# The neurocognitive basis of cognitive and emotional control

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Science is like a journey towards knowledge and so is a PhD. One could say that the important part of a journey is the process. Not because the end is not important (it is), but because the process is the time when we learn the most. The process of my PhD has certainly been the most enriching, challenging, colourful and formative part. However, this journey and the various avenues of it, would not have been possible without the generous, heartfelt and outstanding support from my supervisors, Andrew Lawrence, Natalia Lawrence and Chris Chambers. Not only were they always there to point out alternative views, approaches and provide needed challenges, but they were also there to guide and stimulate me with their knowledge. They have not only allowed me to progress as a scientist, but at the same time, perhaps because such matters cannot be separated so easily, also inspired me to develop as an individual. I am immensely grateful for their insight and for knowing what is best for me at what time. This is something that will stay with me for the years to come.

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this I am grateful to all that were there to share this important journey with me and this I will keep in memory.

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**Summary**

Cognitive models of threat processing maintain that threat, depending on the task at hand, can speed (when task relevant) or impair (when task irrelevant) cognitive performance (Pessoa, 2009). It is generally assumed that attentional bias to threat is modulated by anxiety, with increased anxiety leading to increased bias (Bishop, 2007; Mathews & Mackintosh, 1998). Evidence suggests that such biases are not actually specific to anxiety, however, and instead form part of a broader personality spectrum of negative affect or neuroticism (Clark & Watson, 1991), of which anxiety is but one facet. Further, such emotion-linked attentional biases to threat may be modulated not only by task demands, but also by individual differences in 'regulatory' traits, including emotion regulation and attentional control capacity. Most previous studies have focused on the influence of threat on spatial and temporal aspects of attention. It has recently been suggested, however, that threat material may also influence higher-level cognitive control processes, such as response inhibition. In the current thesis, I examine the influence of threat related material on different tasks of cognitive control: the Stroop task, the Flanker task, and the Stop-signal inhibition task. In addition, I examine the influence of trait negative emotion (neuroticism) and regulatory traits (emotion regulation and attentional control) on selective processing of threat material. I set out to test, for the first time, the idea that individual differences in negative emotionality (neuroticism) and attentional control/emotion regulation would interact to predict the impact of threatening material on cognitive control. More specifically, that good attentional control and/or emotion regulation would 'buffer' the effects of higher levels of neuroticism on the impairment of cognitive control by threatening material.

In the Flanker tasks, I find evidence for speeded processing of positive emotion, whereas performance in the Stroop task is particularly impaired by threat material. By contrast, in the

Stop signal task of response inhibition, I find that response inhibition (stopping) is slowed in the presence of angry facial expressions, and such slowing is greater in individuals high in trait neuroticism. Further, as predicted, the influence of neuroticism is moderated by individual differences in emotion regulation, such that good emotion regulation ‘buffers’ the impact of neuroticism. The implications of these findings for current cognitive models of threat-processing are discussed.

# Chapter 1: General introduction

It has been well-documented that humans have a limited processing capacity, necessitating that certain information, particularly that pertaining to threat, needs to be prioritized (Desimone & Duncan, 1995; Moray, 1967; Pessoa, 2010). This has been demonstrated by a large number of studies showing an attentional bias to threatening material (e.g. Pessoa, 2009; Pourtois, Schettino, & Vuilleumier, in press; Vuilleumier, 2005; see below for a more detailed review). While generally adaptive, some individuals, particularly those with mood/anxiety disorders manifest an exaggerated bias to threat, which might be relevant to the development/maintenance of mood disorder (see e.g. Bar-haim, Lamy, Pergamin, Bakermans-Kranenburg, & IJzendoorn, 2007; Joormann & Siemer, 2011). To date, most of the work in this area has focused on the impact of anxiety on spatial (and more recently temporal) attention, as assessed using, for instance, spatial dot-probe tasks or the attentional blink paradigm (Mathews, Mackintosh, & Fulcher, 1997; Mogg & Bradley, 1998, 1999; Pourtois et al., in press; Vuilleumier, 2005).
The spatial dot-probe task typically involves the presentation of two emotional stimuli (threat vs. non-threat) in vertical arrangement, with participants having to attend to the upper stimulus. Following the offset of the stimuli, a small dot will usually appear at the spatial location of one of these. So, on some trials the dot and the threatening information successively appear in the same position (congruent), whereas on others they appear in opposite positions (incongruent). It is participants' task to indicate the location of the dot, with their response latencies for this being recorded. This permits the calculation of an attentional bias score (incongruent – congruent trials), with positive values indicating attention towards the threatening material and negative

ones avoidance of threat (a score of zero = no attentional bias). Individuals with anxiety/mood disorders typically display an exaggerated attentional bias to threat.

In the attentional blink paradigm, generally a rapid sequence of items (e.g. 16 items) is visually presented at a rate of around 10 per second. As part of this sequence two critical events appear: target 1 (e.g. a white letter in a stream of black ones; T1) and target 2 (e.g. the letter X; T2). The onset of T1 is typically at around positions 6-9 of the sequence, with T2 occurring at variable positions following T1 (e.g. lags 1, 3, 5, 7). Participants, depending on the task, need to report one target or both at the end of the item sequence (dependent measure: proportion of targets correctly identified). Reports of T2 are usually unaffected at lag 1 (= lag-1 sparing), for lags 2-4 performance is impaired (= attentional blink), but then recovers again (close) to baseline at lags 5 or 6. Affective variations of the attentional blink task tend to use emotional stimuli for either T1 or T2. When T1 is threat-related (e.g. an angry face), this can result in impaired detection of a subsequent neutral T2 presented during the period of the ‘blink’ relative to a neutral T1, especially in individuals with high levels of neuroticism (see Peers, Simons, & Lawrence, 2013 for a review). Conversely, detection of a threat-related T2 presented during the period of the blink is typically enhanced relative to a neutral T2 (Peers, Simons, Lawrence, 2013 for review). Both of these findings are suggested to reflect enhanced processing of threatening material.

Research has now begun to examine how emotional material impacts higher level cognitive control mechanisms such as response inhibition, the ability to prevent a prepotent response, which has become obsolete, from execution (Pessoa, 2009; Verbruggen & De Houwer, 2007; Verbruggen & Logan, 2008; Zetsche, Avanzato, & Joormann, 2012). Indeed, inhibition has been suggested as a unifying mechanism to underpin attentional biases (Joormann, 2004).

Specifically, the author argued that impaired inhibitory mechanisms in depressed individuals might be able to explain the dysfunctional maintenance/disengagement (attentional bias) from negative material observed in this disorder. In line with this research, the aims of the current thesis are to examine the impact of threat on inhibitory control processes, in relation to emotional and regulatory individual differences linked to risk for emotional disorders (neuroticism, attentional control, reappraisal). Such afflictions affect a not insignificant proportion of modern society (Somers, Goldner, Waraich, & Hsu, 2006; Waraich, Goldner, Somers, & Hsu, 2004) and hence an enhanced understanding thereof is crucial. In the following sections relevant evidence will be discussed and evaluated in more depth. I will review studies of attention to threat, the role of anxiety in threat appraisal, the impact of emotion on cognitive control, relevant models of threat processing, as well as work on individual differences (neuroticism and reappraisal) and their relation to cognitive control. It is concluded that, amongst others, the association between neuroticism and cognitive control is inconsistent in the literature. I propose that in addition to previously reported factors such as variability in performance or cognitive load, this inconsistency could also be explained by factors such as the affective nature of the task or moderating roles of regulatory individual differences (e.g. reappraisal or attentional control).

## Threat processing

Effective processing of threat is central to our survival and over recent years there has been an intense debate as to the underlying mechanisms. One strand of research has examined the effect of threat on attention. This work is often in line with a framework by Posner and Petersen (Petersen & Posner, 2012; Posner & Petersen, 1990), which proposes that human attention can be divided into three major subfunctions, namely attentional shifting, engagement and disengagement. Theoretical models of threat approach this concept broadly, summarizing data across a range of threatening stimulus materials (e.g. words, faces, other aversive images, or induction of a mild shock; Bishop, 2007; Mathews & Mackintosh, 1998; Mathews et al., 1997; Pessoa, 2009) and focussing on the fear arousing nature of the cues, but not necessarily distinguishing the specific stimulus qualities leading to such arousal (e.g. fearful versus angry stimulus sets). Whilst some work has suggested qualitative differences between threat attributes such as fear and anger (Ewbank et al., 2009), in the studies reviewed in the following the term threat is understood as encompassing the more general category, as put forward in neuro-cognitive models of threat processing (S. J. Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998; Pessoa, 2009). Relevant studies using a visual search task show that negative and threatening faces efficiently capture attention (Eastwood, Smilek, & Merikle, 2003; Fox et al., 2000; M. Williams, Moss, Bradshaw, & Mattingley, 2005; although see Damjanovic, Roberson, Athanasopoulos, Kasai, & Dyson, 2010; Tipples, Young, Quinlan, Broks, & Ellis, 2002). In this paradigm participants' task is to detect a target stimulus (e.g. 1 angry (neutral) face) amongst an array of distracter items (e.g. 3 neutral (angry) faces), allowing comparison of the response latencies for the different conditions. Similar findings are obtained with dot probe (Brosch, Pourtois, Sander, & Vuilleumier, 2011; Pourtois, Grandjean, Sander, & Vuilleumier, 2004) and attentional blink paradigms (Anderson & Phelps, 2001; Anderson, 2005; De Martino, Kalisch, Rees, & Dolan, 2009), revealing faster or more accurate responses towards threatening information. Results are slightly different for the Stroop task (Stroop, 1935). In this task participants are traditionally required to name the font colour of colour words versus neutral words, whilst attempting not to read the words, which is the prepotent (i.e. dominant) response. It is generally found that response latencies of incompatible trials (font colour (e.g. blue) and colour word (e.g. red) do not match) are slower than those of compatible ones (font colour (e.g. blue) and colour word (e.g. blue) match). Several affective variants of the task also exist. In the emotional word Stroop task, for example, participants name the font colour of emotional (vs. control) words (McKenna & Sharma, 1995, 2004). Alternatively, in the word-face Stroop task (Stenberg, Wiking, & Dahl, 1998) emotional words (e.g. target) are overlaid on emotional faces (e.g. distracter), with target and distracter items being either compatible (e.g. angry word and angry face) or incompatible (e.g. happy word and angry face).

Evidence from these Stroop-like tasks suggests that threat related information slows responses, particularly when personally relevant or following priming procedures (Gilboa-Schechtman, Revelle, & Gotlib, 2000; Lundh & Czyzykow-Czarnocka, 2001). However, some researchers maintain that this slowing effect is predominantly manifested between (as opposed to within) trials, reflecting a slowed disengagement process (McKenna & Sharma, 2004; Phaf & Kan, 2007). There have also been concerns that the slowdown in performance in the emotional word Stroop task may, partly, be accounted for by lexical factors (Larsen, Mercer, & Balota, 2006). Indeed, valence and word frequency seem to interact, in that the slowing effect is only observed for low frequency words (Kahan & Hely, 2008), although other work has demonstrated that even when controlling for lexical properties such as word length or frequency, the slowdown effect was found with personally relevant words (Gilboa-Schechtman et al., 2000; Williams, Mathews, & MacLeod, 1996). In summary then, threat can enhance performance (as in visual search, dot probe and attentional blink tasks), but, particularly when task-irrelevant and pertinent to the subject, can also impair performance (as in Stroop-like tasks).

## Threat processing and individual differences in anxiety

An interesting question is whether such findings are modulated by individual differences. Indeed, humans have varying degrees of sensitivity to threat (Mathews et al., 1997; Mathews & Mackintosh, 1998) and anxiety, due to being tightly linked with threat, is therefore likely to have an impact on the processing thereof. Numerous studies have been conducted to further test this assumption. For instance, Byrne and Eysenck (1995) suggest that in a visual search experiment high trait anxious cohorts respond faster to threatening targets, but slower to happy targets when flanked by threatening distracters, demonstrating that target detection in high trait anxiety is facilitated with threatening targets, but hindered with threatening distracters. However, other work with this task only corroborates the impaired performance of anxious individuals in the face of threatening distracters, but does not support the findings of facilitated performance with threatening targets (Miltner, Krieschel, Hecht, Trippe, & Weiss, 2004; Rinck, Becker, Kellermann, & Roth, 2003). Results from studies of attentional blink are slightly more mixed. Whereas some researchers show that the attentional blink effect is reduced for emotional or threatening material in high anxiety, lending additional support to the notion that threat is detected more easily with elevated levels of anxiety (Arend & Botella, 2002; Barnard, Ramponi, Battye, & Mackintosh, 2005; Fox, Russo, & Georgiou, 2005; Trippe, Hewig, Heydel, Hecht, & Miltner, 2007), others have found a reduction in attentional blink for affective stimuli regardless of (social) anxiety (De Jong, Koster, Van Wees, & Martens, 2009). Interestingly, Peers and Lawrence (2009) found that individuals with poor attentional control exhibited stronger emotional distraction effects, an effect that was not observed for high state anxiety nor for a state anxiety X attentional control interaction, calling into question the role of state anxiety in the attentional blink paradigm (although see Barnard et al., 2005 who found effects of state anxiety on attentional blink performance). Taken together, one can conclude from the above results that, in general, anxious individuals are affected by threatening distracters. Some studies also advocate enhanced detection of threatening targets in anxiety. However, further studies are needed to clarify this issue.

A related issue that has generated a sizeable amount of research activity over recent years has been the theoretical debate as to whether the attentional bias of anxious individuals concerns slower disengagement from or a faster shift towards threatening stimuli. This has been addressed with mainly (but not exclusively) two paradigms: the exogenous cueing and the dot probe tasks. For example, using a modification of the exogenous cueing paradigm (Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002; Georgiou et al., 2005; see Mogg, Holmes, Garner, & Bradley, 2008 for a critical view) as well as the dot probe task (Koster, Crombez, Verschuere, & Houwer, 2006; Salemink, van den Hout, & Kindt, 2007) researchers argued that high trait anxious individuals are poor at disengaging attention from threatening stimuli. In the modified exogenous cueing paradigm, crucially, on each trial an emotional stimulus (e.g. threat vs. non-threat) is presented in a box to the left or right of fixation. Shortly afterwards the emotional cue disappears and will be replaced by the target stimulus (e.g. a circle) in either the same box (= valid trial) or the box in the opposite spatial location (= invalid trial). Participants' task is to indicate the location of the target (left or right). Elevated RTs on invalid trials for threatening material (relative to non-threatening cues) are assumed to reflect slower disengagement from threat. Speeded performance on valid trials to threatening (vs. non-threatening) cues would, in turn, indicate a faster attentional shift towards threat.

Other work on the time course of attentional bias revealed that difficulties in disengagement from threatening material are prominent at 100 ms of stimulus presentation time in high trait anxious individuals, whereas at 200 and 500 ms these individuals exhibit greater avoidance (Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006). However, some research with the probe detection task has also suggested that people with increased anxiety may shift their attention more quickly towards threatening material, an effect that was found regardless of awareness (Bradley, Mogg, White, Groom, & De Bono, 1999; Brotman et al., 2007; Li, Li, & Luo, 2005; Mogg, Bradley, de Bono, & Painter, 1997; Mogg, Bradley, & Hallowell, 1994; Mogg & Bradley, 2002). Furthermore, this orienting response seems to be unaffected by exposure duration (Bradley, Mogg, Falla, & Hamilton, 1998; Bradley et al., 1999; Mogg et al., 1997), is enhanced when high trait and high state anxiety interact (Macleod & Mathews, 1988) and can be modulated by a transient activation of the threat network (Helfinstein, White, Bar-Haimb, & Fox, 2008) – further support for attentional shift is derived from eye-gaze cueing (Fox, Calder, Mathews, & Yiend, 2007; Mathews, Fox, Yiend, & Calder, 2003) and eye-movement studies (Mogg, Garner, & Bradley, 2007). The eye-gaze cueing task involves threatening versus non-threatening facial expressions, in which the eyes are directed straight ahead, left or right. Participants need to identify the spatial location (left or right) of two target letters (e.g. T vs. L). Targets can thus be congruent with the gaze direction (e.g. target appears on the left side with the gaze directed at the same spatial location) or incongruent (e.g. target appears on the left side with the gaze directed to the right, i.e. at the opposite spatial location). Generally, faster response latencies on congruent trials would be interpreted as facilitated engagement, whereas slower responses on incongruent trials could be seen to indicate impaired disengagement. The eye-movement study by Mogg and colleagues (Mogg et al., 2007) consisted of a standard dot-probe paradigm using affective stimuli with concurrent tracking of the eye movements.

Overall, the findings from the above studies show that both slower disengagement and faster attentional shift have been implicated in threat processing of high anxious individuals. Several researchers, however, have discussed the issue that commonly used behavioural tasks do not clearly distinguish between the shift and disengagement processes (see e.g. Fox et al., 2001; Mogg et al., 2008), highlighting the need to develop novel tasks or techniques that can more clearly disentangle the mechanisms underlying the shift and the disengagement components of visual attention.

Affective variants of the Stroop paradigm have also been extensively tested in anxious cohorts. This work reveals that high anxious individuals exhibit greater interference for negative or threatening material, especially when it is personally relevant (Becker, Rinck, Margraf, & Roth, 2001; Calvo, Avero, Castillo, & Miguel-Tobal, 2003; Dawkins & Furnham, 1989; Miller & Patrick, 2000; Mogg et al., 2000; Mogg, Mathews, & Weinman, 1989; for a review see Williams et al., 1996; but see van Honk, Tuiten, de Haan, van den Hout, & Stam, 2001 for no effect of trait anxiety with a pictorial emotional Stroop task – this is a variant of the Word-Face Stroop task using emotional scenes instead of photographic images of facial expressions). An experiment by Richards and Blanchette (2004) further corroborates these findings in an important way. The authors employed a classical conditioning paradigm whereby neutral words and non-words were to be associated with either negative or neutral images. An emotional word Stroop task, using these conditioned stimuli, was then administered. As revealed by affective rating scales, for high anxious participants non-words, albeit not the neutral words, were effectively conditioned. Importantly, Stroop interference was found for the negatively conditioned non-words for high anxious individuals, underlining the significance of emotional connotation in this effect. Miller and Patrick (2000) reported that the emotional interference effect in high trait anxious individuals occurs regardless of the level of state anxiety, as manipulated by anticipation of shock (although see Eglo & Hock (2001) who maintain that emotional Stroop interference is not related to the main effects of trait or state anxiety, but is only positively associated with state anxiety at high levels of trait anxiety).

