour (Harmon-Jones, 2003). We can suggest that trait anger will also relate to increased anxiety based upon the studies by (Carre et al., 2012; van Honk et al., 2001). Moreover, here we can also confirm if high scores on the BIS-fear scale proposed by Heym et al. (2008) relate to high scores on the interpersonal fear subscale of the fear survey schedule (Wolpe & Lang, 1969).

6.3. Method

6.3.1 Participants

Participants with no reported history of neurological condition (N = 171, 50 male) were recruited from Goldsmiths, University of London, and had a mean age of 23.6 (SD = 7). 150 were right handed, 18 were left handed, and 2 claimed to be ambidextrous (with 1 response omission). These participants are those that featured in experiment 1 (N = 81) and experiment 3 (N = 90); therefore 76 took part in return for course credit whereas the rest were paid £10. All gave informed written consent in accordance with standard ethical guidelines as reported earlier.

In the studies by Judah et al. (2013) and Reinholdt-Dunne et al. (2013) the smaller hierarchical regression effect of interest is the effect in predicting STAI-anxiety from the combination of the 2 predictors of attentional focussing and attentional shifting, after first controlling for STAI-depression (or STAI-depression after first controlling for STAI-anxiety). In these studies the average R^2 change for this step of the regressions was 0.07 across the 4 analyses. This corresponds to an effect size of f^2=0.075. With such an effect size, g-power reveals that 80% power and alpha=0.05 requires 132 participants.

In the Reinholdt-Dunne et al. study they give enough information to compute the partial r^2 for the independent effect of the separate shifting and focussing predictors, in each of their 2 regressions (predicting STAI-anxiety and predicting STAI-depression). The average of the 4 partial r^2 values from these 2 regressions was 0.08, corresponding to an effect size f^2 of 0.087. For this size of effect, 80% power, and alpha=0.05 two tailed, g-power gives a required sample size of 93.

The participants used in this chapter were aggregated across the samples from experiment 1 and experiment 3 which gave us a total sample size of 171. We were therefore confident that our sample wold be well -powered to detect effects of this magnitude.

6.3.2. Self-report measures

Trait anxiety was initially assessed with the trait anxiety subscale of the State-Trait Anxiety Inventory (STAI, Spielberger et al., 1983). Trait anger was assessed using the trait anger 10 item subscale of the State-Trait Anger Expression Inventory (STAXI, Spielberger, 1988). Once again we also used the STAI subscales described by Bieling et al. (1998). To reiterate, the STAI-anxiety subscale consists of STAI-trait items 22, 28, 29, 31, 37, 38, & 40. The STAI-depression subscale consists of STAI-trait items 21, 23-27, 30, 32-36, & 39. Individual differences in the experiencing of interpersonal fear were assessed using the 23 item interpersonal fear subscale of the Fear Survey Schedule (Wolpe & Lang, 1969). Attentional control was assessed with the Attentional Control Scale (Derryberry & Reed, 2001, 2002).

Once again the attentional focusing and attentional shifting sub-scales of the attentional control scale (as used by Olafsson et al., 2011) were also used. To reiterate, in their analysis one item (question 9) did not load on either factor. Thus, the attentional focusing sub-scale consisted of 9 items (items 1-8 and item 12), and the attentional shifting sub-scale consisted of 10 items (items 10, 11, and 13-20). Behavioural inhibition sensitivity (BIS) and behavioural activation sensitivity (BAS) were measured by the BIS/BAS scales (Carver & White, 1994). The BIS scale from Carver and Whites' BIS/BAS scales was further divided into the BIS-fear scale (items 1, 17, and 20), and the BIS-anxiety scale (items 5, 9, 13, and 19) as proposed by Heym et al. (2008).

6.3.3. Procedure

All participants completed the questionnaires in the traditional pen and paper way as part of experiment 1 or experiment 3. The STAI-trait measure and the trait anger and interpersonal fear measures feature in chapter two whereas the STAI-trait and attentional control measures feature in chapters two and three. The BIS / BAS measures have not featured in this thesis thus far.

Data analysis

First we ran partial correlations between STAI-anxiety (controlling for STAI-depression) and the BIS, BIS-anxiety, BIS-fear, BAS, interpersonal fear, trait anger attentional focasing, attentional shifting, and total attentional control self-report measures, and also the partial correlations between STAI-depression (controlling for STAI-anxiety) and the BIS, BIS-anxiety, BIS-fear, BAS, interpersonal fear, trait anger, attentional focasing, attentional shifting, and total attentional self-report measures. This tests our key interest in determining whether the STAI subscales have any discriminant validity.

We then ran a further regression analysis to determine the differential relationships between both attentional focusing and attentional shifting and the STAI-anxiety and STAI-depression subscales. This analysis relates to our other key interest that was based upon the analyses conducted by Reinholdt-Dunne et al. (2013) and Judah et al. (2013), and will facilitate a direct comparison with their regression analyses.

We carried out one more correlational analysis to illustrate how the total BIS scores, BIS-anxiety scores, BIS-fear scores, BAS scores, trait anger scores, interpersonal fear scores, and attentional focusing and shifting scores relate to one and another, and the proposed umbrella construct of general negative affect that the total scores of the STAI might measure.

6.4. Results

Table 6.1 shows the mean scores and standard deviations for each of the self-report measures. STAI-anxiety and STAI-depression were quite strongly correlated (r=0.69, p<0.001). Table 6.2 shows the partial correlations between STAI-anxiety (controlling for STAI-depression) and the self-report measures, and also the partial correlations between STAI-depression (controlling for STAI-anxiety) and the self-report measures. Both STAI-anxiety and STAI-depression correlated positively with total BIS scale scores (although only the STAI-anxiety correlation withstood the strict Bonferroni correction). STAI-anxiety also correlated positively and robustly with BIS-anxiety. However, it is noteworthy here that although the correlation between STAI-depression and BIS-anxiety was also positive, it was not anywhere near significant. It is also noteworthy here that STAI-anxiety was not correlated with BIS-fear, whereas STAI-depression was, although the relationship was quite weak and non-significant. Interpersonal fear scores and trait anger scores both correlated positively with STAI-anxiety. Thus, the more anxious a person was, the more interpersonal fear and anger they experienced. In contrast, STAI-depression was uncorrelated with interpersonal fear scores and trait anger scores. STAI-depression was negatively correlated with BAS scores, but not significantly. STAI-depression was also significantly and negatively correlated with total attentional control scores, and attentional shifting scores, and also non-significantly and negatively with attentional focusing scores. In contrast, STAI-anxiety was not correlated with BAS scores or any of the three attentional control scores.

Table 6.1: The mean scores and standard deviations for the STAI-trait, BIS, BIS-anxiety, BIS-fear, BAS, interpersonal fear, attentional control and trait anger self-report measures.

	Mean score	**Standard deviation**
STAI-trait	43	10
BIS-total	21	3
BIS-anxiety	12	2
BIS-fear	9	2
BAS	40	5
Interpersonal fear	44	22
Attentional control	50	9
Trait anger	19	6
ACS focusing	22	5
ACS shifting	26	5
STAI-anxiety	15	4
STAI-depression	28	7

Table 6.2: The partial correlations between the STAI-anxiety (STAI-anx) and STAI-depression (STAI-dep) subscales (i.e., STAI-anxiety controlling for STAI-depression and STAI-depression controlling for STAI-anxiety) and BIS, BIS-anxiety, BIS-fear, BAS, interpersonal fear (I/P fear), total attentional control scores (ACS total), trait anger and the attentional control scale focusing (ACS focusing) and shifting (ACS shifting) subscales.

	BIS total	BIS anxiety	BIS fear	BAS	I/P fear	Trait anger	ACS total	ACS focusing	ACS shifting
STAI-anx	***r*= 0.22#** **_p_= 0.004**	***r=0.26**** ***p=0.001***	*r=0.09* *p=0.247*	*r*= 0.11 *p*= 0.176	***r*= 0.26*** **_p_= 0.001**	***r*= 0.22#** **_p_= 0.004**	*r*= -0.02 *p*= 0.806	*r*= -0.10 *p*= 0.197	*r*= 0.06 *p*= 0.422
STAI-dep	*r*= 0.21 *p*= 0.007	*r=0.17* *p=0.033*	*r=0.19* *p=0.015*	*r*= -0.19 *p*= 0.013	*r*= 0.06 *p*= 0.466	*r*= 0.01 *p*= 0.978	***r*= -0.31*** **_p_< 0.001**	*r*= -0.20 *p*= 0.010	***r*= -0.33*** **_p_< 0.001**

*Note: Due to some response omissions N for these measures ranged from 168 to 171. Based upon the fact that 18 correlations are reported a Bonferroni correction would mean that correlations would be considered significant if the p-values are less than 0.05/18 (two-tailed, thus $p < 0.003$, marked *), or 0.1/18 (one-tailed, thus $p < 0.006$, marked #). The correlations that remain significant after either the one or two tailed Bonferroni corrections are also displayed in bold font.*

The partial correlations in Table 6.2 concerned the relationship between the individual difference measures and each of the STAI subscales whist controlling for the other STAI subscale. This analysis did not allow for any comparison with the two attentional control subscales whilst controlling for the other attentional control subscale. Therefore, we also intended to determine whether STAI-anxiety and STAI-depression share any unique relationships with attentional focusing (this time when controlling for attentional shifting) and attentional shifting (this time when controlling for attentional focusing). Table 6.3 contains our regression analyses showing the differential relationships between both attentional focusing and attentional shifting and the STAI-anxiety and STAI-depression subscales. We present this data in the same way as other recently published papers to aid a direct comparison. Table 6.3 shows that attentional shifting independently predicted STAI-depression and not STAI-anxiety. In contrast, attentional focusing did not independently predict STAI-depression, nor did it significantly independently predict STAI-anxiety, although it is noteworthy that the sign of the correlation was negative.

Table 6.3: Regression analyses using the attentional focusing and attentional shifting subscales of the attentional control scale to predict STAI-anxiety and STAI-depression (N = 168 due to some response omissions).

	B	*SE B*	*beta*
Dependant variable: STAI-anxiety			
Step 1 (R^2= 0.46*)**			
STAI-depression	0.41	0.04	0.68***
Step 2 (R^2= 0.47*)**			
STAI-depression	0.41	0.04	0.68***
ACS-focusing	-0.10	0.05	-0.12
ACS-shifting	0.09	0.06	0.11
Dependant variable: STAI-depression			
Step 1 (R^2= 0.46*)**			
STAI-anxiety	1.11	0.09	0.68***
Step 2 (R^2= 0.52*)**			
STAI-anxiety	1.00	0.09	0.61***
ACS-focusing	-0.06	0.09	-0.04
ACS-shifting	-0.33	0.09	-0.23***

*Note: This table follows the same format as Reinholdt-Dunne et al. (2013) and Judah et al. (2013) to facilitate a direct comparison with their regression analyses (*p<0.05, **p<0.01, ***p<0.001).*

To clarify, as already shown by the beta values in the regression analyses presented in table 6.3, the partial correlation between shifting and depression when controlling for focusing and anxiety was r= -0.28, p< 0.001. These regression analyses also show that the equivalent partial correlation between focusing and depression when controlling for shifting and anxiety was *r*= -0.05, *p*= 0.519. Moreover, the regression analyses in table 6.3 also show that the equivalent partial correlation between focusing and anxiety when controlling for shifting and depression was *r*= -0.14, *p*= 0.067, whereas the equivalent partial correlation between shifting and anxiety when controlling for focusing and depression was *r*= 0.12, *p*= 0.119.

Thus far our analyses were structured to tease apart the partial correlations between the subscales of the STAI and the other individual difference measures, and the subscales of the STAI and the subscales of the attentional control measure. However, we were also interested in how the total BIS scores, BIS-anxiety scores, BIS-fear scores, BAS scores, trait anger scores, interpersonal fear scores, and attentional focusing and shifting scores relate to one and another, and the proposed umbrella construct of general negative affect that the total scores of the STAI might measure. Thus we carried out a further correlational analysis to illustrate these relationships. Table 6.4 shows that STAI-trait was positively correlated with BIS-anxiety, BIS-fear, interpersonal fear, and trait anger, but negatively correlated with attentional shifting and attentional focusing scores. STAI-trait was not significantly correlated with BAS scores, although it is noteworthy that the sign of the correlation was negative. BIS-anxiety scores were positively correlated with BIS-fear scores and interpersonal fear scores, but negatively correlated with attentional focusing and attentional shifting scores. BIS-anxiety was not significantly correlated with BAS, or trait anger. The only measure that significantly correlated with BAS was trait anger. As BAS scores increased, trait anger scores increased. Interpersonal fear scores were negatively correlated with attentional focusing scores (but not attentional shifting scores) and positively correlated with trait anger scores. Trait anger was also very weakly negatively but not significantly correlated with attentional focusing scores. BIS-fear was positively correlated with interpersonal fear, and weakly but not significantly correlated with attentional focusing.

Table 6.4: The bivariate correlations between STAI-trait (the total scores of the STAI), BIS-anxiety, and BIS-fear, as well as the BAS, interpersonal fear, attentional focusing, attentional shifting, and trait anger measures.

	2	3	4	5	6	7	8
1: STAI-trait	**0.47***	**0.34***	-0.13	**0.37***	**-0.36***	**-0.35***	**0.27***
2: BIS-anxiety		**0.47***	-0.08	**0.58***	**-0.26***	-0.22	0.11
3: BIS-fear			-0.10	**0.38***	-0.17	-0.13	0.07
4: BAS				0.003	-0.06	0.17	**0.33***
5: I/P fear					**-0.23#**	-0.14	**0.30***
6: Focusing						**0.50***	-0.18
7: Shifting							-0.11
8: Trait anger							

*Note: Due to some response omissions N for these measures ranged from 168 to 171. Based upon the fact that 28 correlations are reported a Bonferroni correction would mean that correlations would be considered significant if the p-values are less than 0.05/28 (two-tailed, thus p < 0.002, marked *), or 0.1/18 (one-tailed, thus p < 0.004, marked #). It is noteworthy here that the correlation between BIS-anxiety and attentional shifting just missed the 2-tailed significance adjustment as p= 0.005. The correlations that remain significant after either the one or two tailed Bonferroni corrections are also displayed in bold font.*

6.5. Discussion

Initially, we used partial correlation to explore the relationship between STAI-anxiety (controlling for STAI-depression) and self-report measures of affective traits and attentional traits, and also the partial correlations between STAI-depression (controlling for STAI-anxiety) and these self-report measures. We also included in this analysis the BIS-anxiety and BIS-fear subscales of the original BIS scale, as proposed by Heym et al. (2008). STAI-anxiety (controlling for STAI-depression) correlated positively with total BIS scale scores. Thus, increased total BIS scale scores were related to increased anxiety. The finding that high anxiety relates to high total BIS scale scores is consistent with the results of many published studies (Beevers & Meyer, 2002; Campbell-Sills et al., 2004; Coplan et al., 2006; Hundt et al., 2007; Johnson et al., 2003; Jorm et al., 1999; Kimbrel, et al., 2007; Muriseta et al., 2005; Segarra et al., 2007; Takahashi et al., 2015). Critically, here we also show that STAI-anxiety (controlling for STAI-depression) also correlated positively and robustly with BIS-anxiety (r = 0.26). It is also noteworthy here that STAI-anxiety (controlling for STAI-depression) was not correlated with BIS-fear (r = 0.09). These analyses with the BIS-anxiety and BIS-fear scales (as proposed by Heym et al., 2008) suggest that it is specifically the anxiety component of the original BIS measure that relates to anxiety, not the fear component.