The emotional word Stroop effects are also found for subliminal versions of the paradigm, suggesting that threat is processed pre-attentively in high trait anxious cohorts (Mogg, Kentish, & Bradley, 1993; van den Hout, Tenney, Huygens, Merckelbach, & Kindt, 1995; Wikström, Lundh, & Westerlund, 2003; but see Thorpe & Salkovskis, 1997). The pre-attentive role of threat is further supported by study from Mathews and MacLeod (1986). They used a dichotic listening task where neutral passages are played into one ear and, at the same time, threatening vs. non-threatening words into the other ear. Participants shadow the neutral passages whilst ignoring the input from the other channel. The authors found that individuals with generalized anxiety states (relative to control participants) display diminished reaction time performance when simultaneously exposed to unattended threatening words. Altogether then, in the emotional Stroop paradigm threatening information usually leads to increased interference in high anxious participants regardless of awareness.

## Theoretical approaches to attention, threat and individual differences

A number of models have attempted to account for the above findings of attention to threat. For example, Mathews et al. (1997) maintain that anxious individuals, regardless of awareness, are more vigilant to threat compared to non-anxious individuals. Their model suggests that the effects of anxiety on threat processing are particularly salient for mild threat cues. This is because for anxious individuals mild threat cues usually exceed a threshold demanding processing resources (not so for their non-anxious counterparts) and will therefore affect their performance (Mathews et al., 1997). Severe threat cues, as the authors propose, are likely to exceed the threshold in both anxious and non-anxious individuals. Hence, according to the model, the distinguishing feature between these groups is the threshold at which the shift to attentional vigilance arises. To a certain degree, as the researchers note, this interference ensuing from the passing of the threshold can be opposed by voluntary effort (task demand) where the target representation is strengthened and the threat representation or emotional distraction minimized. Therefore, interference/attentional bias is a function of the competition between voluntary effort and the threat representation and is manifested only when the threat representation prevails. Behaviourally, the attentional bias in anxious individuals is revealed by either (comparably) faster performance or slower performance, depending on whether attention to threat facilitates identification of the target or whether the experiment requires ignoring threatening stimuli, respectively (Mathews & Mackintosh, 1998), indicating automatic attentional capture of threat in anxious populations. According to the model, such effects on the speed of responding are not expected in non-anxious individuals, as, here, voluntary effort/task demand should counter activation of the threat representation, thereby allowing successful performance. Another feature of the model is that it proposes that attentional bias in anxiety is only found when there is competition between two or more cues (or stimulus attributes), but not when only one cue is displayed, owing to the fact that a sufficient amount of activation to capture attention is consistently produced by one cue. With two or more cues, some being threatening (e.g. distracters) and some being neutral (e.g. task-related), an adequate amount of inhibition of the threat representation is needed in order to block attentional capture thereof, thus ensuring efficient processing of the target (Mathews & Mackintosh, 1998). It is this inhibitory mechanism, the authors argue, that seems to be deficient in anxious individuals (see figure 1 for a graphical representation of the model).

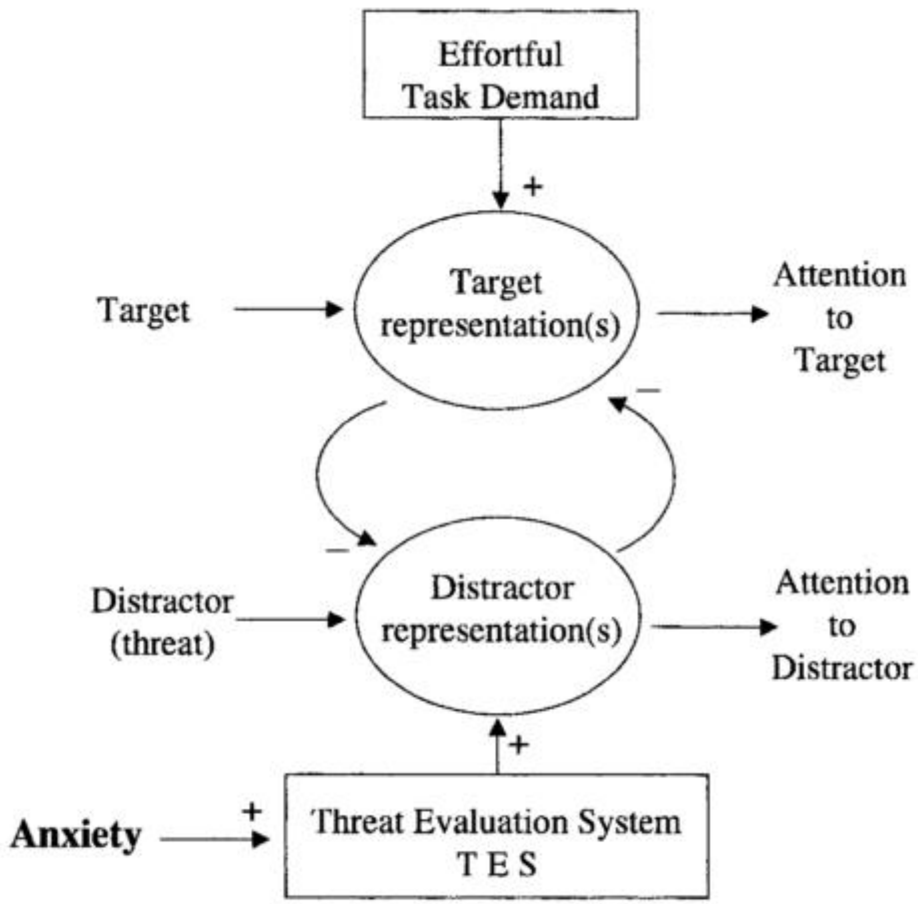


**Figure 1**: The Mathews and Mackintosh model of biased processing in anxiety (adapted from Mathews & Mackintosh, 1998)

Bishop (2007) set out to further integrate the Mathews and Mackintosh model (Mathews et al., 1997; Mathews & Mackintosh, 1998) with recent findings from the neuroimaging literature (see figure 2 for a graphical illustration of the model). The author's main proposition is that a common amygdala-prefrontal network directs attention to threat, with the lateral prefrontal cortex (LPFC) exerting top-down control and the rostral anterior cingulate cortex (ACC) channelling competition from threat distractors. Indeed, Bishop (2007) argues that the interaction between the amygdala and prefrontal areas forms the basis for attentional bias to threat whereby amygdala output affects prefrontal top-down control and prefrontal recruitment, in turn, reduces amygdala activity. The model also posits that this prefrontal-amygdala connection is modulated by individual differences, except at the early stage of perceptual competition where processing is amenable to manipulations of task load (Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). So, (1) hyper-responsitivity of the amygdala coupled with (2) hypo-activity of the prefrontal cortex are considered key features of anxiety (Bishop, 2007). The cognitive equivalent of this process in anxiety, as the author maintains, would be an enhanced threat representation (1) along with diminished voluntary control (2). An extension of the model further asserts that trait anxiety mainly affects the prefrontal regions and state anxiety the amygdala. In sum, anxious individuals, irrespective of awareness, are markedly more vigilant to threat than controls. This tendency is particularly noticeable with mild threat cues and is usually found under competition between two or more stimuli. To some extent the attentional bias can be countered with voluntary effort (task demand), however. Such cognitive processes are represented in an interacting prefrontal-amygdala network, with prefrontal activation (e.g. via LPFC and ACC) enacting top-down control on the amygdala and the amygdala generating outputs modulating the prefrontal system – a mechanism that might be impaired in anxiety.

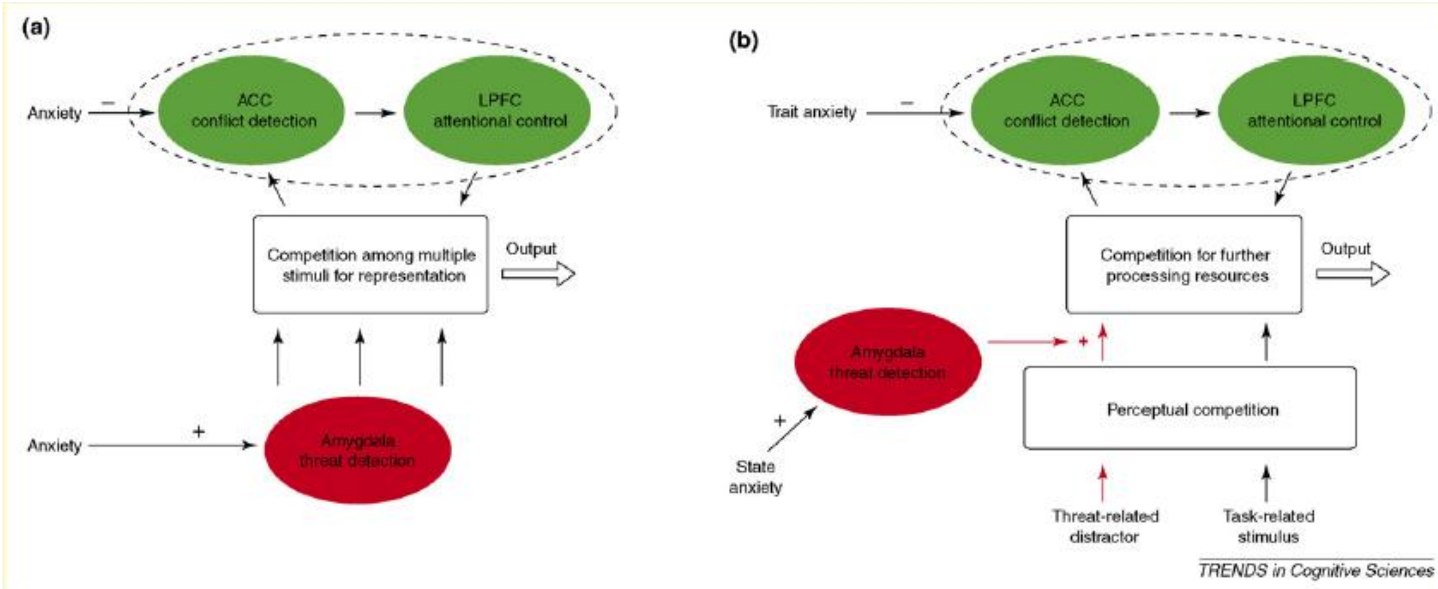


**Figure 2**: Depiction of a neurocognitive model of threat in anxiety (adapted from Bishop, 2007)

The Dual competition model and cognitive control of threat

*The Dual competition model*

A related framework, the dual competition model (see figure 3), was proposed by Pessoa (2009) in the domain of cognitive control. He defined cognitive control as "[involving] a host of 'adjustment processes', including perceptual selection, detection and resolution of conflict, and maintenance of contextual information." (p. 160). According to Miyake et al. (2000), cognitive control consists of three mechanisms, namely "shifting between tasks or mental sets" (shifting), "updating and monitoring of working memory representations" (updating) and "inhibition of dominant or prepotent responses" (inhibition) (p. 54). Shifting, as these researchers note, is assessed by tasks such as the Number-letter, Local-global and other switching-related tasks. In the Number-letter task a number-letter pair (e.g. 8M) is shown in one of four squares displayed on the screen. Depending on whether the pair is presented in one of the top squares or one of the bottom squares, participants need to engage in a different decision (top squares: "is the number odd or even?"; bottom squares: "is the letter a consonant or a vowel?"). In the first two blocks of the experiment the pairs are either presented in the top or bottom squares, with the spatial placement (top or bottom) alternating between the two blocks, but not within any one of these. The third block, in turn, includes placement in both parts (top and bottom), thereby involving a shift between the two decision types across trials. The shift cost can then be computed as the difference in mean response latencies from those trials, in block 3, involving a mental shift in decision type versus the equivalent trials, in blocks 1 and 2, not involving a shift.

A similar type of process is recruited in the Local-global paradigm. Here, participants are presented with different shapes, such as a square whose lines consist of smaller triangles. The task involves either a decision about the global features of the stimulus (here: square) or the local features (here: triangle). The focus (global versus local) is switched across trials, allowing one to calculate the shift cost by taking the difference in RT of those trials where the focus was identical to the previous one (no shift trials) versus those where it was different (shift trials).

Updating, according to the authors, can be tested by the Keep track, Tone monitoring and other working memory related tasks. In the Keep track paradigm the words from multiple categories are serially presented. Participants are instructed to remember the last word of each category that was shown in any one trial sequence (the word-category membership is made explicit to participants at the beginning). This allows one to obtain the proportion of correct recall as the dependent measure. In the Tone monitoring paradigm, in turn, tones of different pitches (high, medium, low) are played, with participants having to identify the $4^{th}$ tone of a particular pitch presented during the trial sequence. For example, participants would need to respond as soon as the $4^{th}$ high-pitched tone was presented, regardless of the count for the other pitches. The proportion correct was also the measure of interest here.

Lastly, inhibition can be investigated using Stroop, Stop signal or Flanker tasks, amongst others (Friedman & Miyake, 2004; Miyake et al., 2000). The Stop signal paradigm, on the one hand side, is a binary choice task where participants respond on the majority of trials, thereby developing a prepotent response (= go trials). However, they are instructed to withhold their button press on the rare occasion that a stop signal (e.g. an auditory signal) is presented on a trial (= stop signal trial). Stop signals are presented at variable delays following the onset of the go-signal and hence a response that is about to be executed (go-signal) needs to be restrained (stop signal) (Rubia et al., 2001). The stop signal task therefore taps into a comparatively later inhibition phase than, for example, the go/no-go task where the stimuli themselves are directly associated with stopping or going responses, a process that has been referred to as selective motor response inhibition (Rubia et al., 2001; Wöstmann et al., 2013). It is also noteworthy that the stop signal represents an additional cue requiring attention; stop signal performance is thus likely to involve detection of a task-relevant cue (Hampshire, Chamberlain, Monti, Duncan, & Owen, 2010). Indeed, whilst motor inhibition has generally been assumed as a key process in response inhibition (Verbruggen & Logan, 2008), recent work suggests that context-monitoring, a construct concerned with the detection and interpretation of the stop signal, may constitute this role in response inhibition (Chatham et al., 2012; Hampshire et al., 2010). Altogether then, the stop signal task yields an executive response (RT on go trials, i.e. go RT or Choice Reaction Time, CRT) as well as a measure of response inhibition on stop signal trials, referred to as Stop Signal Reaction Time (SSRT; see Chapter 5 for further details). This is similar to the colour word Stroop paradigm in the sense that this task (= Stroop) also involves an executive response on each trial (button press), whilst at the same time involving active cognitive (i.e. not directly motor – see below) suppression of a prepotent response (word reading) (Friedman & Miyake, 2004). It should be noted that whilst the word reading process can also be considered a distracting cue in the Stroop task (Nigg, 2000), the underlying process of this cue is dominant (MacLeod, 1991), thereby mapping onto a prepotent response process (Friedman & Miyake, 2004). In the Flanker task, on the other hand side, participants typically identify a target letter that is flanked by compatible (same response category) or incompatible (different response category) letters that need to be ignored. A similar principle applies to other stimulus types that are used in modifications of this task (e.g. emotional faces in an affective Flanker paradigm) – here targets and flankers can also be compatible or incompatible on the dimension of interest, such as valence. In general, response latencies on compatible trials are faster compared to incompatible ones in the Flanker task. It has been argued that Flanker tasks tap into processes of executive control, by virtue of having to execute a response on each trial, as well as into processes of focussed attention towards target cues or selective enhancement thereof (Friedman & Miyake, 2004). Others have proposed that Flanker tasks also involve cognitive inhibition of distracter cues (see below for a distinction from motor response inhibition) as well as response competition in that target and distracter cues map onto different response options on incompatible trials (Eriksen & Eriksen, 1974). It seems reasonable to assume that the Stroop task entails similar processes in that participants also need to focus their attention on a target cue, which may be selectively enhanced, respectively in the Stroop task a task-irrelevant distracter cue, same as in the Flanker task, also interferes with the task-relevant cue (target; MacLeod, 1991). To clarify, some researchers conceptually distinguish motor response inhibition paradigms (e.g. go/no-go and stop signal tasks) from interference inhibition paradigms (e.g. Simon, Flanker and Stroop tasks) (Hart, Radua, Nakao, Mataix-Cols, & Rubia, 2013; Wöstmann et al., 2013). One of the fundamental differences between these tasks is that the former predominantly and explicitly elicit motor response inhibition, whereas the latter focus on cognitive inhibition, that is inhibition of distraction and conflict detection (Chambers, Garavan, & Bellgrove, 2009; Hart et al., 2013; Nigg, 2000). Specifically, interference inhibition tasks require the inhibition of conflicting cues, which may interfere with performance to the target cue, such as prompting an incorrect motor response or creating informational conflict, only when inhibition fails (Hart et al., 2013; Kalanthroff, Goldfarb, & Henik, 2013; Nee, Wager, & Jonides, 2007; Nigg, 2000). Thus, in motor response inhibition paradigms motor suppression forms an intrinsic part of the task instructions, whereas in interference inhibition paradigms an incorrect motor response may only occur when participants fail to adhere to the task instruction of ignoring the distracting cue. Another difference between interference inhibition versus motor response inhibition tasks is that in the former the measure of interest (interference) is recorded on executive trials, whereas the key inhibitory measure of the latter tasks (response inhibition) is measured on non-executive (i.e. stop signal or no-go) trials.