Participants self-reported trait anger scores were positively related to their STAI-anxiety scores (controlling for STAI-depression). This shows that the more trait anxious a person was, the greater amounts of trait anger they experienced. The finding that trait anxiety relates to increases in trait anger resonates with published studies that measured trait anxiety using the total scores of the STAI (e.g., Carre et al., 2012; van Honk et al., 2001). Moreover, (in contrast to the BIS-fear scale analysis) participants self-reported interpersonal fear scores were positively related to their STAI-anxiety scores (controlling for STAI-depression). This shows that the more anxious a person was, the greater amounts of interpersonal fear they experienced.

STAI-depression (controlling for STAI-anxiety) was not correlated with either self-reported interpersonal fear scores, or self-reported trait anger scores. However, in the present study STAI-depression (controlling for STAI-anxiety) was negatively correlated with BAS, but this would be considered a trend after controlling for multiple correlations. This finding resonates with several published studies suggesting that high depression relates to low BAS activity (Beevers & Meyer, 2002; Campbell-Sills et al., 2004; Hundt et al., 2007; Kasch et al., 2002; Kimbrel et al., 2007; Segarra et al., 2007), but is inconsistent with others (Johnson et al., 2003; Jorm et al., 1999; Muris et al., 2005). In the present study BAS was not significantly related to anxiety which is also consistent with several published studies (Beevers & Meyer, 2002; Campbell-Sills et al., 2004; Hundt et al., 2007; Kimbrel et al., 2007; Segarra et al., 2007). In the present study STAI-depression (controlling for STAI-anxiety) was positively correlated with total BIS scale scores. Although this correlation just missed the strict significance adjustment required after using multiple correlations, high depression did seem to relate to higher total BIS scale scores. This finding thus resonates with the results of many published studies (Beevers & Meyer, 2002; Campbell-Sills et al., 2004; Coplan et al., 2006; Hundt et al., 2007; Kasch et al., 2002; Kimbrel et al., 2007; Mellick et al., 2014; Segarra et al., 2007; Takahashi et al., 2015).

The results of the present study therefore do tentatively support the notion that BAS specifically relates to depression. However, the findings obtained with the total BIS scale scores are less likely to be meaningful. Although the correlation between STAI-depression (controlling for STAI-anxiety) and BIS-anxiety was positive ($r = 0.17$), it was not anywhere near as robust as the correlation between STAI-anxiety (controlling for STAI depression) and BIS-anxiety ($r = 0.26$). It is also noteworthy here STAI-depression (controlling for STAI-anxiety) was positively correlated with BIS-fear, although the relationship was not significant ($r = 0.19$). These analyses with the BIS-anxiety and BIS-fear scales proposed by Heym et al. (2008) suggest that it is both the anxiety and fear components of the original BIS measure that relate to depression. Thus, the overall BIS scale scores are not likely to represent the underlying factor that relates to the comorbidity of anxiety and depression, as both of the BIS-anxiety and BIS-fear scales relate to depression, but only the BIS-anxiety scale relates to anxiety.

When controlling for STAI-anxiety, STAI-depression was also negatively correlated with total attentional control, attentional shifting, and unreliably with attentional focusing scores. Therefore, those with greater levels of depression reported less BAS activity and reduced attentional control. In contrast, when controlling for STAI-depression, STAI-anxiety was not correlated with any of the three attentional control scores. This finding suggests that studies which report high trait anxiety is related to lower self-reported attentional control scores, and also report theoretical viewpoints that interpret this as meaning that anxiety relates to poor attentional control abilities, may be interpreting the data incorrectly (e.g., Derryberry & Reed, 2002; Eysenck, Derakshan, Santos, & Calvo, 2007). In short, these theories may be relying upon reported attentional control relationships with trait anxiety that are in fact dependent on the depression components present in the total STAI trait anxiety scores. Moreover, from this analysis we can suggest that the two STAI subscales might well have a reasonable level of discriminant validity.

The partial correlations discussed thus far illustrated the relationship between the self-report affective trait and attentional trait measures, and each of the STAI subscales, whist controlling for the other STAI subscale. Thus, the analyses discussed thus far were limited as they did not allow for any comparison with the two attentional control subscales whilst controlling for the other attentional control subscale. Therefore, we used regression models to determine whether STAI-anxiety and STAI-depression shared any unique relationships with attentional focusing (when controlling for attentional shifting) and attentional shifting (when controlling for attentional focusing). These regression models showed that attentional shifting independently predicted STAI-depression but it did not predict STAI-anxiety. In contrast, attentional focusing did not independently predict STAI-depression, nor did it significantly predict STAI-anxiety. However, it is noteworthy here that the direction of this relationship between attentional focusing and STAI-anxiety was negative. In summary, the only reliable effect we found here was that increases in depression relate to a poorer ability to intentionally shift one's attentional focus towards desired stimuli, whilst avoiding any unintentional focussing on any other stimuli. Thus, the two STAI subscales did seem to offer some discriminant validity. These findings also confirm what we originally reported in experiment 3 (chapter 4) where we used the same analysis on that specific experimental sample (which was a subset of the sample analysed in this chapter).

The results of the present study are somewhat in alignment with those reported by Olafsson et al. (2011), who showed that attentional shifting significantly predicted depression (after controlling for anxiety). However, in contrast to the present study, Olafsson et al. also reported that attentional focusing significantly predicted anxiety (after controlling for depression). However, as stated earlier, Olafsson et al. did not use the actual STAI subscales. Two studies that actually used the STAI subscales also reported that attentional focusing relates to anxiety in addition to attentional shifting relating to depression (Judah, Grant, Mills & lechner, 2013; Reinholdt-Dunne, Mogg & Bradley, 2013). However, it is noteworthy that Judah et al. also reported that depression measured by the Beck Depression Inventory-II (BDI-II; Beck, Steer & Brown, 1996) correlated negatively with focusing but not shifting. This finding was inconsistent with their analysis using the STAI subscales. Moreover, the BDI-II correlated positively and at identical magnitudes with both the STAI-anxiety and STAI-depression scales, which adds some controversy to either the discriminant validity of the STAI-anxiety subscale and/or the discriminant validity of the BDI-11. Across these studies and the present study it does seem that STAI-depression negatively relates to attentional shifting, but that STAI-anxiety may relate unreliably and negatively to attentional focusing.

The total scores of the STAI were proposed to measure an umbrella construct of negative affect by Bieling et al. (1998). Owing to the theoretical importance we also carried out bivariate correlations between the total STAI scores and BIS-anxiety, BIS-fear, BAS, interpersonal fear, trait anger and attentional shifting and attentional focusing scores. Higher STAI-trait scores (i.e., general negative affect) were unsurprisingly related to higher BIS-anxiety, BIS-fear, interpersonal fear, and trait anger scores, but lower attentional shifting and attentional focusing scores. Higher BIS-anxiety scores were related to higher BIS-fear scores and interpersonal fear scores, but lower total attentional focusing and attentional shifting scores. However, BIS-anxiety was not significantly related to BAS or trait anger. The only measure that was significantly related to BAS was trait anger. Higher BAS was related to increased trait anger. This finding is consistent with the notion that trait anger is mediated by the BAS (Carver & Harmon-Jones, 2009), and that trait anger is a behaviour closely related to approach motivation (Harmon-Jones, 2003). Higher interpersonal fear scores were related to lower attentional focusing scores and higher trait anger scores. It is noteworthy here that higher interpersonal fear score were not related to lower attentional shifting scores. As one would expect, higher BIS-fear scores were related to higher interpersonal fear scores. This finding appears to provide some support to the validity of the BIS-fear scale proposed by Heym et al. (2008). However, this finding needs treating with caution as BIS-anxiety shared a larger correlation with interpersonal fear than BIS-fear did. It is also noteworthy that although the BIS-fear and interpersonal fear scales were positively correlated in the present study, they differentially predicted STAI-anxiety and STAI-depression. BIS-fear weakly predicted depression but not anxiety. In contrast, interpersonal fear robustly predicted anxiety but not depression.