In light of these distinctions, there has been behavioural and neural evidence, suggesting that these different task types show some unique features (Brydges et al., 2012; Herba, Tranah, & Rubia, 2010; Nee et al., 2007), although several studies also point to strong functional overlap between these (Stop-signal, Stroop, Flanker) tasks (Aichert et al., 2012; Friedman & Miyake, 2004; Miyake et al., 2000; Miyake & Friedman, 2012; Verbruggen, Liefooghe, Notebaert, & Vandierendonck, 2005; Verbruggen, Liefooghe, & Vandierendonck, 2006; Wager et al., 2005). This evidence is not necessarily contradictory though as the different tasks may well overlap with regard to one mechanism (e.g. response selection), whilst they may differentially recruit other processes (e.g. attentional selection) (Nee et al., 2007). Indeed, linking this back to the broader concept of cognitive control, research has shown that the three constructs of shifting, updating and inhibition are moderately associated, whilst also exhibiting evidence of some independence, suggesting that the concept of cognitive control embodies both commonalities as well as separabilities between its sub-functions (Miyake et al., 2000). This proposal (unity and diversity of cognitive control) also seems to be in line with recent experimental and neurobiological findings (Miyake & Friedman, 2012; Munakata et al., 2011; Verbruggen, Liefooghe, & Vandierendonck, 2004). It has therefore been put forward that these mechanisms of cognitive control are interacting and linked to a common resource pool, whereby if one function is recruited it will also reduce the resources available for the other functions (Pessoa, 2009). Moreover, according to the dual competition model, high threats[1] impact on specific cognitive control functions (e.g. inhibition) as well as on the general resource pool to ensure prioritized and efficient processing of the item. This often entails the drawback of diminished behavioural performance, particularly when the threat cue is task-irrelevant (Pessoa, 2009). The model also posits that such effects are not observed for low threats, which generally do not recruit the common resources and, especially when task-relevant, lead to faster performance. Individual differences, as the author points out, are assumed to play a further modulatory role such that (1) cognitive control functions relevant for the task are adjusted accordingly or (2) the distribution of common-pool resources is potentially altered, which, in turn, has an effect on the remaining cognitive control resources. Taken together, cognitive control can be subdivided into mechanisms of inhibition, shifting and updating. These processes interact and share a common resource pool. High (but not low) threat can affect the specific mechanisms of cognitive control

[1] Whilst Mathews and Mackintosh (1998) refer to high threat in terms of immediate danger (e.g. reaching for a snake), Pessoa (2009) is less explicit about his definition of this term. It can, however, be inferred from the evidence that he discusses (e.g. Frederick Verbruggen & De Houwer, 2007) that, according to his understanding, high threat can be elicited with stimulus content, such as pictures. Hence, it seems that what Pessoa (2009) refers to as high threat cues would be described as to mild threat cues in the Mathews and Mackintosh (1998) model.

and the common resources, with individual differences serving an additional modulatory function.

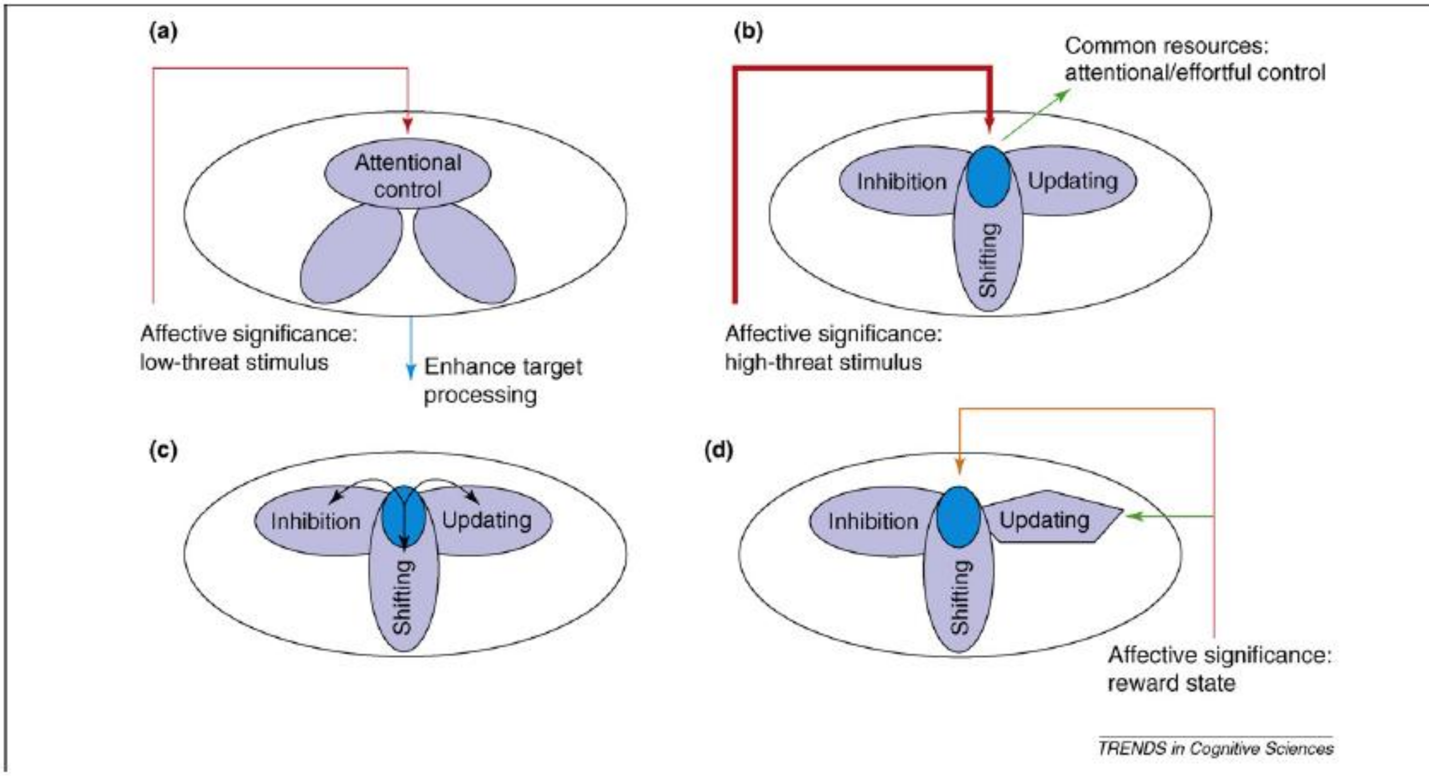


**Figure 3**: Dual competition model illustrating the impact of stimulus-driven and state-dependent effects on cognitive control (grey circles) and the common resource pool (blue circle). Thick (thin) arrow denotes stimuli of elevated (lower/state) threat levels (adapted from Pessoa, 2009).

*Emotion and cognitive control*

There is now an emerging body of research on the relation between cognitive control and emotion. Most of this work has focussed on the broad inhibition mechanism of cognitive control. For example, presenting positive, negative and neutral schematic faces in an affective Flanker task, Fenske and Eastwood (2003) found greater flanker interference effects when the target face was positive (compared to negative or neutral targets), supporting the notion that the detrimental effects of negative information on performance are particularly likely to occur when it is task-irrelevant (see e.g. Mathews & Mackintosh, 1998; Mathews et al., 1997). Stenberg et al. (1998), using an affective word-face Stroop paradigm, reported interference effects across a number of different distractor emotions, showing that response latencies on incompatible trials-types were usually slower than those for compatible ones, regardless of whether the target was positive or negative. Moreover, an affective stop-signal task where emotional images preceded the target stimuli revealed that response and stop latencies were slowed as a function of the high arousal content, but not the valence (positive, negative) of the images (Frederick Verbruggen & De Houwer, 2007). Hare, Tottenham, Davidson, Glover, and Casey (2005), however, revealed an effect of valence in an emotional Go/ NoGo task when affective items functioned as targets. The Go/NoGo paradigm is a binary choice task where usually one stimulus type, occurring fairly frequently, is associated with a button press (target; Go trial), whereas another, occurring rarely, requires participants to withhold their response (nontarget; NoGo trial). This design yields two main outcome measures of interest: response latencies (on Go trials) and proportion of false alarms (on NoGo trials). In their study, Hare and colleagues (Hare et al., 2005) used fearful, happy and neutral face images across a set of different tasks. Each task involved fearful cues as either target or nontarget paired with one of the other expressions. The researchers demonstrated that response latencies to fearful faces were slower than comparison stimuli (i.e. happy and neutral), but participants were less accurate at inhibiting responses for happy items, an effect that can also be modulated by individual differences (e.g. Ladouceur et al., 2006). All in all, these findings suggest that emotion tends to affect the inhibition component of cognitive control. Such effects are also obtained when emotion is task-irrelevant in some scenarios (e.g. in affective Stroop and Flanker tasks), although interference from emotional valence can be reduced when this information temporally precedes the target.

Some evidence has also been put forward regarding emotion and the updating and shifting components of cognitive control. The updating component, as described above, is linked to the direct manipulation of content in working memory, as opposed to the mere storage of information (Miyake et al., 2000). The literature on emotion and the updating component is relatively sparse. However, a study by Schweizer and Dalgleish (2011), which combined emotional material with a working memory task, might shed some initial light on this. Using a novel emotional working memory capacity (eWMC) task where participants with lifetime history of posttraumatic stress disorder (PTSD) and a comparison group were instructed to remember neutral words whilst at the same time processing trauma-related (versus neutral) sentences, Schweizer and Dalgleish (2011) found that eWMC performance of the PTSD cohort was impaired for trauma-related sentences and that generally this group exhibited poorer eWMC relative to the controls. Still, more direct and numerous measures of emotion and updating are needed. In an affective Internal Shift Task (De Lissnyder et al., 2012), depressed individuals (versus controls) displayed diminished shifting performance, something that was unaffected by emotional information. In this task, which is a measure tapping into both shifting and updating components, emotional faces (angry versus neutral) of both genders are presented. In one block participants focus on the gender dimension of the faces, counting male versus female images; in another block the focus is on the emotion dimension where angry versus neutral expressions need to be counted. On each trial, response latencies are recorded via a simple button press, once the mental count has been updated by participants for that stimulus. At the end of a block participants report their mental counts for each stimulus category. This design allows computation of switch costs (shifting performance), which constitute the difference in RT of switch vs. no-switch trials within a block. In switch trials, the category to be counted differs from that of the previous trial (e.g. target trial (n) = male face; previous trial (n-1) = female face), whereas in no-switch trials it is identical (e.g. target trial (n) = male face; previous trial (n-1) = male face).

The findings by De Lissnyder and colleagues (De Lissnyder et al., 2012) were corroborated by De Lissnyder, Koster, Derakshan and De Raedt (2010) whose Affective Shift Task, again, yielded no effects of valence on switch cost, but instead showed effects of valence for inhibition. In their task, arrays of four faces were presented. The faces varied along the dimensions of emotion (angry vs. happy), gender (male vs. female) and colour (light grey vs. dark grey). Participants needed to determine which of the four faces differed from the others on a particular dimension (emotion, gender or colour), with participants being informed of the task-relevant dimension prior to each trial. Based on RT performance, the authors computed measures of inhibition and of set-shifting cost. Inhibition scores were obtained by taking the difference between inhibitory versus control trials. Inhibitory trials signified those trials where the stimulus dimension of the target trial (n) differed from that of the previous trial (n-1), but was identical to the dimension two trials preceding (n-2) (e.g. gender – emotion – gender). In control trials the stimulus dimensions of the two preceding trials (n-1 and n-2) were different from that of the target trial as well as from each other (e.g. colour – emotion – gender). Thus, both inhibitory and control trials (both trial n) followed two set-shifts. However, on inhibitory trials a previously inhibited dimension (in the example above: gender in trial n-2) becomes activated again, whereas in control trials another dimension, compared to that of the two preceding trials, is presented. Set-shifting cost (also: switch cost), in turn, reflects the time needed to respond on non-inhibitory trials where the stimulus dimension differs from that of the preceding trial (e.g. switch from colour to emotion) relative to repeat trials where the stimulus dimensions are the same on two consecutive trials (e.g. emotion – emotion).

Altogether, these findings clearly show that emotion generally affects performance on cognitive control tasks, indicating that it may impact on a common resource pool, as hypothesized by (Pessoa, 2009). This conclusion is also in line with research on event-related potentials. This work indicates that threatening or affective information increases one event related potential (ERP) component, occurring ~ 400-600ms post stimulus onset, the late positive potential (LPP), suggesting greater consumption of resources (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Flaisch, Stockburger, & Schupp, 2008; MacNamara, Ferri, & Hajcak, 2011; Schupp et al., 2004; Weinberg & Hajcak, 2010, 2011; see Hajcak, MacNamara, & Olvet, 2010; Schupp, Flaisch, Stockburger, & Junghöfer, 2006 for reviews). For the shifting component, valence, to the author's knowledge, has not yet been demonstrated to modulate task performance, but this can partly be explained by the fact that existing affective task-switching paradigms have exerted a high task demand on participants by involving several cognitive control mechanisms in the same task (shifting and updating: De Lissnyder et al. (2012); shifting and inhibition: De Lissnyder et al. (2010)). Such an increased task demand might have, according to the Mathews and Mackintosh model (Mathews & Mackintosh, 1998; Mathews et al., 1997), diminished potential effects of valence on shifting by inhibiting the input from the threat evaluation system.

Measures of individual differences in anxiety and related emotional traits

*Neuroticism as a measure of threat processing*

Individual differences in attentional bias to threat have been linked to trait anxiety as indexed by the STAI-T (Spielberger, Gorsuch, & Lushene, 1970; Spielberger, 1983), and to anxiety disorders (Bishop, 2007; Mathews & Mackintosh, 1998; Mathews et al., 1997; see also evidence discussed above). However, although several studies have not found attentional bias to threat or negative stimuli in other emotional disorders (Gilboa & Gotlib, 1997; Karparova, Kersting, & Suslow, 2005; E. Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2005; Mogg, Bradley, Williams, & Mathews, 1993; Wisco, Treat, & Hollingworth, 2012; for a review see Mathews & MacLeod, 2005), there is now emerging evidence that there is in fact a link between attentional bias and such disorders, including unipolar depression and bipolar disorder (B. P. Bradley, Mogg, & Lee, 1997; Caseras, Garner, Bradley, & Mogg, 2007; Donaldson, Lam, & Mathews, 2007; Eizenman et al., 2003; Gotlib, Krasnoperova, Yue, & Joormann, 2004; Joormann & Gotlib, 2007; Leyman, De Raedt, Schacht, & Koster, 2007; Leyman, Raedt, & Koster, 2009; Rinck & Becker, 2005), only that this effect may not be evident for all features of selective attention and may depend on the type of threat (Joormann & Siemer, 2011). This suggests that these disorders (i.e. anxiety and other emotional disorders) are linked as part of a coherent internalizing spectrum, with neuroticism as the temperamental core of such disorders (Griffith et al., 2010; see also the so-called 'Tripartite' model for a similar proposition Clark & Watson, 1991; Clark, Watson, & Mineka, 1994). Indeed, this idea is further supported by a study showing that neuroticism or negative affectivity, rather than anxiety or depression, predicts an initial attentional bias for angry faces (Oehlberg, Revelle, & Mineka, 2012). Such findings are also in line with the profile of neuroticism, whereby this trait’s principal manifestations are a sensitivity to threat, punishment and negative affect (DeYoung, Quilty, & Peterson, 2007; DeYoung, 2010a, 2010b). Moreover, one of the principal instruments to measure anxiety in research of attentional bias to threat, the trait version of the State-Trait Anxiety Inventory (STAI-T; Spielberger et al., 1970; Spielberger, 1983), may not be a reflection of trait anxiety but, instead, of negative affect (Bados, Gómez-Benito, & Balaguer, 2010). Watson and Clark (1984) put forward a similar argument, suggesting that both trait anxiety and neuroticism constitute features of the same overarching trait: negative affectivity. One conclusion emerging from these findings then is that individual variation in the overarching trait of neuroticism may be particularly relevant for understanding individual variation in attention to threat.

*Measures of neuroticism*

The main scales for neuroticism (as a personality trait), include the NEO (labelled such as it was developed for the investigation of the three dimensions of Neuroticism, Extraversion and Openness to experience; Costa & McCrae, 1985, 1992), Trait Descriptive Adjectives (Goldberg, 1992) and the Big Five Inventory (BFI; Benet-Martinez & John, 1998; John, Donahue, & Kentle, 1991). These scales possess impressive reliability, convergent validity and discriminant validity (John, Naumann, & Soto, 2008), thereby avoiding some of the shortcomings of the STAI-T scale. John et al. (2008) recommend the Revised NEO Personality Inventory (NEO PI-R) measure for use when there is sufficient testing time, participants are educated and the subject of investigation are the facets of the Big Five. In all other cases, they argue, the BFI-44 might be preferable. In general then, it can be said that, based on the validity and reliability of the scales as well as its content (sensitivity to threat), neuroticism constitutes a suitable measure for the exploration of individual differences concerning negative affect and threat.

*Neuroticism: behavioural (threat processing) and clinical findings*

Given this profile it does not come as a surprise that neuroticism, like trait anxiety, has been associated with enhanced threat processing (Leikas & Lindeman, 2009; Reynaud, El Khoury-Malhame, Rossier, Blin, & Khalfa, 2012; Tamir, Robinson, & Solberg, 2006; Wilson, Kumari, Gray, & Corr, 2000) and, in line with the Tripartite Model (Clark & Watson, 1991; Clark et al., 1994; see also Griffith et al., 2010) amongst others, with a number of emotional disorders (see also Bienvenu & Brandes, 2005; Brandes & Bienvenu, 2006). The Tripartite Model (Clark et al., 1994; Clark & Watson, 1991) stipulates that neuroticism is a core feature underlying both anxiety and depression. So, to distinguish these disorders, according to this model, further features need to be considered: anhedonia (specific to depression) and physiological hyperarousal (specific to anxiety). Studies that have directly linked neuroticism to threat processing have shown that threatening information evokes elevated startle reactions, as measured by eye-blink amplitude (Wilson et al., 2000), skin conductance responses (an index of peripheral physiological arousal) and expressive activity (e.g. in the corrugator supercilii muscle, which controls the frowning response) in high trait neuroticism (Reynaud et al., 2012). Moreover, in high (relative to low) trait neuroticism speeded threat identification is related to lower negative affect (Tamir et al., 2006), whereas the interaction between neuroticism and threat identification predicts negative recall bias (Leikas & Lindeman, 2009).