The findings of the present study do not lend much support to the theory that the total scores on the BIS scale represent a factor for the comorbidity of anxiety and depression. However, BAS was uniquely related to depression (albeit non-significantly due to controlling for the amount of correlations we carried out). The BAS scale might still prove to be a useful measure to delineate the internalising disorders of anxiety and depression. RST (Gray & McNaughton, 2000) suggests that the BAS is a reward based motivational system that is associated with the neurotransmitter dopamine. Impoverished BAS activity may thus relate to reduced reward seeking and/or reward processing, which may lead to depression. Indeed, research suggests that the pathophysiology of depression is related to a dysfunctional mesocorticolimbic dopamine system, which is involved in reward processing. However, it is currently unclear what the precise nature of the dysfunction is (Martin-Soelch, 2009). Moreover, depressed patients show abnormal behaviour in response to punishment and reward. These tendencies relate to aberrant frontostriatal brain function that is subserved by the monoamine systems (Eshel & Roiser, 2010). However, it is noteworthy that, from an RST perspective, punishment responses are controlled by the BIS, which are argued to be based upon cholinergic neurotransmission (Gray, 1989). From this perspective it is the BIS that inhibits the dopamine based BAS. Thus, one can see how neural activity in the BIS might still indirectly contribute to depression, even if this relationship is not evident psychometrically, when using the so called BIS/BAS scales.

6.6. Conclusion

In conclusion, we administered BIS, BAS, trait anger, interpersonal fear, attentional shifting, and attentional focusing measures to investigate the discriminant validity of the proposed STAI-anxiety and STAI-depression measures. Overall we found some evidence of discriminant validity between the scales, as they differentially predicted several other measures. This is generally in contrast to our findings with behavioural measures of emotion and cognitive control. We suggest that these behavioural measures may have actually measured the reactivity of specific cognitive emotional systems that relate to both anxiety and depression, or some shared components of anxiety and depression. These shared components of anxiety and depression may represent the umbrella factor of negative affect that is suggested to be measured by the total scores of the STAI.

Chapter 7

7. General discussion

7.1 Discussion

The purpose of this thesis was to determine whether trait anxiety relates to any variability in the activity of three interrelated cognitive processes. We wished to determine whether trait anxiety relates to enhanced conflict resolution, enhanced cognitive interference as experienced as distraction, and the enhanced processing of threat-relevant visual stimuli. We also wished to determine whether the threat-related attentional bias interacts with the conflict resolution and/or distraction processes. A further rationale for this work was based upon the idea that, if trait anxiety relates to a threat-related modification to any stimuli processing functions, it may reflect an anxiety-related increase in the reactivity of the survival circuits proposed by LeDoux (2012). We also wished to determine how trait anxiety relates to individual differences in trait anger, interpersonal fear, and attentional control abilities. Moreover, we wished to conduct some exploratory analyses to determine whether the other three personality variants are also related to the aforementioned conflict resolution, cognitive interference/distraction and threat processing functions.

We designed a series of RT experiments in order to answer several specific questions. Firstly, we wished to ascertain how anxiety is related to the recognition of happy, fearful, and angry faces. Secondly, we wished to ascertain how anxiety relates to distraction by the other emotional faces when identifying these emotions. Thirdly, we wished to ascertain whether anxiety relates to differences in how conflict resolution is achieved in situations of goal conflict when identifying the emotional faces. Fourthly, we wished to determine how anxiety relates to trait anger, interpersonal fear, and attentional control. And fifthly, we wanted to develop and test a novel emotional conflict resolution paradigm that is practical for other researchers to use in future research.

In experiment 1 we designed a novel emotional face flanker paradigm that assessed the three processes discussed above (i.e., emotional face recognition, emotional distraction, and emotional conflict resolution). This task included predominantly congruent trials, thus the conflict caused by incongruent trials was infrequent. This task also included single face trials as a simple test of emotion recognition. Two emotional conflict conditions were included: a between-valence condition (happy faces versus fearful faces), and a within-valence condition (angry faces versus fearful faces). Experiment 1 showed that trait anxiety was selectively related to a RT bias for fearful faces, but it was dependent upon the context provided by the other task relevant faces. The bias was only present when happy faces were the alternative face, not when angry faces were the alternative face. Trait anxiety was not related to distraction caused by the flankers, even though the predicted effects were detected in the whole sample. However, trait anxiety was related to the sequential effects of emotional conflict processing. This was evidenced by an enhanced congruency sequence effect (CSE), but only in the between-valence condition. Based upon these initial findings we devised three more experiments.

Experiment 2 differed considerably from experiment 1 as we used an emotional word-face Stroop task. The proportions of congruent and incongruent trials were kept the same as in experiment 1. The only other differences in design were that the single face trials were replaced with neutral word trials, and there was only a between-valence condition (not a within-valence condition). Thus, experiment 2 also assessed emotional face recognition, emotional distraction, and emotional conflict resolution. In experiment 2 the emotional word-face Stroop task resulted in an anxiety-related speed-accuracy trade-off. This resulted in an anxiety-related reduction in accuracy for incongruent trials. However, anxiety seemed to be mainly related to increased interference by positive emotional words as opposed to increased interference by threat-related words. Anxiety was unrelated to the CSE in this experiment. Thus, anxiety did not appear to relate to conflict resolution in this experiment (taking the CSE as an index of conflict resolution).

Experiment 3 used an emotional expression recognition task, and therefore assessed only emotion recognition, but not distraction or conflict resolution. This task was inspired by the emotional face recognition effects found in experiment 1. However, this task allowed a more detailed analysis of between-valence emotional expression recognition, as we varied the salience of the mouth region on the expressions. Moreover, in this task two between-valence conditions were included: happy versus fear and happy versus anger. Social anxiety was robustly related to faster responses to threat-related faces, and slower responses to happy faces. However, further planned comparisons showed that this effect was only detectable when the facial expressions display less salient mouth regions. Trait anxiety measured by the total scores of the STAI was not related to these effects. However, further analyses showed that trait anxiety as measured by the proposed anxiety subscale (Bieling, Antony, & Swinson, 1998) of the STAI was related specifically to the discrimination of fearful faces from happy faces. In contrast, social anxiety was related to the discrimination of both fearful and angry faces from happy faces.

Experiment 4 built upon the CSE component of experiment 1. However, whereas the flanker task used in experiment 1 adhered as closely as possible to traditional flanker tasks, the task in experiment 4 was quite different. In experiment 4 the person identities of the flanker faces were always different to the person identities of the target faces. Moreover, this task differed from experiment 1 as the proportions of congruent and incongruent trials were kept equal. Nevertheless, this task also assessed all three cognitive processes: emotion recognition, emotional distraction, and emotional conflict resolution. In experiment 4 the pattern of the CSEs found in the RTs was unexpected, as it was only present only in trials where fearful faces were the target face (not where happy faces were the target face). Moreover, this effect was only reliably present in the fearful face condition when target emotion and response did not repeat, and was also in reverse to what is usually found in conventional flanker tasks. This offered no support to any of the theoretical accounts of the CSE as none of the accounts predict the reversed CSE in RTs (after accounting for target and response repetition). However, we changed the design of the task considerably from experiment 1. Our analysis using the total STAI scores did not reveal that anxiety related to any CSE in RTs, although there was a weak effect of anxiety in the accuracy data. However, critically there was an effect of anxiety, measured by the STAI-anxiety subscale: increased anxiety seemed to be related to an increased RT difference between hFiI trials and hFcI trials (after controlling for general RT variance). This effect was driven by increased anxiety being related to slower RTs for hFiI trials (i.e., fearful target faces surrounded by happy distractor faces when they were preceded by a trial consisting of happy target faces surrounded by fearful distractor faces). Although this effect was marginal, it does suggest that trait anxiety might be related to a difference in how emotional conflict resolution is achieved.