As for the relationship between neuroticism and emotional disorders, research suggests, for instance, that neuroticism is linked to the symptomatology of depression (Farmer et al., 2002; Saklofske, Kelly, & Janzen, 1995) and vulnerability to depression (Saklofske et al., 1995; but see Farmer et al., 2002). Genetic data further show that there is substantial overlap between the factors affecting genetic variation in trait neuroticism and those relating to the symptoms of anxiety and depression (Jardine, Martin, & Henderson, 1984). Overall, it can be concluded that neuroticism is a trait related to affective disorders, to enhanced responding to threat and is characterised by affective dysregulation. These topics and the links between them are explored in this thesis.

## Neuroticism and cognitive control: behavioural and neural evidence

### *Neuroticism and behavioural studies*

There is also evidence of an association between neuroticism and cognitive control (Haas, Omura, Constable, & Canli, 2007; Helode, 1982; Paelecke, Paelecke-Habermann, & Borkenau, 2012; Robinson & Tamir, 2005). Work with early adolescent males, for instance, revealed a positive correlation between neuroticism and the interference effect of a modified colour-word Stroop task (Helode, 1982). Moreover, increased attentional blink magnitude was found in individuals with high levels of neuroticism (Bredemeier, Berenbaum, Most, & Simons, 2011). A link between stop signal reaction time (SSRT), a measure of response inhibition, and impulsivity, which – amongst others – is related to neuroticism (see DeYoung, 2010c), was established by Logan, Schachar and Tannock (1997). However, other studies have yielded no significant relationship between neuroticism and cognitive control (Olvet & Hajcak, 2012) or attentional bias tasks (Chan, Goodwin, & Harmer, 2007). Nonetheless, in a series of affective and non-affective reaction time (RT) experiments, including two cognitive control paradigms (Stroop and Go/No-Go tasks), Robinson and Tamir (2005) showed that neuroticism correlated with virtually all of their RT measures, but only when these represented intra-individual variability (as in RT standard deviations; RT SDs) rather than mean RTs. This led to the formulation of the mental noise hypothesis, which stipulates that elevated levels of neuroticism are linked with increased intra-individual variability in RT performance, as measured by RT SDs. By contrast, administering a vocal emotional Stroop task, an emotional word Stroop task where participants vocalise their response choices, Paelecke et al. (2012) found that neuroticism did correlate with mean RTs, but only when cognitive load was high. Finally, behavioural and neuroimaging findings by Haas et al. (2007) also suggest that neuroticism and cognitive control are overlapping. An emotional Word-Face Stroop task exhibited a positive association between the anxiety facet of neuroticism and incompatible trial-types, equivalent correlations with the depression facet or neuroticsm did not reach significance nor did any of these correlations with a Stroop cost measure (Haas et al., 2007). A similar pattern emerged in this study for correlations between the amygdala and the subgenual anterior cingulate whereby during high conflict trials these regions were positively associated with neuroticism and with the anxiety facet of neuroticism in particular. The findings pertaining to the relationship between neuroticism and cognitive control are therefore mixed. Whilst some studies have found a straightforward link between these variables, others have not and it seems that intra-individual variability of performance (RT SDs) and cognitive load play a role in some contexts. It is noteworthy, however, that most studies of cognitive control that involved affective stimuli did report an association, suggesting that the affective nature of a task may contribute to the association. This idea would also be in line with several accounts of neuroticism that emphasize its specific sensitivity to threat and negative affect (DeYoung et al., 2007; DeYoung, 2010a, 2010b). It is important to attempt to separate out the effects of neuroticism on basic negative affect sensitivity and cognitive control, which is one aim of this thesis. Specifically, I will examine this using affective cognitive control tasks where emotion is task-relevant versus task-irrelevant and correlating the resulting scores from these tasks with neuroticism.

*Neuroticism and neurotransmitters*

The relationship between neuroticism and intra-individual performance variability or mental noise, as this is also termed, has found additional support in research on neurotransmitters. Specifically, there have been suggestions that a decrease in γ-amino butyric acid (GABA) transmission between cells in the dorso-lateral prefrontal cortex (dlPFC), as manipulated by micro-injection of $GABA_A$ antagonists, is linked to within-subject variability in performance (Pouget, Wattiez, Rivaud-Péchoux, & Gaymard, 2009). Such variability has, as discussed above, also been associated with neuroticism, whereby high trait neuroticism is marked by a greater intra-individual variability in performance (mental noise; Flehmig, Steinborn, Langner, & Westhoff, 2007; Robinson & Tamir, 2005), indicating that trait neuroticism may be correlated with the inhibitory neurotransmitter GABA. This hypothesized association between GABA and neuroticism has been further affirmed in a recent Magnetic Resonance Spectroscopy (MRS) study. Boy et al. (2011) found that the concentration of GABA in the dlPFC, as measured by MRS, was negatively associated with variation in trait urgency, which is a facet of neuroticism (DeYoung, 2010c). Furthermore, various genetic and neuroscientific studies have implicated GABA in neuroticism and emotional disorders (Aleksandrova, Souza, & Bagby, 2012; Crestani et al., 1999; Glue, Wilson, Coupland, Ball, & Nutt, 1995; Liu et al., 2007; Sanders & Shekhar, 1995; Sen et al., 2004; but see Monteleone, Maj, Iovino, & Steardo, 1990; for reviews see Cryan & Kaupmann, 2005; Kalueff & Nutt, 2007). Other work has also proposed links between neuroticism and serotonin transporter (Sen et al., 2004), glutamic acid decarboxylase (GAD) 1 (Hettema et al., 2006) and cannabinoid variants (Aleksandrova et al., 2012). Particularly the finding of an association between GAD enzymes and neuroticism is quite relevant here. GAD enzymes synthesize GABA from glutamate, and so variation in GAD genes is theoretically connected to the proposed relationship between GABA and neuroticism. Altogether, these findings lend support to the idea that there is a relationship between mental noise/GABA concentration (e.g. in the dlPFC) and neuroticism.

*Neuroticism and evidence from neuroimaging*

Neuroimaging studies have also yielded promising links. Here, during affective behavioural tasks, structural scans or rest, associations between neuroticism and a variety of brain regions have been demonstrated, including in the amygdala (Haas et al., 2007; Harenski, Kim, & Hamann, 2009), anterior cingulate (Chan, Harmer, Goodwin, & Norbury, 2008; Haas et al., 2007), insula (Deckersbach et al., 2006; Feinstein, Stein, & Paulus, 2006), cerebellum (Schutter, Koolschijn, Peper, & Crone, 2012), right superior parietal cortex (Chan et al., 2008), medial prefrontal cortex (Haas, Constable, & Canli, 2008; Kim, Hwang, Park, & Kim, 2008) and the dorsolateral prefrontal cortex (Harenski et al., 2009). In particular, the prefrontal and amygdala involvement of neuroticism attests to its role in threat detection or emotion generation and overlaps with attentional control (disengagement from threat) and emotion regulation (e.g. attentional avoidance), which are known to recruit the similar areas (Cisler & Koster, 2010; Ochsner & Gross, 2007). Additional support for this interpretation comes from work showing that emotion regulation has also directly been connected with neuroticism, whereby neuroticism tends to lead to worse regulatory efforts (Gross, 2008; John & Gross, 2007). A longitudinal study by Kokkonen and Pulkkinen (2001) also demonstrated that neuroticism predicted increased use of emotional ambivalence, a form of emotion dysregulation, and decreased use of repair, a beneficial regulatory strategy. Overall, these findings show that whilst the link between neuroticism and cognitive control has not always been consistent at a behavioural level, it is possible that this inconsistency can be explained by intra-individual variability (mental noise), cognitive load or the affective nature of the tasks. Furthermore, neural findings suggest that similar regions are recruited for neuroticism, emotion regulation and attentional control/attentional bias, lending support to the idea that these constructs overlap to a certain extent.

## Mechanisms of emotion regulation

### *The process model of emotion*

The relationship between neuroticism and emotion (dys)regulation has been a recurring theme in the literature. Emotion regulation denotes the ability to regulate which emotion to feel, when an emotion is initiated and what the nature of the emotional experience or expression is (Gross, 1998a). The process model of emotion (Gross, 1998b; see figure 4) has proposed that emotion regulation can usefully be divided into different temporal stages. At a broad level, the model maintains that emotion regulation is manifested in modulating either the incoming information to the system (*antecedent-focussed* emotion regulation) or the outgoing information (*response-focussed* emotion regulation). These two stages, according to the model, each consist of several sub-processes. On the one hand, response-focussed emotion regulation involves a variety of approaches that shorten, extend, increase, or decrease the emotional experience, expression or physiological functioning (e.g. suppression; Gross, 1998b). On the other hand, according to the model, antecedent-focussed emotion regulation involves strategies such as situation selection (i.e. engaging (or not) with people or in situations dependent on their potential emotional influence), situation modification (i.e. changing a situation in order to adjust its emotional impact), attention deployment (i.e. choosing to attend or not attend something with the goal of modulating one's emotions), and cognitive change (i.e. modulating the emotional impact by reinterpreting one's environment or one's ability to cope with the environment, e.g. reappraisal).

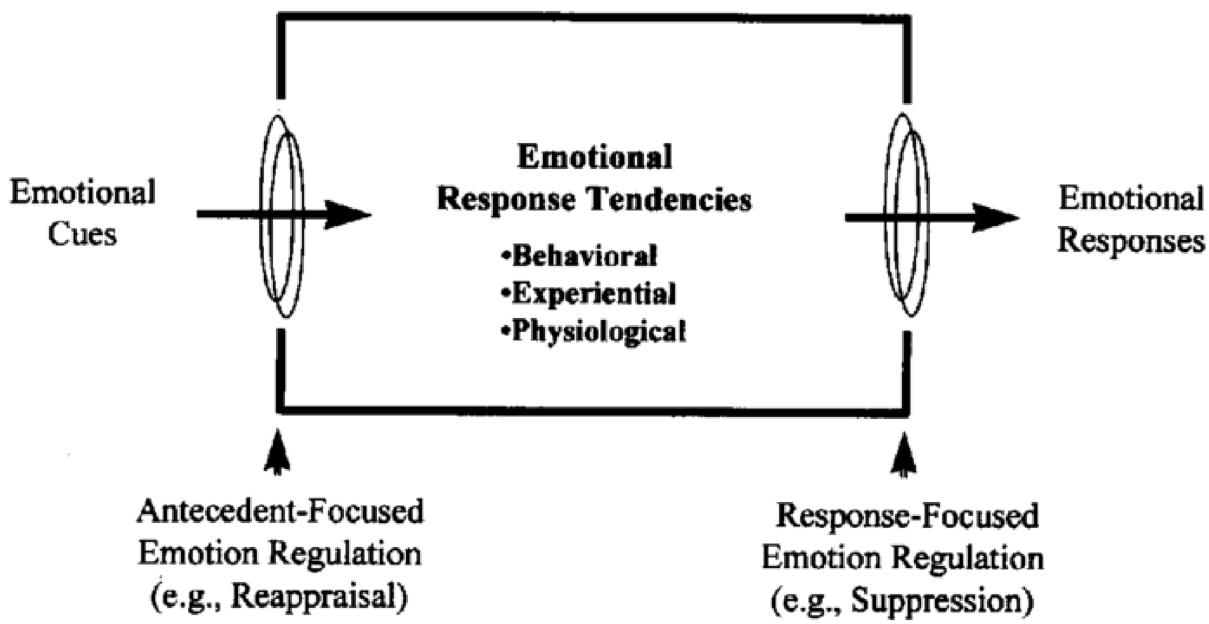


**Figure 4**: Process model of emotion (adapted from Gross, 1998b)

*Emotion regulation outcomes*

Although a plethora of emotion regulation strategies exists (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Garnefski, Kraaij, & Spinhoven, 2001), reappraisal and suppression are certainly amongst the more prominent ones in research (Gross, 2002), possibly due to their contrasting outcomes. Reappraisal is an adaptive strategy of emotion regulation (Gross, 2002), which, in the form of cognitive restructuring, also constitutes a key component of Cognitive Behavioural Therapy (Beck, Rush, Shaw, & Emery, 1979). Early findings have established that instructed reappraisal is effective in regulating negative emotion by decreasing the subjective emotional experience as well as the overt expression of emotion whilst maintaining physiological indices at baseline level (Gross, 1998b). By contrast, instructed suppression, that is the inhibition of emotional expressions, is often seen as a maladaptive regulatory strategy (Gross, 2002). It leads to increases in sympathetic recordings, decreases in expressive behaviour, but, crucially, not to changes in emotional experience, as Gross (1998) shows. More recent findings have corroborated this beneficial role of reappraisal (but see work by Sheppes and colleagues (Sheppes, Catran, & Meiran, 2009; Sheppes & Meiran, 2007, 2008) who maintain that the onset time of reappraisal affects the regulatory success). Following a reappraisal manipulation, Jamieson, Nock and Mendes (2011) have reported ameliorated cardiovascular responses to arousal in a stressful situation and a diminished attentional bias, as measured by an emotional word stroop task involving threatening and control words. Typically in studies of reappraisal/ emotion regulation participants are confronted with multiple negative (or positive) emotional scenes or movie sequences. Their task is to re-interpret the emotional situation (e.g. in a more positive light – positive reappraisal) or to regulate their emotions by means of other strategies (e.g. suppression), such as to alter their negative (or positive) feelings. Outcome measures of emotion regulation are often self-report or physiological indices, comparing emotional reactivity of time periods where no regulatory instructions were given to emotional reactivity during regulatory phases. Alternatively (or additionally), emotional reactivity can be compared on these indices as a function of different regulatory strategies. Blechert and colleagues (Blechert, Sheppes, Tella, Williams, & Gross, 2012) further demonstrated that reappraisal renders evaluations of angry faces less negative at both explicit and implicit task levels. In a second study these researchers found that although instructed reappraisal concerning angry expressions increased P100 amplitudes (a positive peak of the event related potential recorded at 100 ms following stimulus onset), reflective of enhanced attentional processing at this initial phase, in later amplitudes (N170, early posterior negativity (EPN), late positive potential (LPP)) reductions were manifested, suggesting less configural/emotional face processing and emotional attention, as well as sustained attention and meaning evaluation, respectively. The N170 reflects a negative peak of the event related potential recorded at 170 ms following stimulus onset, whereas the EPN is typically recorded just afterwards, between 200 ms to 300 ms. Modulations of the LPP by reappraisal have also been demonstrated in other work (Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006), thus corroborating these findings and indicating that reappraisal can diminish the extent to which unpleasant information commands central resources.

*Neurobiology of emotion regulation*

A neural model of emotion regulation developed by Ochsner and Gross (2007; see figure 5) has implicated the dorsal medial and lateral prefrontal cortex (dmPFC and dlPFC) as well as the anterior cingulate cortex (ACC) in a top-down description-based appraisal system, the ventral and orbital prefrontal cortex in a top-down outcome-based appraisal system and the posterior cortical (e.g. parietal lobe) along with the subcortical regions (e.g. amygdala) in bottom-up perceptual and bottom-up affective appraisal systems, respectively. The model posits that the top-down description-based and outcome-based appraisal systems regulate the emotional responses, with the former system engaging higher cognitive functions for emotional control and the latter system recruiting mechanisms concerned with passive conditioning and instrumental choice for the purpose of emotion regulation. This top-down neural architecture has recently been confirmed in a meta-analysis of reappraisal studies by Kalisch (2009). Moreover, mirroring the findings at behavioural and physiological levels, instructed reappraisal (compared to instructed suppression) is identified with reduced activation in regions of emotional reactivity such as the amygdala and insula (Goldin, McRae, Ramel, & Gross, 2008). In sum, these findings confirm the idea that reappraisal is an effective emotion regulation strategy that can modulate the extent to which threat impacts on cognitive resources and performance (see e.g. work on the LPP). Furthermore, it is associated with positive outcomes at behavioural, physiological and neural dimensions and mainly recruits the frontal network (e.g. dmPFC and dlPFC) to exert its regulatory role.

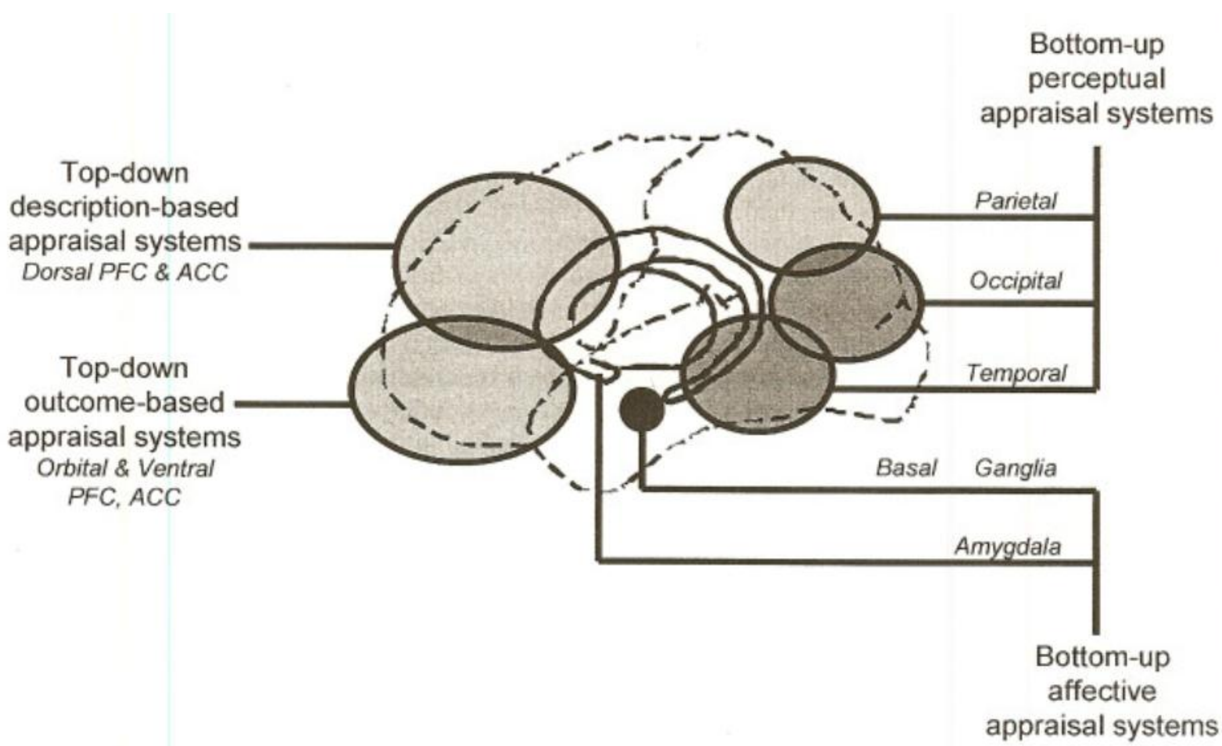


**Figure 5**: Neurocognitive model of emotion regulation (adapted from Ochsner & Gross, 2007)

*Habitual reappraisal*

Typically in emotion regulation research, reappraisal is manipulated experimentally. Gross and John (2003) argue that this approach is suitable for establishing causal effects, but is restricted to identifying only the short-term outcomes of a strategy. Emotion regulation plays an intrinsic part of our daily lives, however, where rather than being instructed to adopt a particular strategy we have developed or genetically inherited automatic regulatory habits (i.e. trait emotion regulation; Gross & John, 2003; Gutknecht et al., 2007; Murakami, Matsunaga, & Ohira, 2009; Williams, Bargh, Nocera, & Gray, 2009; van Rijn, Swaab, Aleman, & Kahn, 2006; for reviews see Canli, Ferri, & Duman, 2009; Canli & Lesch, 2007), which in turn can be linked to longer-term consequences of these regulation processes. Akin to the evidence from instructed emotion regulation, trait reappraisal has been related to improved well-being together with enhanced functioning in various other personal and social facets (Gross & John, 2003; McRae, Jacobs, Ray, John, & Gross, 2012). These findings are further corroborated by a recent study, which found in a subsample of previously depressed individuals that elevated depressive symptoms were related to lower trait reappraisal, but high trait scores on rumination and suppression (Joormann & Gotlib, 2010). Employing an anger induction, Mauss, Cook, Cheng and Gross (2007) also observed that high (versus low) trait reappraisal, at both baseline and provocation stages, effectively reduced anger and negative emotion, enhanced positive affect and led to fairly adaptive cardiovascular challenge responses. Work by Arndt and Fujiwara (2012) provides a possible cognitive explanation of this adaptive profile of anger regulation. They ran an emotional dot-probe paradigm with angry and neutral face images. Their results showed that individuals with high trait reappraisal (but low anxiety) as well as those with high trait anxiety (but low trait emotion regulation) both exhibited slower disengagement from the threatening stimuli compared to controls. The authors suggest that this negativity bias is due to increased attention to negative information in reappraisers, thus permitting the information to undergo a detailed cognitive evaluation during reappraisal. For high trait anxiety, by contrast, the researchers considered the bias to be maladaptive. Using angry and fearful faces to evoke emotional responses, Drabant and co-researchers (Drabant, McRae, Manuck, Hariri, & Gross, 2009) examined the neural basis of trait reappraisal. As is commonly found in studies of instructed reappraisal (see above), their study revealed increased activation in the prefrontal (e.g. dlPFC and dmPFC) and parietal areas along with decreased amygdala activity. Altogether, these findings of trait reappraisal complement those from experimental manipulations, confirming that reappraisal recruits similar neural regions and is adaptive regardless of whether it is instructed or habitual.

### Emotion regulation and cognitive control

Emerging evidence suggests a link between reappraisal and cognitive control (Joormann & Gotlib, 2010; Joormann & Siemer, 2011; McRae et al., 2012; Sheppes & Meiran, 2008). For example, a study by Sheppes and Meiran (2008) revealed that a delayed initiation of instructions to downregulate emotions with reappraisal tapped into self control resources, as reflected in diminished performance in a test of cognitive control (Stroop task) at a later testing point. By contrast, upregulation of negative emotions with reappraisal resulted in improved Stroop performance and an elevated LPP (Moser, Most, & Simons, 2010). Using a negative affective priming task, Joormann and Gotlib (2010) reported that trait reappraisal was positively associated and trait suppression negatively associated with inhibition of negative material. In negative priming tasks consecutive trial pairs are presented, with one of these trials being the prime trial and the other the test trial. On each trial, target and distracter stimuli are displayed (e.g. two (emotional) adjectives), whereby participants are instructed to ignore the distracter and respond to the target. The crucial manipulation of this paradigm is that in the so-called negative priming condition the valence of the distracter in the prime trial and the target in the test trial is identical, whereas, in the control condition, the valence of these is different. It is generally expected that inhibition of the distracter in the prime trial should lead to longer response latencies towards the target in test trials when the valence category is the same for both (i.e. the distracter in the prime and the target in the test trial; negative priming condition), as compared to when it is different (control condition).

In another study McRae et al. (2012) tested participants on a variety of cognitive control tasks and examined correlations with reappraisal ability. Whereas working memory capacity, abstract reasoning (marginally) and set-shifting costs correlated positively with reappraisal ability, the Stroop cost measure and verbal ability did not. Further supporting findings are derived from work with other emotion regulation strategies (Gyurak et al., 2009; Schmeichel & Demaree, 2010; Schmeichel, Volokhov, & Demaree, 2008; Wilkowski, Robinson, & Troop-Gordon, 2010), suggesting that, more generally, emotion regulation and cognitive control may be closely interwoven and may rely on common underlying neural mechanisms (e.g. McRae et al., 2010). Taken together these findings confirm that there is a connection between emotion regulation and cognitive control.

Interaction of neuroticism and emotion regulation (reappraisal)

Even though neuroticism and reappraisal both exhibit links to cognitive control, it seems likely that they each exert unique roles in this regard. Indeed, some work suggests that emotion regulation mediates the impact of neuroticism (Muris, Roelofs, Rassin, Franken, & Mayer, 2005; Wang, Shi, & Li, 2009). To that effect, Wang et al. (2009) reported that reappraisal (but not suppression) mediated the relationship between neuroticism and self-reported positive versus negative affect. Similarly, Muris et al. (2005) presented results showing that the impact of neuroticism on anxiety and depression may be operating through effects on two maladaptive emotion regulation strategies (rumination and worry) (see also Verstraeten, Bijttebier, Vasey, & Raes, 2011). By contrast, other work has put forward the idea that emotion regulation moderates (i.e. buffers) the effect of neuroticism (Auerbach, Abela, & Ringo Ho, 2007; Troy & Mauss, in press; Troy, Wilhelm, Shallcross, & Mauss, 2010). In line with this work, Troy & Mauss (in press) suggest that the link between stress and resilience is moderated by cognitive reappraisal. This proposal is corroborated by findings from Troy et al. (2010). These researchers found that reappraisal ability moderated the association between high stress levels and symptoms of depression, whereby high (versus low) reappraisal levels were associated with lower symptom levels in response to high (but not low) stress. In addition, Robinson and colleagues (Ode, Robinson, & Wilkowski, 2008; Ode & Robinson, 2009; Robinson, 2007) have reported that agreeableness, which they argue is related to emotion regulation, moderates the association between neuroticism and negative affective processing tendencies, such as anger or depression. Furthermore, results from Auerbach, Abela and Ringo Ho (2007) indicated that, subsequent to an exacerbation (relative to a reduction) of depression or anxiety symptoms, individuals with high neuroticism and low emotional repair exhibited more frequent risk taking behaviours. The authors also reported that the level of risk taking was reduced when, holding the other factors equal, participants were high in emotional repair, which was attributed to increased practice in ameliorating negative mood states or isolation effects. Yet, some work from the developmental literature advocates that attentional control or effortful control moderate the relationship between neuroticism or negative affect and psychological difficulties (Meesters, Muris, & Rooijen, 2007; Muris, 2006; Rothbart & Bates, 2006; Rothbart & Posner, 2006; see also Robinson, 2007) – effortful control is a temperament factor encompassing aspects of cognitive and attentional control (Muris, 2006). Overall, these findings demonstrate that emotion regulation mediates as well as moderates the relationship between neuroticism and maladaptive outcomes (e.g. symptoms of depression), with attentional control also playing a potential moderating role of this relationship.

It has also been shown that cognitive control moderates the effect of neuroticism on negative outcomes. This begs the questions to what degree emotion regulation and cognitive control represent common underlying mechanisms and to what extent they interact. A study by Moser, Most and Simons (2010) shed some light on this issue, showing that up-regulating negative emotion by means of reappraisal decreased subsequent Stroop interference and modulated the sustained potential. The sustained potential, in this study, was reflective of peak activity in the temporal window of 750 to 900 ms following Stroop-onset and has generally been linked to cognitive control (Lansbergen, Van Hell, & Kenemans, 2007; West, Jakubek, Wymbs, Perry, & Moore, 2005; West, 2003). These results, along with the findings above, indicate, somewhat tentatively, that the association between neuroticism and cognitive control may be moderated by reappraisal – this idea could also account for the mixed findings in the literature concerning this association. This topic will be further investigated in this thesis.

## Summary

Depending on the nature of the task, threat can either enhance or impair performance. Similar tendencies are found in high anxious individuals who can also detect threat when presented unconsciously. It seems that such effects in anxiety partly arise from both faster shifts towards and slower disengagement from threatening material. Theoretical models posit a general vigilance towards threat in anxiety, which is particularly prominent in scenarios of mild threat and competing cues and is often observed even when stimuli are presented outside of awareness (Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998). According to these models, such attentional bias can, to some extent, be countered by voluntary control mechanisms. It is assumed that a prefrontal-amygdala network controls threat processing and is dysfunctional in anxiety (Bishop, 2007). A related framework is proposed for cognitive control whereby high threat stimuli as well as some individual differences can impact on cognitive control mechanisms and a common resource pool, thus affecting performance (Pessoa, 2009). This proposition is generally supported by behavioural (i.e. cognitive control) and physiological (i.e. LPP) work, with the exception perhaps for the shifting component of cognitive control. The measures of anxiety employed in much of this research overlap with neuroticism, the latter of which might therefore be a suitable alternative measure. Neuroticism is related to emotional disorders, to impaired threat processing, to mental noise, to several neurotransmitters (e.g. GABA) and genetic variation thereof as well as to emotion regulation at behavioural and neural levels.

Reappraisal is an adaptive emotion regulation strategy, leading to positive outcomes at behavioural, physiological and neural levels, and this is irrespective of whether its use is explicitly instructed or habitual. It can reduce the impact of threat on cognitive resources and performance, recruiting the frontal network to exert its regulatory function. There is evidence that both emotion regulation and neuroticism are linked to cognitive control. The latter association (i.e. neuroticism versus cognitive control) is somewhat inconsistent in the literature and might be affected by (1) intra-individual variability of performance, (2) cognitive load, (3) the affective nature of a task and (4) be moderated by reappraisal. The latter possibility (4) also seems consistent with theoretical models of threat processing, which propose that the impact of anxiety on performance can be moderated by voluntary control (Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998).

## Aims of the thesis

In line with neurocognitive models of threat processing (Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998; Pessoa, 2009) as well as the mental noise hypothesis (Robinson & Tamir, 2005), I have set out to investigate several key questions in this thesis. It was of interest to examine, across a series of different affective cognitive control tasks, the influence of threatening material on performance under high versus low task demands (Word-Face Stroop and - Flanker tasks, see below) and in the presence of one or more stimulus cues (Stop signal task, see below). Furthermore, it was sought to establish to what degree i) neuroticism is related to intra-individual variability in performance (RT SDs), ii) neuroticism is related to the affective nature of a task and iii) its influence on threat processing is moderated by voluntary control skills such as reappraisal.

To this end, I have developed affective versions of a number of well-known cognitive control tasks that all tap into the inhibition component of cognitive control, specifically

Response-Distractor Inhibition (Friedman & Miyake, 2004). This type of inhibition consists of two closely linked functions that may have a common underlying inhibitory mechanism: (1) Prepotent Response Inhibition, “the ability to deliberately suppress dominant, automatic, or prepotent responses” and (2) Resistance to Distractor Interference, “the ability to resist or resolve interference from information in the external environment that is irrelevant to the task at hand” (Friedman & Miyake, 2004, p. 104). It is generally important using several tasks to measure components of cognitive control to circumvent the problem of “task impurity” (i.e. where a particular ‘inhibition’ task taps into multiple, potentially confounding, processes in addition to the process of interest). Hence, for each of these two related functions (numbered 1 and 2 above) I have developed two tasks, resulting in four different paradigms. In particular, I devised affective Face-Flanker (2)[2], Word-Face Stroop (1), Word-Face Flanker (2) and Stop-Signal (1) paradigms. Each of these tasks included angry and happy stimuli and was run (except the first task) with two versions: one where emotion was task-relevant and another where it was task-irrelevant. Briefly, the Flanker tasks involved affective targets (faces or words) that were flanked by facial expressions of emotion presented to the left and/or right of the target stimulus. Targets and flankers could be compatible (i.e. they both expressed the same emotion) or incompatible (i.e. they both expressed different emotions). Although some Flanker studies using affective material have already been published (Fenske & Eastwood, 2003; Ochsner, Hughes, Robertson, Cooper, & Gabrieli, 2009), these employed schematic facial expressions or word stimuli. However, except for one conference presentation (Palermo & Coltheart, 2004a) there have been

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[2] The numbers denote which of the two inhibitory functions, (1) Prepotent Response Inhibition and (2) Resistance to Distractor Interference, a particular task maps onto according to the taxonomy used by Friedman and Miyake (2004). Although the authors initially categorized tasks conforming with this taxonomy, their findings revealed that (1) and (2) were strongly associated, as discussed in the main text. Hence, the distinction used here is based on the initial theoretical, rather than empirical, rationale of these researchers, focussing on the processes that these tasks predominantly (but not necessarily exclusively) seem to tap into.

no published scientific reports of Flanker studies using photographic emotional expressions as both targets and flankers (affective Face-Flanker paradigm). This is somewhat surprising in light of the finding that emotion and face recognition seem to be automatic (Lavie, Ro, & Russell, 2003; Tracy & Robins, 2008), with threatening distracters being particularly salient (Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998). There have been propositions of capacity limits for face processing (Bindemann, Burton, & Jenkins, 2005), but these have only been tested with neutral faces. A novel contribution of the Face-Flanker paradigm is therefore to specifically test the effect of emotion in a face flanker paradigm with photographic expressions of emotion. This is important as such stimuli can be considered to possess higher ecological validity (e.g. Horstmann & Bauland, 2006) and are frequently utilised in emotion research. Similarly for the affective Word-Face Flanker task, although there have been reports of such tasks using neutral material (Bindemann et al., 2005), this paradigm, to the author's knowledge, has not been tested with affective material yet. A particular strength of this paradigm is that careful attention was paid to matching the word stimuli on a large number of lexical criteria, thereby controlling for possible confounding explanations of the results based on lexical factors, something that is often not followed with sufficient rigor in other research (see Larsen et al., 2006 for a related criticism regarding the Stroop paradigm).

The Word-Face Stroop paradigm was comparable in principle to the Flanker tasks, only that this time the targets (words) were overlaid on the distracters (faces) – targets and distracters were also compatible or incompatible in content as in the Flanker tasks. For each of these three tasks (Flanker and Stroop tasks) a measure of emotional interference (cost) was then obtained by contrasting response latencies of incompatible versus compatible trial-types (see Chapters 2-4, Results). Although affective Word-Face Stroop tasks have been reported previously (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006; Haas, Omura, Constable, & Canli, 2006; Haas et al., 2007; Preston & Stansfield, 2008; Stenberg et al., 1998), these studies have either not or only sparsely controlled for lexical confounding factors. This potential problem was extensively addressed in this study, by controlling for a large number of lexical characteristics of the word targets.

In the Stop-Signal paradigm a face target was presented on each trial. On the majority of all trials (75%) participants needed to make a binary response (e.g. whether the target is pleasant or unpleasant); on the remainder of the trials (25%) a stop signal appeared in the form of a blue rectangle and participants needed to withhold their responses. This permitted computation of response latencies on trials where participants pressed a button (Choice Reaction Time; CRT) as well as, on stop signal trials, the stop signal reaction time (SSRT), a measure of response inhibition (see Chapter 5, Methods). In previous stop signal paradigms, affective material either served as task-irrelevant information (Sagaspe, Schwartz, & Vuilleumier, 2011; Verbruggen & De Houwer, 2007; Wilkowski, 2012) or as stop signals (Pessoa, Padmala, Kenzer, & Bauer, 2012; Wilkowski, 2012), with emotion not affecting behavioural performance when task-irrelevant unless combined with high trait emotionality (e.g. trait anger). However, there have been no reports yet, examining the effect of task-relevant emotional targets on stop signal performance. Indeed, the author is not aware of any published records where task-relevance was systematically varied in affective Word-Face Flanker/Stroop as well as Stop signal paradigms, which would be an important test and extension of relevant models of threat processing (Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998; Pessoa, 2009).

Each of these four tasks has been allocated one chapter in this thesis and more detailed descriptions of the tasks and the relevant associated scores are provided in the corresponding chapters. This design, involving experimental variations in task-relevance, enabled calculation of emotional interference (cost) when attention was directed towards (task-relevant) or away from (task-irrelevant) emotional content and served as a manipulation of task demand for the Stroop and Flanker tasks (see Mathews & Mackintosh, 1998; Mathews et al., 1997). It has been shown in previous research that task goals, such as categorizing the gender versus the colour of an affective stimulus, can modulate emotional interference (Van Dillen, Lakens, & Den Bos, 2011). For the stop signal tasks this manipulation of task-relevance served a different purpose. Here, it was of interest to examine whether one cue (i.e. emotion task-relevant) was sufficient to obtain interference effects from emotion or whether, as Mathews and colleagues maintain (Mathews & Mackintosh, 1998; Mathews et al., 1997), a minimum of two cues is required (e.g. gender task-relevant and emotion task-irrelevant). In this respect the Stop signal task where emotion is task-irrelevant could be considered comparable to the traditional affective word Stroop paradigm, with a neutral target (here: gender) and an emotional distractor (here: emotion).