Experiment 5 examined the discriminant validity of the STAI subscales proposed by Bieling, Antony and Swinson (1998). We administered BIS-anxiety, BIS-fear, BAS, trait anger, interpersonal fear, attentional shifting and attentional focusing measures to investigate the discriminant validity of the proposed STAI-anxiety and STAI-depression measures. We found that these scales had a degree of discriminant validity. This was generally in contrast to our findings with the behavioural measures of emotion and cognitive control. We suggest that the behavioural measures may have actually measured the reactivity of specific cognitive emotional systems that relate to both anxiety and depression, or some shared cognitive and/or neural components of both anxiety and depression that might relate to the emotional survival circuits proposed by LeDoux (2012). These shared cognitive and/or neural components of anxiety and depression might also represent the umbrella factor of negative affect that was suggested to be measured by the total scores of the STAI by Bieling et al. (1998).

We now turn to a more detailed summary of the key findings in this series of experiments, and to a summary of how trait anxiety relates to emotional conflict resolution, emotional cognitive interference/distraction, and the processing of emotional faces. To sum up the emotional face recognition effects, experiment 1, 3, and 4 showed that happy faces were responded to faster than negatively valenced faces. These results are consistent with the findings of several published emotional facial expression recognition studies (Silvia, Allan, Beauchamp, Maschauer, & Workman., 2006; Cooper, Rowe, & penton-Voak, 2008; Hietanen & Astikainen, 2013; Leppanen & Hietanen, 2004; Leppanen, Tenhunen, & Hietanen, 2003; Kirita & Endo, 1995; Feyereisen, Malet, & Martin, 1996; Werheid, Alpay, Jentzsch, & Sommer; 2005).

The key findings in experiment 1 and 3 showed that sub-clinical levels of anxiety robustly relate to a threat-related face recognition advantage. More specifically, in experiment 1 trait anxiety (as measured by the total scores of the STAI) related to a reduced happy face recognition advantage when discriminating happy faces from fearful faces. In experiment 3 increased trait anxiety (as measured by the scores of the STAI-anxiety subscale) related to a reduced happy face recognition advantage when discriminating happy faces from fearful faces. However, increased STAI-anxiety scores did not relate to this effect when discriminating happy faces from angry faces. In addition, these effects were not present for the total scores of the STAI. Moreover, in experiment 3 increased social anxiety related to a reduced happy face recognition advantage when discriminating the happy faces from both fearful faces and angry faces.

The effect of trait anxiety (as measured by either the total scores of the STAI, or the STAI-anxiety subscale) upon the happy face recognition RT advantage was not present in experiment 4. However it is noteworthy that in experiment 4 (after controlling for general RT variance) those with higher total STAI scores responded to congruent fearful face trials faster than those with lower total STAI scores. Thus trait anxiety did seem to affect the speed of the detection of threat related stimuli when no emotional distractors were present, although the effect was marginal. Moreover, higher total STAI scores were marginally related to a reduced difference in response accuracy between happy and fearful faces. This was driven by a non-significant anxiety related increase in accuracy for fear trials. Although social anxiety was not part of the main emotional goal conflict analysis in experiment 4 (chapter 5), we wished to confirm whether social anxiety related to the main effect of emotional face recognition. Thus, we also carried out one more exploratory analysis. We confirmed that in spite of trait anxiety not affecting the happy face recognition RT advantage in experiment 4, social anxiety was still implicated. This analysis is contained in appendix C, and shows that increased social anxiety was related to a decreased happy face recognition RT advantage. However, the effect was marginal, and as such the effect in this flanker experiment was much weaker than in the single face recognition experiment (experiment 3).

We can summarise the emotional distraction effects upon trait anxiety as being very specific. Experiments 1 and 4 suggest that trait anxiety is not related to distraction caused by peripheral emotional faces. However, experiment 2 showed that trait anxiety was related to distraction caused by positive emotional words. One could suggest that trait anxiety may be affected by verbal distraction more than visual face distraction, however the effects were only present for positive words. We offered a detailed if speculative explanation of this effect in experiment 2 (chapter 3) and will not repeat it here. Suffice to say that the effect was very specific and probably driven by subtle differences in how attention is affected by emotion. We do not consider this effect to result from a general distraction effect in high trait anxiety. We suggest this as if it were a general anxious distraction effect, we would have expected the effect to be less specific (i.e., show up in some way in the flanker experiments).

We can also summarise the emotional conflict resolution effects upon trait anxiety as being very specific. Experiment 1 showed that trait anxiety measured by the total scores of the STAI was related to the sequential effects of conflict resolution when fearful faces and happy faces were the stimuli. Experiment 4 showed that the STAI-anxiety subscale (but not the total scores of the STAI) marginally predicted a very specific CSE concerning the hFiI trials. Therefore, the effects of trait anxiety across the two flanker experiments were not very reliable. Moreover, experiment 2 suggested that trait anxiety was not related to the sequential effects of conflict resolution, however the Stroop task was a very different paradigm than the flanker tasks used in experiments 1 and 4. It is also noteworthy that in experiment 1 it seemed to be the shared variance of trait anxiety and trait anger that accounted for the trait effects upon the CSE, and thus emotional conflict resolution.

The effects of both trait anxiety and social anxiety upon emotional face recognition found in the series of studies presented in this thesis support the perspectives on anxiety offered by Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg and van Ijzendoorn (2007), Beck and Clark (1997), Mathews and Mackintosh (1998), Mogg and Bradley (1998), Ohman (1996), Williams, Watts, MacLeod and Mathews (1988). These perspectives suggest that anxiety is related to a bias in attention for threat-related stimuli. We suggest the findings of this thesis and the above theories on anxiety and the threat-related attentional bias can be accommodated within the survival circuit theory of emotion and brain function proposed by LeDoux (2012). We can suggest that any survival circuit that pertains to threat-monitoring may be more reactive in high anxiety. However, this only seems to be the case when the threat-related faces are the target stimulus, not when they are the distracting stimulus. We say this as we did not find that performance in high anxiety individuals was specifically affected by any flanker faces.

We can also suggest that the effects of anxiety upon emotional conflict resolution (as evidenced by anxiety effects upon the CSEs), might also have represented some increased reactivity of an emotional survival circuit in the brain. However, these effects appear to be more subtle, and harder to detect, than the emotional face recognition effects. It is also noteworthy that the differential effects of anxiety upon conflict resolution are somewhat in alignment with the RST proposition that anxiety is sub-served by a defensive conflict resolution system (Gray & McNaughton, 2000). However, more work is needed before this relationship can be clearly understood.

It is noteworthy here that there is some controversy concerning how to make hypotheses from the RST perspective of Gray and McNaughton (2000). Corr (2004) suggested that the ‘separable subsystems hypothesis’ in RST research proposes that those high in BAS activity should be more responsive to reward when compared to those low in BAS activity. This hypothesis also suggests that those high in BIS activity should be more responsive to punishment (or conflict) than those low in BIS activity. This perspective suggests that reactions to reward ought to be the same at all levels of BIS activity, whereas reactions to punishment (or conflict) ought to be the same at all levels of BAS activity. Reward is simply defined as stimuli that activate the BAS[7]. In this thesis it would be the happy faces. From the perspective of the ‘separable subsystems hypothesis’ punishment is defined as stimuli that activate the FFFS (or BIS).

Corr (2004) proposed that an alternative hypothesis referred to as the ‘joint subsystems hypothesis’ can offer better predictions, as the data found in RST research is not really accommodated by the ‘separable subsystems hypothesis.’ From this perspective there are two effects (antagonistic and facilitatory) elicited by each reinforcement sensitivity. BIS activity facilitates reactions to aversive stimuli but reduces reactions to appetitive stimuli. BAS activity facilitates reactions to appetitive stimuli, but reduces reactions to aversive stimuli. Thus the two reinforcement systems can be said to be interdependent. However, Corr suggested that this need not always be the case. In experimental settings where strong aversive and appetitive stimuli are present this interdependence may not occur. In addition, Corr suggested that if high BAS and BIS participants are tested, or if there are only aversive OR appetitive stimuli used, this interdependence may also not occur. Corr also suggested

[7] NOTE: However, it is possible that non-reward stimuli such as the angry faces could have also activated the BAS as anger is an approach motivation, and might facilitate an approach response.

that the interdependence may not occur if there is no requirement for quick behavioural or attentional shifting between stimuli that are aversive and appetitive.

In experiment 1 of this thesis (after controlling for general RT effects) trait anxiety (as measured by the total STAI scores) was related to faster RTs for fearful faces, but was unrelated to RTs for happy faces. In addition, in experiment 3 (after controlling for general RT effects) trait anxiety (as measured by the STAI-anxiety subscale scores) was also related to faster RTs for fearful faces, but was unrelated to RTs for happy faces. Thus, if the BIS sub-serves trait anxiety then this supports the notion that those high in BIS activity (high trait anxious individuals) were more reactive to threat/punishment than those low in BIS activity. Moreover, these data also suggest that reactions to reward (i.e., the happy faces) were the same at all levels of BIS activity. Thus, these findings actually support the separable subsystems hypothesis. In contrast, in experiment 3, social anxiety was related to faster RTs to threat-related faces, but slower RTs for happy faces. Thus, if social anxiety is sub-served by BIS activity, then the BIS facilitated socially anxious participants' reactions to aversive stimuli but reduced socially anxious participants' reactions to appetitive stimuli. Thus, these findings actually support the joint subsystems hypothesis. This inconsistency is intriguing, as it tentatively suggests that the BIS may react in a slightly different way in high trait anxiety than it does in high social anxiety (assuming that the BIS subserves both trait anxiety and social anxiety).

A different theoretical perspective on anxiety offers an explanation of the lack of a general anxiety related effect of cognitive interference / distraction (particularly in our flanker tasks). ACT (Eysenck et al., 2007) suggests that anxiety relates to an increased influence of a stimulus driven attentional system, coupled with a decrease in the influence of a goal directed attentional system. However, this perspective also suggests that the negative effect of the stimulus driven systems dominance can be overcome with the use of compensatory strategies (i.e., enhanced effort or the increased use of processing resources). Eysenck and Derakshan (2011) clarified this issue. They suggested that if a task is not very demanding (or there is not a clear goal to the task) those high in anxiety have a low level of motivation, and thus recruit the minimal amount of attentional control resources. In contrast, Eysenck and Derakshan suggested that if a task is demanding (and there is a clear goal to the task) those high in anxiety have a high level of motivation. In this situation they thus recruit extensive attentional control resources, in order to reduce the dominance of the stimulus driven attentional system. This would thus result in the use of compensatory strategies such as effortful processing in order to achieve the goals of the task in hand. In our flanker experiments the goal of the task was very clear. The perspective of Eysenck and Derakshan suggests that if our high anxious participants' motivation was high, then they may have adopted a processing strategy that enabled them to override the effects of the flankers during the incongruent trials. From the perspective of Eysenck and Derakshan this would explain why in our flanker studies trait anxiety was not related to any cognitive interference / distraction effects.

This ACT based explanation of our results that show that anxiety is unaffected by incongruent flankers is flawed. In important real life situations, where trait anxiety and/or clinical anxiety causes problems, the situations would be demanding and would also have a clear goal. ACT does not explain why high anxious patients cannot engage their compensatory tactics in everyday life. We suggest that the ACT notion that anxious patients have this processing bias which makes them do worse cognitively under certain conditions is a weak theory. We suggest this as we find that there is no effect of anxiety in the high distraction conditions in our flanker experiments where the anxiety effect would be expected. The ACT suggestion that compensatory mechanisms can prevent the occurrence of this expected anxiety effect makes their theory almost unfalsifiable.

Experimental neurocognitive research has shown that trait anxiety is related to the impaired reactivity of cognitive mechanisms that are mediated by the prefrontal cortex, when goal conflict resolution and the inhibition of distractor processing is required. These effects have been found when neutral distractors are used (Bishop, 2009), and when threat-related distractors are used (Bishop, Jenkins, & Lawrence, 2007). Bishop (2009) proposed that these findings may explain why clinical anxiety patients suffer daily problems with concentration. More specifically, Bishop (2009) used a response conflict task (with neutral digit stimuli) that manipulated conditions of high demand upon attention and low demand upon attention (high vs. low perceptual load). Relative to those with low trait anxiety, those high in trait anxiety showed a reduced difference (incongruent – congruent) in neural activity in the left DLPFC, under low perceptual load, and an increased difference (incongruent – congruent) in neural activity in the left DLPFC under high perceptual load. Relative to those with low trait anxiety, those high in trait anxiety also showed slower RTs to target stimuli under conditions of both high and low perceptual load. Moreover, in a median split analysis, those high in anxiety were slower to respond to incongruent trials than congruent trials (under low perceptual load), whereas those low in anxiety were not. Neither group showed this effect under high perceptual load.

Bishop (2007) used a letter search paradigm with conditions of both high and low perceptual load. Stimuli were overlaid upon neutral or fearful distractor faces. High trait anxiety relative to low trait anxiety was related to reduced lateral PFC, dorsal ACC, and rostral ACC activity to fearful face distractors under low but not high perceptual load. High trait anxiety was related to reduced accuracy in the high perceptual load condition relative to low trait anxiety. The design of these two studies differed from the designs used in our studies. It is noteworthy that in addition to the anxiety related differences in brain activity, these studies revealed some behavioural effects that may relate to a general anxiety related increase in distraction. However, it is also noteworthy here that both of these studies used 17-18 participants in each and as such the behavioural data should be interpreted with caution.

Theoretical accounts of how perceptual load modulates distractor processing suggest that perception of distractors can be inhibited when perceptual load is high (i.e., if many task relevant distractors are present), but not when perceptual load is low (i.e., just one task relevant distractor is present). From this perspective, when perceptual load is low, spare processing resources attend to the distractor (Lavie, 1995). It is not easy to quantify the exact level of perceptual load in our flanker experiments as although there were eight flanker faces present, there were always only two emotions present in incongruent trials. However, it is interesting to note that Lavie, Ro and Russell (2003) showed that interference from emotionally neutral distractor faces was unaffected by perceptual load in an emotionally neutral name search task. Lavie et al. suggest that in contrast to other irrelevant stimuli, it might be adaptive to process irrelevant faces as they may still convey important social cues. Thus, we suggest that in our flanker studies the level of perceptual load would not have affected the magnitude of distractor interference. However, it is also worth briefly considering that in our emotional word-face Stroop task that trait anxiety was selectively affected by the happy word distractors during incongruent trials. In contrast, in our emotional face flanker tasks trait anxiety was not affected by the happy face flankers during incongruent trials. It seems possible that perceptual load was lower in the Stroop task than in the flanker tasks, however we cannot be sure. It would be beneficial if future studies on trait anxiety, goal conflict resolution, and distractor processing use a design that manipulates different levels of perceptual load.