In terms of the research goal concerning individual differences (aim ii) above), the outcome measures of the affective cognitive control tasks were correlated with self-report measures of reappraisal and neuroticism in order to clarify which type of cognitive / emotional control is associated with these traits. Moreover, I tested whether neuroticism and emotion regulation interacted in predicting threat appraisal, as measured by the aforementioned cognitive/ emotional control tasks (aim iii) above). Previous work has found that attentional control can reduce the impact of emotional distracters (Peers & Lawrence, 2009). However, it has not yet been examined to what degree other types of voluntary control, such as reappraisal, may affect the cognitive control of emotional information respectively may moderate the association between neuroticism and threat appraisal. It is this latter interaction that will be explored in this thesis by manipulating threat appraisal in a number of different affective cognitive control paradigms. To date, there have been no studies reporting a systematic examination of this issue across a large number of such tasks. Indeed, although abundant evidence has been accumulated on the effect of anxiety and threatening material on spatial (and more recently temporal) attention (Mathews, Mackintosh, & Fulcher, 1997; Mogg & Bradley, 1998, 1999; Pourtois et al., in press; Vuilleumier, 2005), the number of studies examining the effect of threat or anxiety on cognitive control is relatively sparse (Pessoa, 2009; Verbruggen & De Houwer, 2007; Zetsche et al., 2012). This is particularly true for neuroticism whose nature and origin requires further clarification (Lahey, 2009; Ormel et al., 2013). At the same time evidence has implicated neuroticism as one of the key factors in a wide range of clinical disorders, attesting to its significance in public health (Kotov, Gamez, Schmidt, & Watson, 2010; Lahey, 2009; Ormel et al., 2013). An improved understanding of neuroticism and its boundary conditions can therefore have profound implications for this sector. Additionally, with emotion dysregulation being strongly linked to mental disorders (Aldao et al., 2010; Gross & Munoz, 1995), the regulation of emotion has become an integral part of most modern psychotherapies (e.g. Beck, Rush, Shaw, & Emery, 1979). It is therefore particularly promising to test the effect of reappraisal, a beneficial emotion regulation strategy (Gross, 2002), on threat behavior, which has only recently begun to receive attention from other researchers (e.g. Blechert et al., 2012).

Further novel contributions of this work include the comprehensive investigation, across several cognitive control paradigms, of task-relevance on emotion processing in the light of individual differences. In particular, unique to the approach taken in this thesis is that I not only examine the links between individual differences and mean RT performance to threat, but that I also look at the corresponding intra-individual variability in RT performance in that regard (mental noise hypothesis). This has not been reported before with such a broad range of cognitive control tasks where task-relevance of threat is varied. This work can therefore usefully test and extend existing models of threat processing (Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998; Pessoa, 2009) by investigating the role of task-relevance, emotional and regulatory traits (neuroticism and reappraisal) and their interaction on threat processing. Specifically, such models tend to focus on mean performance, but not the intra-individual variability thereof, which thus poses a crucial extension.

Another novel contribution, something that up to now has received comparatively little attention in the research community, includes that effect sizes have consistently been reported in all experiments of this thesis, thereby providing, unlike p-values, a true measure of the experimental effects independent of sample size (Hentschke & Stüttgen, 2011).

The above evidence and the tasks used in this thesis, lead to the following predictions. That is, Pessoa (2009) hypothesizes that high threat leads to impaired performance. The Mathews and Mackintosh model (Mathews et al., 1997; Mathews & Mackintosh, 1998), in turn, predicts that the impact of threat on performance is strongest when it functions as a distractor and when the stimulus display involves more than one cue. These predictions will be tested by examining the difference in RT performance between threatening versus non-threatening targets as well as distracters.

The Mathews and Mackintosh model further leads to the prediction that increased task demand reduces any emotional distraction effects. This hypothesis will be explored with the gender decision tasks of the Word-Face Stroop and - Flanker tasks, where emotion constitutes task-irrelevant information. Specifically, it will be examined in these tasks if threatening versus non-threatening distracters lead to greater interference effects (costs). Altogether then, the hypotheses outlined until this point will serve as a test of principle of whether the models' predictions can be extended to encompass the novel affective cognitive control paradigms developed for this thesis.

It can also be expected from the Mathews and Mackintosh model that the higher the level of trait neuroticism (anxiety), the more threatening material will interfere with performance. Similarly, in line with the mental noise hypothesis (Robinson & Tamir, 2005), I predict that increased levels of neuroticism are associated with greater intra-individual variability in performance towards threatening information. For the Stroop and Flanker tasks, this will be tested by running correlation analyses between the trait measures (especially neuroticism and reappraisal) and the cost scores (based on RTs and RT SDs). For the Stop signal task difference scores will be created for CRTs, CRT standard deviations (CRT SDs) and SSRTs (angry minus happy trial types; see Chapter 5, Results, for further details); these scores will then be correlated with the relevant trait measures. Except for the Stroop task (Haas et al., 2007), this, to the author's knowledge, has not been directly tested with the other affective cognitive control paradigms (Flanker and Stop signal) before. Particularly, only a few studies have examined the link between neuroticism and RT SDs in tasks involving affective material (e.g. Robinson & Tamir, 2005) and this has not been done for any of the paradigms presented in this thesis.

The Mathews and Mackintosh model further predicts that the association between neuroticism and threat appraisal (mean RTs) can be moderated by voluntary control mechanisms such as reappraisal or attentional control. Based on this rationale, I have generated an equivalent hypothesis in terms of the mental noise hypothesis, using RT SDs. So, I would expect that the link between neuroticism and threat appraisal (RT SDs) is moderated by the above voluntary control skills. There have been no studies that have tested the potential moderating role of positive emotion regulation skills such as reappraisal, which is a suitable factor for interventions (Beck et al., 1979; Gross, 2002), on this association. Importantly, such boundary conditions have not been tested for the relationship between neuroticism and intra-individual performance variability.

## **<u>Chapter 2: Selective attention to facial emotion in a Flanker Paradigm</u>**

### **Introduction.**

The Eriksen flanker task (Eriksen & Eriksen, 1974) is a conflict paradigm where participants focus on and make a decision about a target stimulus which is flanked by nearby distracting stimuli (flankers) that need to be ignored. The crucial conditions of a typical flanker letter task can be illustrated with the following letter arrays: (1) H H H or (2) H T H. Here, the letter in the middle of these arrays is the target and is enclosed by the flankers, which are task irrelevant and should be ignored. The general finding is, that participants exhibit difficulties avoiding processing the flankers, despite instructions not to. In particular, it is observed that when target and flankers are different (i.e. incompatible; see (2)) participants show slowed response latencies compared to when the target-flanker pair is identical (compatible; see (1)). This slowing effect on incompatible trials is presumed to arise, amongst others, from stimulus conflict, denoting a mismatch between target and distracter stimuli, as well as response competition, where target and distracter cues are associated with two opposing responses; on compatible trials such competition does not arise as target and distracter cues are matched respectively are mapped onto the same response (Eriksen & Eriksen, 1974; Wager et al., 2005). The difference in response latencies between compatible versus incompatible trial types is known as the flanker compatibility effect. Although the flanker compatibility effect is modulated by factors such as stimulus size, inter-stimulus distance, pre-cues and category membership (e.g. Paquet & Craig, 1997), it is generally found to be a robust behavioural effect – as noted by Rouder and King (2003), for example. More recently, researchers have reported emotional variants of the flanker task; instead of letters such studies have utilised emotional face stimuli (e.g. Fenske & Eastwood, 2003; Palermo & Coltheart, 2004). Relevant to this work is an emerging literature suggesting capacity limits in face processing in the flanker paradigm (e.g. Bindemann, Burton, & Jenkins, 2005; Brebner & Macrae, 2008; Palermo & Rhodes, 2002). However, such capacity limits have only been demonstrated with fairly neutral face stimulus sets, but not yet for facial expressions of emotion. Indeed, emotional faces are generally recognized automatically (Tracy & Robins, 2008) and especially threatening distracters are known to impair performance (see e.g. Bishop, 2007; Mathews & Mackintosh, 1998; Mathews et al., 1997). Moreover, a study by Lavie, Ro, and Russell (2003) indicated that neutral face flankers show a strong interference effect that is not affected by perceptual load, suggesting that face processing is automatic. Given the automaticity of face processing and emotion recognition as well as the general interference effects found with threatening distracters, it is possible that an emotional face flanker task yields flanker compatibility effects. Indeed, although modulated to some degree by context, this is just what Palermo and Coltheart (2004) found in their study using facial expressions of emotion (see also Fenske & Eastwood, 2003).

Despite the relatively large number of cognitive flanker studies, only a limited number of studies concerning an emotional version of the flanker task are available. For example, Ochsner, Hughes, Robertson, Cooper and Gabrieli (2009) conducted an fMRI study using a cognitive and affective word flanker task. They found that in both conflict tasks common brain regions were activated, including the bilateral dorsal anterior cingulate, posterior medial frontal, and dorsolateral prefrontal cortices. Some regions were activated dependent on the conflict type, however, with the rostral medial prefrontal cortex being recruited in the affective condition and the left ventrolateral prefrontal cortex in the non-affective (cognitive) condition. Furthermore, Fenske and Eastwood (2003) reported an affective flanker study where they presented participants with positive, negative and neutral schematic faces. The authors demonstrated that the flanker effect is modulated by emotion. Specifically, the results of their final experiment (experiment 2) showed that the magnitude of the flanker compatibility effect for negative targets was smaller than that of neutral or positive targets; the effect for neutral targets, in turn, was smaller compared to positive targets. These findings support the notion that threatening distracters are linked with elevated interference effects (see e.g. Bishop, 2007; Mathews & Mackintosh, 1998; Mathews et al., 1997). However, some work has also questioned Fenske and Eastwood's (2003) interpretation of emotional modulation of the flanker compatibility effect on the grounds of the perceptual characteristics of the schematic faces (Horstmann, Borgstedt, & Heumann, 2006).

In an attempt to replicate Fenske and Eastwood's (2003) study – experiment 2 in particular – I devised a similar task, but this time using photographic images of facial expressions, which have higher ecological validity than schematics (e.g. Horstmann & Bauland, 2006). In our experiment we presented participants with angry, happy or neutral facial expressions as targets and flankers. Participants' task was to judge the emotion of the target face whilst ignoring the flankers.

Based on (Mathews et al., 1997; Mathews & Mackintosh, 1998; Pessoa, 2009) I expected that angry material impairs performance. Moreover, I predicted that greater interference from threatening material as well as greater intra-individual variability would be associated with elevated levels of neuroticism. However, it was expected that these associations would be moderated (i.e. buffered) by reappraisal and/or attentional control skills.

**Methods.**
**Participants**

Participants were recruited, in exchange for course credit, through the Research Participation Scheme of the School of Psychology, Cardiff University. This is an online experimental management system (EMS) used for advertising experiments and recruiting participants based at Cardiff University. The study had been approved by the local Research Ethics committee and each volunteer provided written informed consent to take part – this applies to all studies reported in this thesis. Participants were 18 students (2 males) and had a mean (SD) age of 21.2 (5.0) years (range: 19-38); other studies of cognitive control have used comparable sample sizes and have informed the choice for this particular sample size (Bellgrove et al., 2006; Cai, George, Verbruggen, Chambers, & Aron, 2012; Chambers et al., 2006, 2007; Verbruggen, Aron, Stevens, & Chambers, 2010). Students have been tested in a large number of similar studies (Bredemeier et al., 2011; Haas et al., 2008, 2007; Logan et al., 1997; Paelecke et al., 2012; Robinson & Tamir, 2005; Tamir et al., 2006) and were hence, as well as due to their associated ease of recruitment, the population of choice for all experiments presented in this thesis (although see Sears (1986) for potential problems concerning the generalizability from student samples). This sample consisted predominantly of females as the majority of the available sample at the School of Psychology, Cardiff University, is female, thereby being a pragmatic choice. Moreover, research has generally shown that females exhibit superior performance in emotion recognition compared to males – this is therefore expected to maximise any effects of emotion in this task (Collignon et al., 2010; Donges, Kersting, & Suslow, 2012; Hall & Matsumoto, 2004; Hall, 1978; Hampson, Vananders, & Mullin, 2006; but see Erwin et al., 1992; Grimshaw, Bulman-Fleming, & Ngo, 2004; Hoffmann, Kessler, Eppel, Rukavina, & Traue, 2010; Li, Yuan, & Lin, 2008; Rahman, Wilson, & Abrahams, 2004 for qualifications of this effect). Each participant had normal or corrected-to-normal eyesight, was right-handed and had no past history of psychiatric disorders.

**Stimuli**

A Toshiba Satellite® Pro A200 laptop (Toshiba Information Systems Ltd., Surrey, UK) with an Intel® Pentium® Dual-Core™ processor (Intel corp., Santa Clara, CA) and a screen size of 39.5 cm (15.55 inch) was used to run the experimental task. Stimulus presentation and recording was controlled by Microsoft® Visual Basic 6.0 (Microsoft Corporation, 1987–1998).

Stimuli were photographs of angry, happy and neutral facial expressions for three different female identities (MF, MO and NR) selected from the Pictures of Facial Affect (PoFA) database (Ekman & Friesen, 1976). Faces were chosen based on high accuracy, reaction time and intensity ratings reported by Palermo and Coltheart (2004). Adobe® Photoshop® version 6 (Adobe Systems Inc., Mountain View, CA, USA) was utilised for preparation of the face stimuli. All faces were cropped to an identical elliptical form to remove hair, shape and background cues.

The fixation screen and viewing distance (62.5 cm to the screen) were kept similar across all experiments reported in this thesis. Fixation was comprised of a white addition symbol (+) that was presented in the centre of the screen. Depending on the experiment, it subtended 0.37° or 0.44° of visual angle in height and width respectively. Here, the experimental display consisted of a target face (angry, happy or neutral expression) in the centre of the screen, which was flanked horizontally by a pair of face stimuli (flanker faces). The flanker faces also showed angry, happy or neutral expressions and both always displayed the same expression on any one trial. On each display target and flanker faces were either identical (compatible) or different (incompatible) in terms of the emotional expression. All faces presented on each trial were of the same identity. Face stimuli subtended 2.93° x 2.20° of visual angle (in height and width, respectively). The inter-elements-distance between target and flanker faces was .73° of visual angle. All stimuli were presented against a grey background – this colour was maintained for all subsequent experiments. Examples of the face stimuli sets are shown in Figure 6.

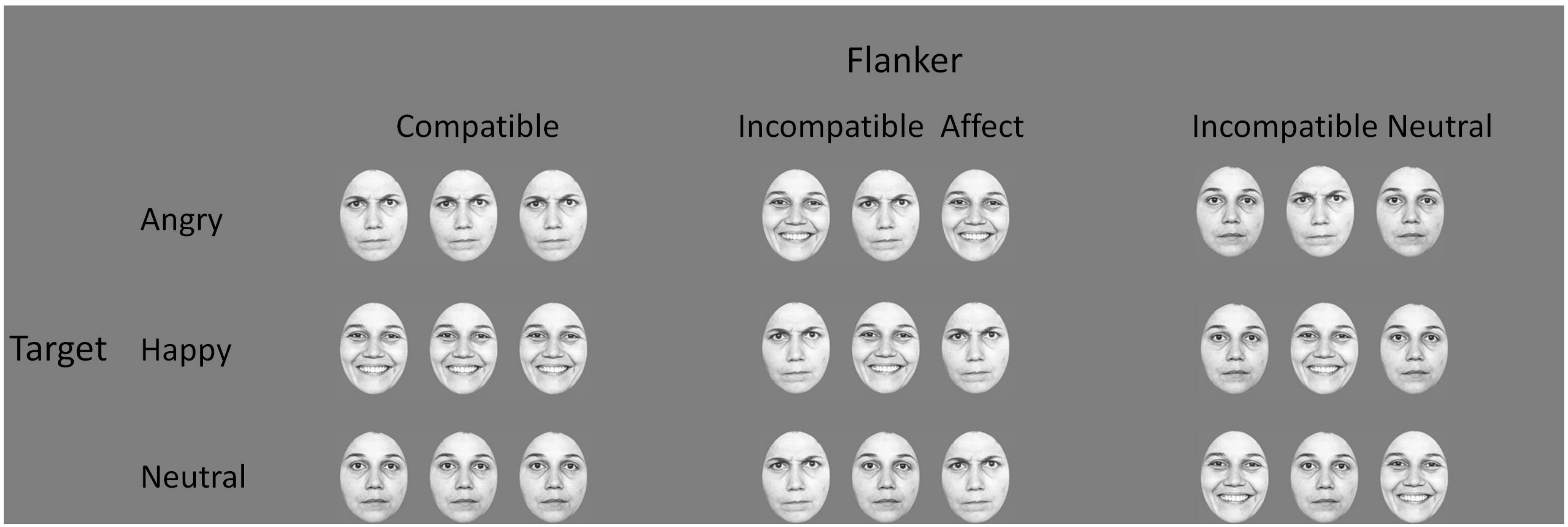


**Figure 6.** Stimulus displays for all experimental conditions illustrated with one of the three identities that were used. *Note*: for neutral targets: incompatible affect = incompatible angry; incompatible neutral = incompatible happy.

**Questionnaire measures**

Participants completed the Short Big Five Inventory (BFI-11; Rammstedt & John, 2007), measuring the five-factor personality dimensions (see below), along with the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003), an instrument assessing trait emotional control (see below), and the state and trait anxiety scales of the Spielberger State-Trait Anxiety inventory (STAI; see below; Spielberger, 1983; Spielberger, Gorsuch, & Lushene, 1970). A number of other self-report measures were collected for the purpose of another study and are thus not reported here.

*Neuroticism and other 'big five' personality traits: BFI-11*

Neuroticism (trait negative emotionality) was measured, together with the other 'big five' personality traits (i.e. extraversion, agreeableness, conscientiousness, openness) using a brief version of the 'big five inventory' – the BFI-11. The BFI-11 manifests an at least comparable predictive validity of external measures (e.g. behaviour) to the longer personality scales (Credé, Harms, Niehorster, & Gaye-Valentine, 2012; Thalmayer, Saucier, & Eigenhuis, 2011). Particularly the neuroticism scale of the BFI-11 correlates well with the BFI-44 ($r = .86$), whilst also showing good test-retest reliability (Rammstedt & John, 2007). In light of these findings as well as the advantages associated with brief measures (e.g. reduced testing time, avoidance of fatigue) the BFI-11 could be seen as a suitable measure of trait neuroticism. The BFI-11 was constructed by selecting 2 (out of 8 to 10)[3] representative items from each factor of the BFI-44 (Rammstedt & John, 2007). The authors found an overall mean correlation of .83 between the BFI-11 and the BFI-44, with the BFI-11 explaining 70% of variance in the complete scale. Their analyses further showed a decent retest stability (overall stability coefficient: .75; stable variance: 56%), substantial support for discriminant validity (mean intercorrelations: .11 (range: .08 to .13)), a mean convergence validity with the NEO-PI-R of .67 (45% shared variance) and some evidence for external validation (overall convergent validity correlation: .44). The BFI-11 (Rammstedt & John, 2007) examines participants on five factors, using a 1 (*disagree strongly*) to 5 (*agree strongly*) rating scale. The factors comprised *extraversion* (i.e. ".. is outgoing, sociable"; "..is reserved" (reverse scored)), *agreeableness* (i.e. ".. is considerate and kind to almost everyone"; "..tends to find fault with others" (reverse scored); ".. is generally trusting"), *conscientiousness* (i.e. "..tends to be lazy" (reverse scored); ".. does a thorough job"), *neuroticism* (i.e. "..is relaxed, handles stress well "(reverse scored); ".. gets nervous easily") and *openness* (i.e. "..has few artistic interests " (reverse scored); ".. has an active imagination"), with each item constituting a continuation of the sentence fragment "I see myself as someone who ...". Items were summed to obtain an overall score for each factor, with higher scores denoting higher trait levels for a particular factor (here the focus was on neuroticism only: maximum score: 10; minimum score: 2).

[3] These numbers vary as there was not an equal number of items for each personality construct in the original BFI-44 scale, with numbers ranging from 8 to 10 items per construct (e.g. neuroticism: 8 original items; openness: 10 original items).

*Habitual Emotion Regulation Styles: the Emotion Regulation Questionnaire (ERQ)*

Gross and John (2003) created a set of 10 items (the ERQ) that each specifically mapped onto the emotion regulation strategies of either **reappraisal** (e.g. "When I want to feel more *positive* emotion (such as joy or amusement), I *change what I'm thinking about*.") or **suppression** (e.g. "When I am feeling *positive* emotions, I am careful not to express them.") – items relating to positive as well as negative emotions were included for each regulation strategy. In support of this dual representation of the strategies, these researchers reported that intercorrelations between the two scales (reappraisal versus suppression) were minimal across samples (mean r = -.01). Moreover, their factor analyses indicated a two-factor solution, with one factor for reappraisal and one for suppression (positive and negative emotions were split equally across both factors). Each factor, as these authors demonstrated, exhibited a respectable mean internal consistency (reappraisal: .79; suppression: .73) and a test-retest reliability of .69 was found over a time interval of 3 months. Finally, Gross and John (2003) showed over a series of experiments that reappraisal is generally positively associated with well-being as well as numerous other facets of adaptive functioning at personal and social levels whereas the direction of these associations was the other way round (negative) for suppression (for further evidence regarding the link between trait reappraisal and behavioural/ neural measures, see viii) Mechanisms of emotion regulation, General Introduction). Responses were collected using a 1 (*strongly disagree*) to 7 (*strongly agree*) rating scale. Items were summed for each factor and high scores indicated high trait levels on the relevant emotion regulation strategy (here we focussed on reappraisal; maximum score: 42; minimum score: 6).

*State and trait anxiety: STAI*

The STAI (Spielberger et al., 1970; Spielberger, 1983) involves two main scales of 20 items each, one measuring state and the other trait anxiety. The former scale assesses participants' feelings at a particular time point (e.g. "I feel calm" (reverse scored); "I feel tense"), using a 4-point rating scale (1 = "Not at all"; 2 = "Somewhat"; 3 = "Moderately so"; 4 = "Very much so"). The latter scale assesses how participants generally feel (e.g. "I feel satisfied with myself" (reverse scored); "I get a state of tension or turmoil as I think over my recent concerns and interests"), also on a 4-point rating scale (1 = "Almost never", 2 = "Sometimes", 3 = "Often", 4 = "Almost always"). For each scale, all 20 items are summed to yield a total score of state or trait anxiety, respectively (maximum score: 80; minimum score: 20) – higher scores denote higher levels of anxiety. Although the STAI generally manifests acceptable internal consistency and test-retest reliabilities (Barnes, Harp, & Jung, 2002), there are potential issues with the convergent and discriminant validity of this instrument (Bados et al., 2010; Bieling, Antony, & Swinson, 1998; Vigneau & Cormier, 2008). Given its wide use in research on attentional bias to threat (Bar-haim et al., 2007; Bishop, 2007; Pessoa, 2009), I decided to include this inventory for reasons of comparability of findings with previous research.

**Procedure**

Participants signed up on the EMS for a time of their convenience. Time slots were available between 7 am and 10 pm and participants made use of the full range. Upon arrival at the testing laboratory participants were given a verbal overview of the study by the experimenter. They were then asked to read the information sheet and consent form, were provided with an opportunity to ask questions for clarification and, if agreeing to participate, asked to sign the consent form. Next, participants were given a chance to familiarise themselves with the target stimuli (here: target faces) and the according labels thereof and were given specific instructions for the experiment. This general procedure was followed in all behavioural experiments reported in this thesis.

Here, participants were instructed to concentrate on the target faces on each trial, ignoring the flanker faces. They needed to determine whether the emotion of the target face was angry, happy or neutral and were asked to respond as quickly as possible whilst maintaining a high level of accuracy. Responses to the target faces were self-paced and could be indicated using the sideways and downwards pointing cursor keys – stimulus-response mapping was counterbalanced across participants. During training, feedback on the accuracy of their decision was provided at the end of each trial and participants were asked to use this to improve their accuracy of emotion labelling.

There were nine unique trial types derived from the factorial combination of target (angry, happy, neutral) and compatibility (compatible, incompatible affect[4], incompatible neutral[5]). Each trial type was repeated 12 times in every block, thus leading to an overall of 108 trials per block (i.e. 33% compatible trials and 67% incompatible trials). This then allows a Flanker compatibility score to be computed (performance in incompatible minus compatible trials; see Chapter 1 and Introduction for further details).

Blocks were initiated by pressing the enter button and trials were shown in random order, using the Rnd function in Microsoft® Visual Basic 6.0 (Microsoft Corporation, 1987–1998).

[4] incompatible angry (for neutral targets)
[5] incompatible happy (for neutral targets)

There was one practice block (or more if necessary) and there were four experimental blocks, leading to a total number of trials of approximately 540 (depending on the amount of practice). Trials started with the presentation of the fixation cross for 508ms (32 refreshes @ 63 Hz) to indicate where participants should focus their gaze. After this the face stimuli were shown. Prior to the next trial, feedback in the form of the words “correct”/”incorrect” presented in black upper case letters was displayed for 603ms (38 refreshes @ 63 Hz) and there was an inter-trial interval (with fixation) for 1000ms (63 refreshes @ 63 Hz). With an average response time of 1 sec. per trial, each block lasts around 5 minutes, amounting to approximately 25 minutes of testing time for the Face-Flanker task. On completion of a block participants could take a break for as long as needed and after the first two experimental blocks, to provide an additional opportunity for rest, participants were asked to fill in the questionnaires. There was a full debrief at the end of the experiment.

**Results.**

One participant was excluded from the analyses due to technical errors with the experiment. For all other participants mean reaction time (RT), RT SDs, both for correct responses, and mean accuracy (ACC) data were computed. In line with recommendations by Ratcliff (1993) and Osborne and Overbay (2004), RT data were treated for outliers at (1) the individual trial level (i.e. “raw” RT scores) as well as (2) with regard to trial type across participants. The latter of the two stages accounts for atypical factors affecting a participant’s performance (e.g. poor concentration). (1) For any one participant those individual RT scores that were more than 2.5 SDs from the mean RT for a particular stimulus-type were removed along with their corresponding ACC values. (2) Next, I computed means (SDs) across all participants for each stimulus-type. Here, participants whose scores for one or more trial-types were at least 2.5 SDs from the mean were excluded from the analyses. At both stages of outlier removal (i.e. (1) and (2)) this procedure led to less than 18% of the data being discarded as extreme scores. Mean RT was divided by mean accuracy in order to create a new combined measure for every participant (adjusted RT (ART); Townsend & Ashby, 1983) that linearly accounts for speed accuracy trade-offs. This was necessary since, in some conditions, error rates larger than 10% were found for a few participants. Subsequent analyses will therefore focus on this measure (ART)[6]. Data were also normalised using the procedure suggested by Loftus and Masson (1994). As these authors note, whilst this procedure does not affect the outcome of the statistical within-subjects tests, it removes the between-subjects variance, which is irrelevant for within-subjects analyses, on the error bars. For the normalisation I computed the individual subject means by taking the mean of all conditions for each participant. The individual subject means, in turn, were averaged across participants to form the grand mean. Next, the grand mean was deducted from each of the individual subject means, yielding a subject-deviation score for each participant. Data normalisation was completed by subtracting the subject-deviation score from the original ART score for each participant and each condition.

I expected slower response times when faced with threatening information, particularly when this information acts as a distracter. Within-subjects analyses of variance (ANOVA) were performed with target (angry, happy, neutral) and compatibility (compatible, incompatible neutral, incompatible affective (angry/happy)) as factors. There was a significant main effect of target ($F(2, 28) = 10.90$, $p < .001$, $\eta_p^2 = .44$), whereas the main effect of compatibility ($F(2, 28) =$

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[6] Analyses with RT and accuracy lead to the same conclusions. ART scores were not computed for the RT SD data. This was because some participants obtained an accuracy of 100% for some trial-types, resulting in the corresponding SD to be of a score of 0. Since dividing the relevant RT SD scores by an SD of 0 (which would be a necessary step to obtain the ART SD score) would lead to mathematical issues, it was decided to not compute ART SDs for any of the experiments reported in this thesis, using RT SDs instead.

1.80, p = .18, $\eta_p^2$ = .11) and the compatibility X target interaction (F(4, 56) = .36, p = .88, $\eta_p^2$ = .02) were not significant. Pairwise comparisons using Bonferroni correction demonstrated that angry targets exhibited slower ART's relative to happy targets (p = .005, 95% CI 42.39; 238.89) but were not significantly different from neutral targets (p = 1, 95% CI -106.44; 62.84). Happy targets revealed faster ART's compared to neutral targets (p = .008, -284.05; -40.83). The means (standard errors; SEs) for ART are presented in Figure 7.

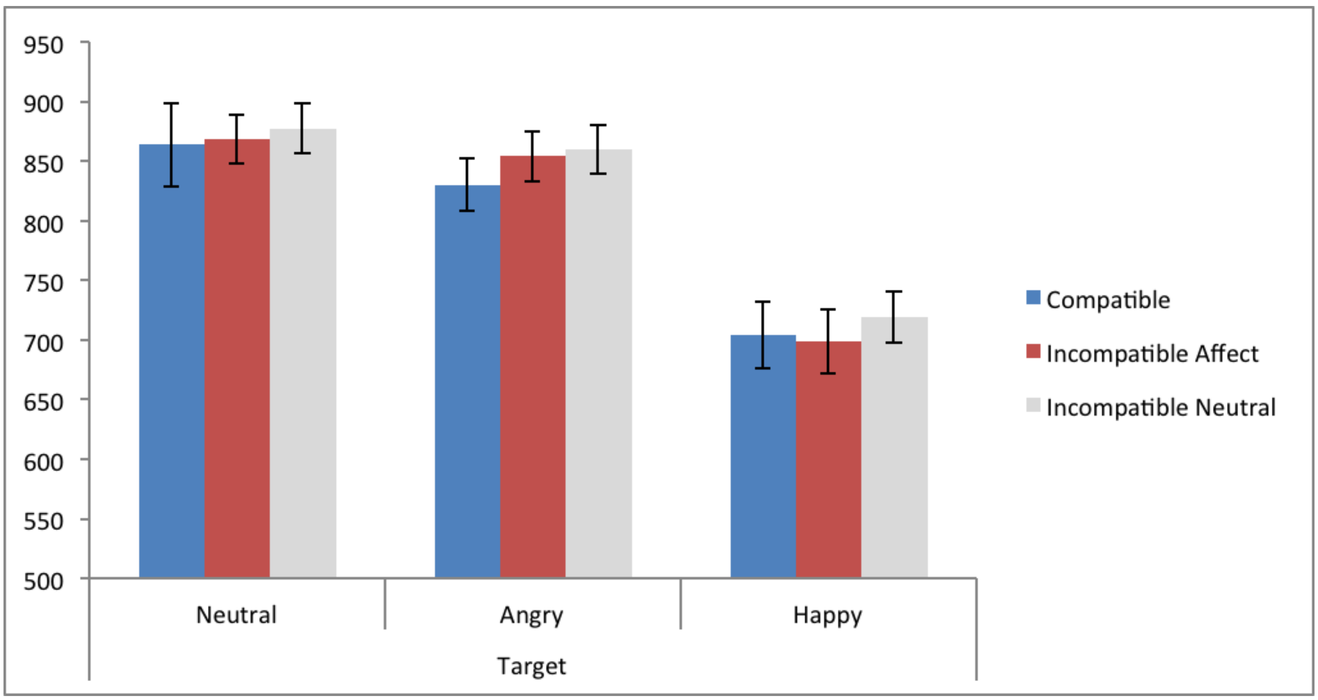


**Figure 7.** Mean (SE) ART identification of the target emotion for each flanker condition. *Note*: For neutral targets: Incompatible Affect = Incompatible Happy; Incompatible Neutral = Incompatible Angry.

In summary, happy targets showed faster ART's than angry or neutral targets. Due to the lack of predicted main effects (see page 73f) for compatibility or a compatibility X target interaction, tests examining individual differences, flanker costs or comparing the magnitude of the flanker effects across targets were not conducted.

**Discussion.**

The present experiment sought to investigate whether the flanker compatibility effect can be observed with emotional stimuli using photographic images of facial expressions. I predicted that angry material impairs performance. Furthermore, I expected that greater interference from threatening material as well as greater intra-individual variability would be associated with elevated levels of neuroticism, with these associations being moderated (i.e. buffered) by reappraisal and/or attentional control skills. However, the results suggest that happy targets exhibit faster ART's compared to angry or neutral targets, with angry targets not being slower than neutral ones, which, against predictions, does not suggest an impairment that is unique to angry stimuli. Also against our expectations, no flanker compatibility effects were obtained, with angry faces in particular not creating increased interference effects. Hence no individual difference analyses were carried out.

There are several possibilities that may explain our findings. Firstly, Bindemann, Burton and Jenkins (2005) suggested that the face processing capacity is limited to one face per display. In my task this capacity limit may have been exceeded (I had three faces per display). It seems plausible that when participants focussed on the target face they had already reached their capacity limit and therefore did not have sufficient resources available to process the flanker faces, which would, in turn, explain the absence of significant flanker compatibility effects. Secondly, the superior performance of happy targets in our task is in line with previous research where happy faces are generally found to have faster RT and higher ACC (see Palermo and

Coltheard, 2004). This could be consistent with Pessoa's (2009) Dual-competition model which argues that low arousing emotional stimuli have enhanced early sensory representations and thereby improve behavioural performance when task-relevant. Indeed, prior neuroimaging evidence has shown enhanced early visual cortex activation for happy relative to neutral faces (Pessoa, 2009). This superiority effect might be driven by the perceptually salient features of happy faces, including the comparatively large proportion of white in the mouth region of these expressions (e.g. Calvo and Nummenmaa, in press). It could be argued that such differences in emotion recognition may have contributed to the lack of flanker compatibility effects (e.g. perhaps individual differences in emotion recognition ability created additional noise in our data, making it more difficult to detect flanker effects). Thirdly, previous research has shown that flanker compatibility effects are affected by stimulus size and precues (e.g. Paquet and Craig, 1997). For example, our stimuli were larger than those of Fenske and Eastwood (2003), who used schematic faces, to facilitate emotion recognition. However, it could be that reducing the size of our stimuli somewhat would increase flanker compatibility effects.

It is also possible that the relatively low proportion of compatible trials in this experiment (33%) contributed to the lack of compatibility effects. Studies have shown that a low rate of compatible (combined with a high rate of incompatible) trials in a task can substantially reduce interference effects (Casey et al., 2000; Crump, Gong, & Milliken, 2006; Crump, Vaquero, & Milliken, 2008; Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; West & Baylis, 1998). Hence, the low proportion of compatible trials in this task may have prevented a prepotent response tendency to be build up for these trials. This explanation could be examined in future studies by systematically manipulating the proportion of compatible trials.

It should also be noted that despite research suggesting that females exhibit superior emotion recognition performance compared to males (Collignon et al., 2010; Donges et al., 2012; Hall & Matsumoto, 2004; Hall, 1978; Hampson et al., 2006), some evidence indicates that this is dependent on the gender of the cue, with women being particularly efficient at recognizing male faces (Erwin et al., 1992; Rahman et al., 2004). It is therefore conceivable that the selection of female faces for this study may have dampened any potential facilitatory effects in emotion recognition that would otherwise (i.e. using male faces) be observed with female participants. Another potential shortcoming of this study concerns the sample size. Although the sample size was informed by other studies of cognitive control in the field (Bellgrove et al., 2006; Cai et al., 2012; Chambers et al., 2006, 2007; Verbruggen et al., 2010), none of these studies involved emotional material. Indeed, Fenske and Eastwood (2003) recruited 48 participants for a comparable Flanker design with schematic expressions of emotion. The relatively low sample size in this experiment may thus not have provided sufficient power to detect the, perhaps more subtle, effects of emotion on Flanker interference. Still, one way to circumvent the issue of power might have been to run a Bayesian t-test or ANOVA.