7.2. Limitations

7.2.1. Limitation 1

There is a limitation to the research presented in this thesis as female participants outnumbered male participants. A lot of research with UK psychology student samples has this bias, as females outnumber males on UK psychology degrees by three or four to one. However, we are not overly concerned with this issue here for five reasons. Our first two reasons concern emotional face processing. Firstly, Hoffmann, Kessler, Eppel, Rukavina and Traue (2010) have shown that there is no gender difference in recognition accuracy for full blown emotional expressions (although a female recognition advantage exists for subtle emotional expressions). Secondly, Wager, Phan, Liberzon and Taylor (2003) conducted a meta-analysis of 65 neuroimaging studies and reported that when averaging across the whole brain there was no significant gender difference in the likelihood of brain responses to emotion (although some regions were more reliably active in women, whereas others were more reliably active in men).

Our third and fourth reasons concern distraction, goal conflict, and thus cognitive control. Our third reason for not being overly concerned with the gender imbalance in our samples is specific to Stroop tasks. MacLeod (1991) reviewed Stroop studies spanning half a century and reported that research has not found any reliable gender difference in Stroop task performance. Our fourth reason is specific to flanker tasks. Clayson, Clawson and Larson (2011) used an emotionally neutral flanker task which showed that although females responded slower and were less accurate than males, there were no gender differences present in the CSE data. In addition, Fischer, Danielmeier, Villringer, Klein and Ullsperger (2016) also used an emotionally neutral flanker task to examine gender effects. In this study gender did not affect accuracy which is in contrast to the study by Clayson et al. (2011). Fischer et al. reported that females only displayed a very small increase in the RT congruency effect compared to males (mean = 5 msecs). However, males responded faster than females did, which is consistent with the study by Clayson et al. (2011). Schulte Holthausen, Regenbogen, Turetsky, Schneider and Habel (2016) used an emotional face flanker type task which showed that females responded faster than males. This is inconsistent with the studies by Clayson et al. (2011) and Fischer et al. (2016). There was no effect of gender upon emotion recognition accuracy. They do not report an analysis of gender upon their non-significant congruency effect, thus one assumes there was no effect of gender present here. In summary, we can suggest that gender differences in flanker tasks are not very reliable, and as such we are not overly concerned with this issue here.

Our fifth reason concerns gender differences in anxiety. We are aware that Feingold (1994) conducted a large meta-analytic study examining the literature on gender differences in personality. This study showed that females score higher than males on anxiety measures in general, but there were no gender differences reported specifically for social anxiety. However, here we are interested in the relationship between anxiety and behavioural measures (and other personality constructs) as opposed to how our actual sample mean anxiety scores generalize to the population mean anxiety scores. Considering the inconsistent gender effects described above, we find it unlikely that there would be any robust gender differences in how anxiety interacts with the behavioural effects (or other personality constructs) we are interested in. Thus, we suggest that the gender imbalance in our sample is probably of minimal consequence here.

7.2.2. Limitation 2

Another limitation is the fact that the personality trait measures we used are labelled a measure of one specific construct, and yet they are factorially complex. For example, the STAI (Spielberger et al., 1983). the BIS scale (Carver & White, 1994), and the attentional control scale (Derryberry & Reed, 2001, 2002) have this limitation as they both claim to measure unitary constructs, but may actually consist of constituent constructs (i.e., anxiety and depression in the STAI, anxiety and fear in the BIS scale, and attentional focusing and attentional shifting in the attentional control scale). This thesis has gradually addressed this issue throughout the behavioural chapters, and chapter 6 addresses this issue psychometrically and discusses it in more detail.

Bieling, Antony and Swinson (1998) suggested that the STAI (Spielberger et al., 1983) may measure an umbrella factor of negative affect. Thus, it is hard to psychometrically distinguish between anxiety and depression, and in our series of experiments it is possible that the behavioural effects that related to anxiety were mediated by a general negative affect system. Nettle (2004) suggests that a moderately reactive negative affect system would facilitate a person to work hard for desirable outcomes whilst avoiding negative outcomes. Nettle suggests that this could increase fitness. As discussed above, both anxiety and depression fall under this umbrella term. From an evolutionary perspective anxiety is considered a specialised state that has been designed by natural selection and has evolved to help an individual cope with threat and/or aid escape from threat. (Marks & Nesse, 1994). Thus, anxiety can increase inclusive reproductive success (i.e., Darwinian fitness). Depression may also increase fitness in two ways. Firstly it may increase a person's focus upon difficult life problems, by avoiding them using energy on everyday social activity. Moreover, depression may also signal to others that help is required (Nettle, 2004). Another evolutionary perspective on depression suggests that depressed states evolved to reduce risk in social situations where a person perceives their social value to be low or where they may become a burden. From this perspective low social value and social burden could lead to a person being excluded from future social contexts that are critical to fitness. Thus avoiding being in any situation where future exclusion might arise, could well be adaptive (Allen & Badcock, 2003). Thus, it is easy to see how and why both anxiety and depression related to some of our behavioural measures of emotional face processing, and emotional conflict resolution. It is also easy to see why higher depression was related to lower BAS scores, and thus reduced reward seeking. In short, we suggest that our experiments might have tapped into the activity of emotional survival circuits in the brain that sub-serve both anxiety and depression.

Considering that the STAI might measure general negative affect we reanalysed the key social anxiety and RT correlation from experiment 3 (chapter 4), with a view to determining if this correlation remained stable after controlling for the total STAI scores. When controlling for the total STAI scores the correlation between social anxiety and the RT difference for threat-related and happy faces remained negative. The correlation value was $r = -0.26$, and the correlation was still significant ($p=0.018$). Thus, if the STAI was ever proven to measure general negative affect, one could interpret these results as meaning that social anxiety relates to emotional face processing independently to the effects of general negative affect.

7.2.3. Limitation 3

A further limitation concerns the behavioural tasks we used. We designed RT paradigms that are more ecologically valid than most we observed in the literature. However, the tasks are still likely not to be capturing large emotional effects as they are still quite artificial. Thus, the threat-related stimuli used in our tasks may actually elicit slightly different responses compared to environmental and/or social threats that occur in the real world. It is entirely possible that strong trait anxiety effects can’t be observed very easily when using the artificial type of threat stimulation that we used in our experiments.

7.2.4. Limitation 4

The fourth limitation that requires mentioning relates to cognitive task design and interpretation in general. Cognitive tasks are designed to measure one process but can easily be argued to be addressing other processes instead (or as well). The long debate about the mechanisms in implicated in Stroop tasks or in the CSE are cases that we have reviewed and discussed earlier. The CSE might not reflect conflict resolution processes (as discussed in detail in chapter 5). If it does then the relationship between trait anxiety and the CSE, which was inconsistent across the experiments in this thesis, might be evidence of the link between conflict resolution and anxiety. However, it is important resist the temptation to argue that the CSE measures conflict resolution in the task that shows a link to anxiety (i.e., experiment 1) and doesn't measure conflict resolution when the relationship with trait anxiety is missing (i.e., experiment 2; and somewhat in experiment 4). This argument would be circular as it lacks any independent evidence for the dependence of the CSE on conflict resolution. Moreover, we cannot be sure that the CSE task used in experiment 4 would have activated the same cognitive control mechanisms as in experiment 1, or in conventional flanker tasks. We say this as the trial type congruency effect present in the RTs was unexpectedly very weak, and not statistically significant. It is entirely possible that experiment 4 activated a different cognitive control mechanism than that which was active in experiment 1. In short, it is possible that if a conflict monitoring / conflict adaptation system in the brain was responsible for producing the CSE in experiment 1, that this neural system did not receive enough conflict to be activated in experiment 4.

7.2.5. Limitation 5

This series of experiments were based upon both cognitive and biological theories of anxiety. However, these experiments were all behavioural and/or psychometric, thus here we cannot determine how other factors that influence human behaviour may have affected our results. In short, this series of experiments did not take into account how genes, biological structures, chemical imbalances, and/or individual participants' life experiences may have affected task performance, or the relationship between anxiety and task performance. However, in this thesis we have suggested conducting some further studies using electrophysiological methods such as EEG. Further studies concerning anxiety, emotion and cognition should also consider using a range of biological methods, along with a means of assessing participants' individual life experiences (e.g., stressful life events).

7.2.6. Limitation 6

The studies in this thesis examined the effects of emotional valence upon face processing. However, there is another emotional dimension referred to as emotional arousal. Emotional arousal can also affect the processing of stimuli, as arousal levels can affect how the amygdala modulates the cortical representation of stimuli (e.g., Phelps & LeDoux, 2005). The studies in this thesis were limited to interpreting the data from a valence-based perspective that was predicated upon theories of face perception and information processing. However, we cannot rule out the possibility that arousal levels of the different emotional expressions depicted in our stimuli also affected the results.

We briefly touched on this issue in experiment 3, as we manipulated the salience of the mouth regions of the faces (and suggested that open mouthed expressions represent a more intense and therefore probably a more arousing version of an emotion relative to closed mouthed expressions). However, future studies should obtain arousal ratings for the emotional faces used as stimuli, and determine if/how arousal levels of the stimuli used affect emotional face processing and cognitive control.

Lundqvist, Juth and Ohman (2014) showed that higher emotional arousal ratings for emotional facial stimuli related to higher emotional intensity ratings. However, emotional intensity ratings predicted emotional face recognition scores (as indexed by RTs) better than emotional arousal ratings did. Lundqvist et al. suggest that both emotional arousal and emotional intensity ratings are both a type of intensity measure. They further suggest that the two types of ratings just differ in terms of the perspective taken when providing the ratings. They propose that when providing emotional intensity ratings participants adopt an objective perspective and rate the intensity of the stimulus. In contrast, they propose that when providing emotional arousal ratings participants adopt a subjective perspective and rate the intensity of their own reaction to the stimulus. Accordingly, future studies using emotional faces should obtain both emotional arousal and emotional intensity ratings for each of the faces used, with a view to determining if arousal and intensity differentially affect emotional face recognition.

7.3. Conclusion

We wished to determine whether anxiety relates to enhanced conflict resolution, enhanced cognitive interference which is experienced as distraction, and the enhanced processing of threat-relevant visual stimuli (in this case emotional faces). We found good evidence that anxiety relates to the enhanced processing of threat-related faces. Trait anxiety was related to the more rapid processing of specifically fearful faces, whereas social anxiety was related to the more rapid processing of both fearful and angry faces. We found no evidence that anxiety was related to cognitive interference/distraction caused by peripheral emotional faces (threat-related or otherwise). However, we found a very specific distracting effect of happy words that was related to anxiety. However, we suggest that this was not due to a general distraction effect, but was due to an interaction between an anxiety-related speed accuracy trade-off, and micro differences in how emotional stimuli are processed. We found that anxiety was related to conflict resolution as evidenced by the CSEs. However, we suggest that this area needs further work before the relationship can be properly understood. We also found some evidence supporting the idea that a widely used measure of trait anxiety (STAI; Spielberger et al., 1983) may measure an umbrella construct of negative affect, and that the scale has two sub-factors of anxiety and depression. From this perspective it seems that some (if not most) of the behavioural effects present in our experiments may relate to the umbrella construct of general negative affect, or to both anxiety and depression. We have suggested throughout this thesis that the anxiety related behavioural effects may represent the activity of the emotional survival circuits in the brain theorised by LeDoux (2012). We cannot rule out the possibility that an umbrella factor of general negative affect also reflects the activity of these survival circuits. Further work is required to determine if, how, and why both anxiety and depression relate to the altered functioning of these survival circuits.

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Appendices

Appendix A

Reanalysing experiment 1 using the STAI-anxiety and STAI-depression scales.

Here we investigated the relationship between the two STAI subscales and the key RT effects reported in experiment 1. The analyses are exploratory, but to aid interpretation of the data we adopt a significance level of 0.05/2. STAI-anxiety (N = 80) significantly correlated with the happy face recognition advantage (r= -0.29, p= 0.008), as did STAI-depression (N = 78; r= -0.28, p= 0.014). However, the depression correlation was noticeably less robust. The sign of the correlations shows that as STAI-anxiety and STAI-depression increased, the happy face recognition advantage decreased.

We then repeated the analyses using partial correlations to ascertain whether these effects related to the umbrella factor of negative effect that is measured by the total STAI scores, or just one of the subscales. When controlling for STAI-depression, STAI-anxiety was no longer significantly related to the happy face recognition advantage (r= -0.19, p= 0.106). Similarly, When controlling for STAI-anxiety, STAI-depression was no longer significantly related to the happy face recognition advantage (r= -0.07, p= 0.552).

We also reanalysed the sequential effects in the RTs, whist adopting an adjusted significance level of 0.05/2. STAI-anxiety (N = 80) significantly correlated with the CSE (i.e., the (in)congruency repetition advantage) in RTs during the between-valence condition (r= 0.26, p= 0.020), but STAI-depression (N = 78) only showed a trend towards this correlation (r= 0.20, p= 0.086). The sign of the correlations shows that as STAI-anxiety and STAI-depression increased, the (in)congruency repetition advantage increased.

We then conducted partial correlations to ascertain whether these effects related to the umbrella factor of negative effect that is measured by the total STAI scores, or just one of the subscales. When controlling for STAI-depression, STAI-anxiety was no longer significantly related to the (in)congruency repetition advantage (r= 0.18, *p*= 0.109). Similarly, when controlling for STAI-anxiety, STAI-depression was not related to the (in)congruency repetition advantage at all (*r*= 0.01, *p*= 0.946).

Appendix B

Reanalysing experiment 2 using the STAI-anxiety and STAI-depression scales.

Here we investigated the relationship between the two STAI subscales and the key RT and accuracy effects reported in experiment 2. These analyses are exploratory, but to aid interpretation of the data we adopt a significance level of 0.05/2. STAI-anxiety did not significantly correlate with overall RTs when judged against this adjusted p-value, but was a trend (r= -0.24, p= 0.041), but STAI-depression did (r= -0.30, p= 0.011). The sign of the correlations shows that as STAI-anxiety and STAI-depression increased, mean RTs decreased. STAI-anxiety did not significantly correlate with overall proportion correct (r= -0.19, p= 0.113), and nor did STAI-depression, although this was a borderline trend (r= -0.26, p= 0.027). STAI-anxiety did not significantly correlate with the proportion correct for incongruent fear trials (r= -0.19, p= 0.098), but STAI-depression did (r= -0.29, p= 0.011).

We then repeated the analyses using partial correlations to ascertain whether these effects related to the umbrella factor of negative effect that is measured by the total STAI scores, or just one of the subscales. When controlling for STAI-depression, STAI-anxiety did not correlate with overall RTs (r= -0.04, p= 0.713), overall accuracy (r= -0.01, p= 0.946), or accuracy for incongruent fearful trials (r= -0.02, p= 0.873). Similarly, when controlling for STAI-anxiety, STAI-depression did not correlate with overall RTs (r= -0.19, p= 0.113), overall accuracy (r= -0.18, p= 0.125), or accuracy for incongruent fearful trials, although this was a trend (r= -0.23, p= 0.054). Clearly, the specific relationship with STAI-depression is numerically quite a lot larger than the near-zero specific relationship with STAI-anxiety.

Appendix C

Reanalysing the basic emotional face recognition RT effect in experiment 4 using the social anxiety scale.

We wished to confirm whether social anxiety related to the main effect of emotion found in experiment 4. Social anxiety was negatively correlated with the happy face RT advantage at a trend level (r= -0.19, p=0.088). Thus, as social anxiety increased, the RT advantage for happy faces relative to fearful faces decreased. However, it is noteworthy that when controlling for the general RT factor this correlation was strengthened slightly (r= -0.21, p=0.056).