Mathews et al. (1997) stipulate that attentional bias to threat increases exponentially, with the bias being particularly strong at higher levels of anxiety; bias effects at lower levels of anxiety may therefore not always be prominent. For this study a non-clinical sample was taken. Such samples are comparatively easy to recruit in larger numbers and have the advantage that performance is not affected by concurrent medication, as is often the case in patient research. However, at the same time this poses the difficulty that participant’s levels of anxiety/neuroticism may not have been sufficiently high or varied to elicit the attentional bias found in individuals with elevated levels on these traits. One way to, at least partly, address this in future research could be to induce state anxiety in participants (see e.g. Macleod & Mathews, 1988), whilst it would also be of interest to test whether the capacity limits in face processing (Bindemann et al., 2005) are attenuated in clinical anxiety, with, in this case and as predicted, threatening distracters impairing performance. The current findings do not allow any direct conclusions in this respect (i.e. state anxiety/ clinical samples).

In conclusion then, our results support previous research on face processing capacity (e.g. Bindemann, Burton and Jenkins, 2005; Brebner and Macrae, 2008) by showing that flankers may not be processed in an emotion identification task where more than one real face is presented on each trial. These results could also lend support to the notion that threatening distracters do not always affect performance. Specifically, this might be in line with the idea that increased task demands (here: possibly manifest through capacity limits in face processing) may reduce attentional bias to threat, as postulated by Mathews and Mackintosh (Mathews et al., 1997; Mathews & Mackintosh, 1998). However, these findings challenge existing accounts of threat processing in that threat may not always uniquely lead to specific enhancements or impairments in performance (e.g. Pessoa, 2009). Some caution should, however, be exerted in the interpretation of these findings as it is possible that they were influenced by differences in emotion recognition (Palermo and Coltheard, 2004), the low sample size, the low proportion of compatible trials (Casey et al., 2000; Crump et al., 2006, 2008; Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; West & Baylis, 1998), or the specific characteristics of our stimuli (e.g. stimulus size, Paquet and Craig, 1997 or the use of female faces in a sample of mainly female participants, see Erwin et al., 1992; Rahman et al., 2004)). Whilst the current chapter examined the effects of threat in a distracter interference paradigm, the following chapter will more closely test the impact of personality and threat in a distracter interference paradigm involving a prepotent response (Word-Face Stroop task).

# **Chapter 3: Selective attention to emotion in a Stroop paradigm**

## **Introduction.**

The Stroop paradigm (MacLeod, 1991; Stroop, 1935) is one of the most well known cognitive control tasks. In its frequently used format participants are presented with colour words (e.g. red) that are either displayed in a font colour matching the semantic meaning of the word (compatible trial, here: red font colour) or in a font colour that differs from the semantic meaning (incompatible trial, here: green font colour). Generally, participants are then instructed to name the font colour of a word whilst ignoring its semantic meaning. It is found that response latencies on compatible trials are faster compared to those of incompatible trials, which is commonly referred to as the Stroop interference effect. Over the years Stroop-like variations of the task have been devised, including an emotional word Stroop (e.g. Williams, Mathews, & MacLeod, 1996), a pictorial Stroop (e.g. Lavy & van den Hout, 1993) or a word-face Stroop task (e.g. Egner & Hirsch, 2005; Etkin, Egner, Peraza, Kandel, & Hirsch, 2006; Kavcic & Clarke, 2000; Stenberg, Wiking, & Dahl, 1998).

In the emotional word Stroop paradigm (Williams et al., 1996) emotionally relevant words (e.g. shark) or emotionally neutral words (e.g. pear) are presented in different colours, the latter of which participants need to name. It is expected that response latencies are slowed for emotionally salient compared to emotionally neutral words and this effect is, in turn, interpreted as emotional interference. As Etkin et al. (2006) noted, the emotional word Stroop task has been criticised for not testing emotional interference with cognitive processing, however. Instead, it measures the effect of emotional material on diverting attention from the primary task. This stems from the fact that, amongst others, the emotional words do not create response competition or semantic disruption with the primary task (word colour; Algom, Chajut, & Lev, 2004). For these reasons the emotional interference effect assessed in the emotional word Stroop task is not considered equivalent to the cognitive interference effect tested in the original word Stroop task. In the word-face Stroop paradigm (e.g. Egner & Hirsch, 2005; Etkin et al., 2006; Kavcic & Clarke, 2000; Stenberg et al., 1998) these problems (i.e. lack of semantic and response conflict) are overcome. Here, a word (emotional or nonemotional) is overlaid on the centre of a photographic image of a face (emotional or nonemotional) and participants' task is to respond to either the face or word. The advantage of the word-face Stroop paradigm over the emotional word Stroop task is that the task-irrelevant stimuli can be in semantic and response conflict with the task-relevant stimulus set, thus making its measure of Stroop interference more comparable to that of the classical colour-word Stroop task. The word-face Stroop paradigm generally elicits strong interference effects from distractors (compared to compatible trials) in its cognitive and emotional versions (e.g. Egner & Hirsch, 2005; Etkin et al., 2006; Haas, Omura, Constable, & Canli, 2006, 2007; Kavcic & Clarke, 2000). Although differential interference effects for specific emotions are not consistently reported in this paradigm, there is a tendency showing that response latencies for task-relevant negative emotions are slower when paired with an incompatible emotion (positive) relative to a compatible emotion (negative) and vice versa for task-relevant positive emotions (see Preston & Stansfield, 2008; Stenberg et al., 1998).

Some work has also examined the effects of task-relevance on threat processing in a Word-Face Stroop paradigm. Lin (2008) conducted a study where cognitive and emotional versions of this paradigm were contrasted. In this experiment participants discriminated the faces on emotion, whilst ignoring in-/compatible words of emotion (task-relevant) or gender (task-irrelevant), and also discriminated faces on gender with in-/compatible gender (task-relevant) or emotion (task-irrelevant) words as distractors. The author found interference effects of both emotion and gender words on face discrimination (i.e. faster response latencies for compatible relative to incompatible trials) when the words were task-relevant, but not when they were task-irrelevant.

Similar to Lin (2008) we devised a Word-Face Stroop task for the present study where the emotional information task-relevant versus irrelevant. Specifically, in one task participants were presented with angry-related, happy-related, non-emotional target word, whereas non-gender and gender-related (male/female) targets were presented in a second task. In each task the target words were overlaid on a number of distracter images (i.e. angry, happy and calm facial expressions of both genders as well as scrambled images). Participants' task was to identify the gender (male-related, female-related, non-gender) or the emotion (happy-related, angry-related, non-emotional) of the words whilst ignoring the faces.

I selected calm faces as control stimuli for several reasons. Neutral facial expressions (an alternative stimulus set to calm faces) are commonly perceived as ambiguous in valence (Cooney, Atlas, Joormann, Eugène, & Gotlib, 2006) and their interpretation is easily rendered more negative through learned associations (Yoon & Zinbarg, 2008) or individual differences (Donegan et al., 2003; Somerville, Kim, Johnstone, Alexander, & Whalen, 2004). Past research has addressed this problem with artificially generated control stimuli, such as 25% happy faces (Mourão-Miranda et al., 2012; Phillips et al., 1997, 2001). However, I opted for calm expressions for posing a perceptually similar, but emotionally less salient and thereby potentially "more neutral" alternative to neutral expressions (Tottenham et al., 2009).

The rationale for using scrambled images, my set of non-face control stimuli, is derived from the face processing literature. In 1986 Bruce and Young proposed facial expression and facial identity nodes as two separate entities in the face recognition system. Whereas the former draws on information about view-centred descriptions, the latter relies on information about specific facial components (featural information) and the spatial arrangement thereof (configurational information). These researchers later acknowledged, though, that facial expression and identity nodes overlap to some degree (Calder & Young, 2005; Young & Bruce, 2011; see also Ganel & Goshen-Gottstein, 2004), suggesting that processing of facial expressions may indeed be affected by featural and configurational information, a conclusion that is also supported by some patient work (see Gagliardi et al., 2003). According to this work then, there are two main routes of disrupting recognition of emotional expressions: (1) changing the view-centred descriptions of the face (e.g. by changing the orientation) and (2) impairing configurational and featural processing. Since it was my aim to render these control stimuli comparable to the affective faces, except with regard to their emotional nature, it was important to preserve as many other qualities of the original images as possible whilst, at the same time, blocking recognition of the emotional expression. The first route - i.e. (1) – would add/remove information to the original image and would hence not be ideal. In terms of disrupting the second route there seem to be several methods available, of which blurring, scrambling and inversion of the face are commonly used (e.g. Collishaw & Hole, 2000). Blurring is known to predominantly hinder featural processing (Collishaw & Hole, 2000; Schwaninger, Lobmaier, & Collishaw, 2002), but, again, removes information from the original image (i.e. high spatial frequencies; Costen, Parker, & Craw, 1994) and is therefore not in line with my aims. Although face inversion and scrambling both impair configurational processing[7], face scrambling can also reduce featural information, depending on the extent of the procedure (Collishaw & Hole, 2000)

[7] Tanaka & Farah (1993) argue that face scrambling disrupts holistic information, which in some ways is related to configurational processing.

and therefore might have a broader impact on disrupting the recognition of expressions. For this reason I created scrambled faces as control stimuli. In selecting a suitable pixel size for this procedure, I was careful to select a size that was sufficiently small to prevent any specific facial features (e.g. the eye) to be recognized. So, although configurational information will have been affected by the scrambling procedure, it is likely that featural information was also impaired at this level of pixilation. Another aspect that may well have been affected by the scrambling procedure, too, is the facial symmetry (Chen, Kao, & Tyler, 2007). Due to facial symmetry, configurational as well as featural processing being disrupted by the scrambling procedure (and the resulting impairment of expression and identity processing), scrambled images are best seen as approximately matched non-emotional, non-face control images. Scrambled images have been employed for similar purposes in previous research (Eger, Jedynak, Iwaki, & Skrandies, 2003; Hagan, Hoeft, Mackey, Mobbs, & Reiss, 2008; Platek et al., 2006; Seitz et al., 2008).

We chose a gender decision as the manipulation of task-relevance (in addition to the emotional one) because it requires participants to process the face (something that is likely to be necessary for emotion recognition) rather than merely a perceptual characteristic of the stimulus such as whether the face was surrounded by “red” or “blue” circle (see Lavy & van den Hout, 1993 for an example of presenting faces in a coloured circle in a Stroop task), thereby possibly making it more difficult to ignore the emotional aspects. An alternative decision to gender that also requires processing of the face is identity. Identity and emotion seem to be interdependent (Calder & Young, 2005; Ganel & Goshen-Gottstein, 2004), however, which could complicate the interpretation of our results. By contrast, although gender may affect emotion recognition (Atkinson, Tipples, Burt, & Young, 2005; Williams & Mattingley, 2006), the reverse effect is only minimal, thus making it preferable over identity.

I predicted that a slowing in performance should be observed for threatening information. Furthermore, I expected this distraction effect to be attenuated with increased task demand (gender decision task). I also predicted that as the level of trait neuroticism rises, interference from threatening material as well as intra-individual variability increase (i.e. greater compatibility scores – see below for further details). Finally, I expect that the influence of neuroticism on the appraisal of threat (based on mean response latencies and RT SD measures) is lessened in those with adequate reappraisal (or attentional control) skills.

**Methods.**

**Power analyses**

G*Power, version 3.1.3, was used to conduct a priori power calculations (Faul, Erdfelder, Buchner, & Lang, 2009; Faul, Erdfelder, Lang, & Buchner, 2007). This was done to ensure that this study would have sufficient experimental power to detect the main effects of interest. Particularly, I sought to examine (1) the simple contrast of attentional bias to threat vs. non-threat within subjects (within-subjects t-test), (2) the association between attentional bias versus neuroticism (correlation) and (3) the interactions between neuroticism and emotion regulation/attentional control in predicting degree of attentional bias (multiple regression). Power calculations for each of these statistical tests are discussed in turn, with the desired levels of power = 0.8 and alpha = 0.05 being set at conventional levels (Noordzij et al., 2010). (1) On the basis of a recent meta-analysis (Bar-haim et al., 2007), the effect size for attentional bias to threat is d = 0.45.  Based on this effect size then, a one-tailed within-subjects t-test, comparing attentional bias to threat vs. non-threat, with a total sample of N = 32, would have 80% power to detect an effect of this size, whereas a sample of N = 63 would have 97% power to detect such an effect.[8] (2) By convention, a correlation of r = 0.3 is a small effect, and a sample of N= 64 would have 80% power to detect a one-tailed correlation of this magnitude. For a medium correlation (r = 0.5, one-tailed), then a sample of N = 21 would have 80% power. (3) Calculating effect sizes for multiple regression requires knowing the $\delta R^2$ value. However, I could not find any indications of this value for relevant studies in the literature. So, assuming a medium effect size for $R^2$ change (effect size $f^2 = 0.15$) and setting the number of tested predictors = 2 and the total number of predictors = 5, then a sample size of N = 68 would have the desired level of power to detect this (80%). In line with these considerations, I conclude that a sample of size N = 68 should have sufficient power to yield the effects of interest. Given that the remaining studies of this thesis also seek to examine the above effects, similar sample sizes were selected for these, too, thereby ensuring adequate experimental power.

**Participants**

Participant recruitment and requirements were identical to those of the Face Flanker paradigm, except where noted otherwise. A total of 70 participants (35 females) were recruited for this experiment. Participants had a mean (SD; range) age of 21.8 (4.1; 18-47), were native speakers of English and were either left or right handed.

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[8] This suggests that the sample size for the Face Flanker study (chapter 2) was likely too low.

**Stimuli and questionnaire measures**

An RM™ Expert 3030 (RM plc, Milton Park, UK) with an Intel® Pentium® Dual-Core™ processor E2180 at 2.00 GHz (Intel corp., Santa Clara, CA) and a ViewSonic® VA1916W-2 monitor (ViewSonic Corporation, Walnut, CA) with a screen size of 38 cm (19 inch) were used to run the experimental task. The experiment was administered using the Psychophysics Toolbox extensions running in Matlab® (MathWorks, Natick, MA; Brainard, 1997; Pelli, 1997).

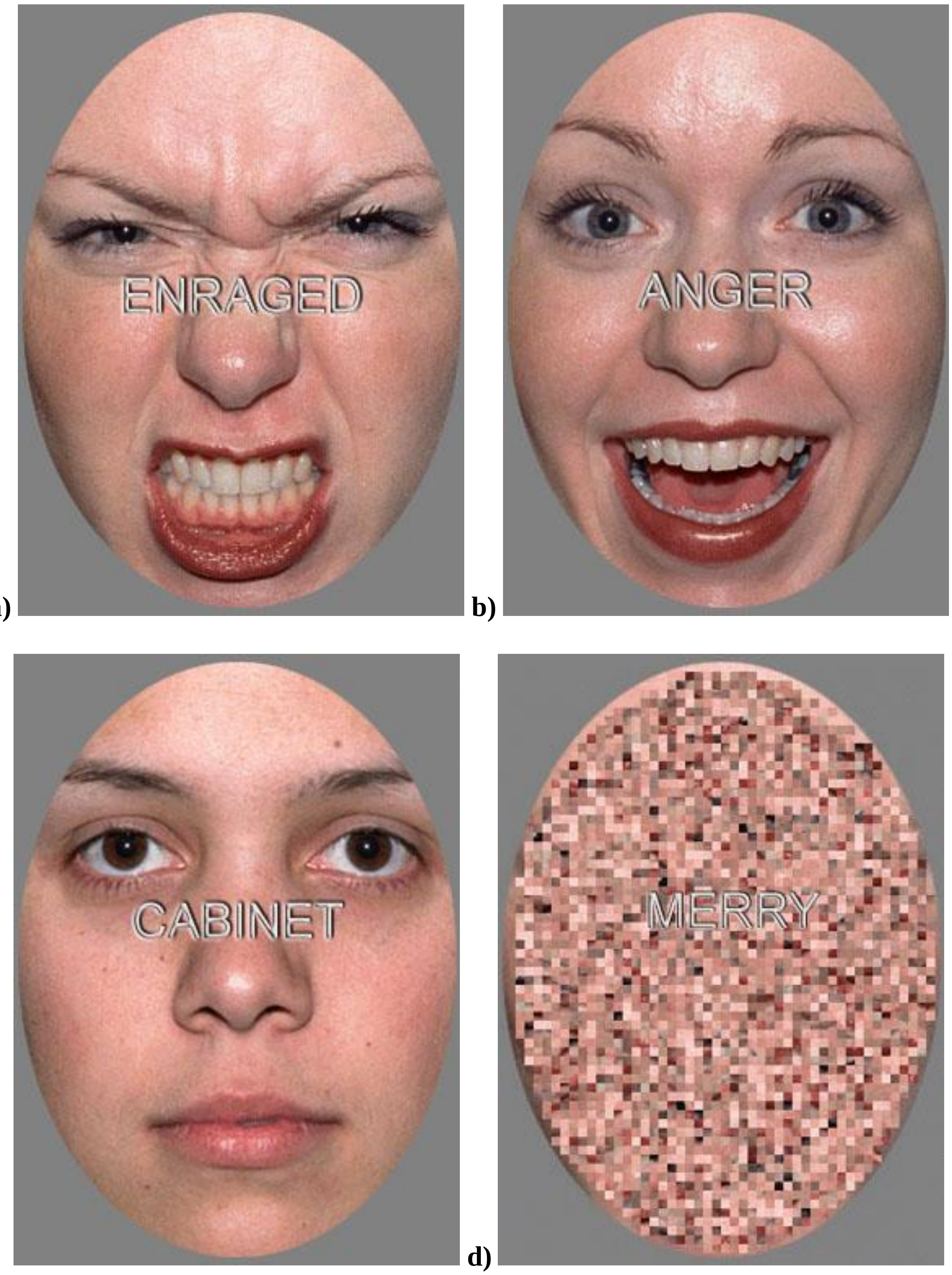
The face stimuli were photographs of calm, angry and happy expressions (as well as scrambled versions thereof) selected from the NimStim set of facial expressions (Tottenham et al., 2009). I chose 9 Caucasian identities (4 females; models #01, 02, 03, 06, 22, 23, 24, 25, 34), which ensured legibility of the target words when overlaid on face and scrambled face distractors, respectively. In order to match angry and happy facial expressions of emotion on rated arousal I selected the open-mouth (angry faces) and exuberant (happy faces) versions (see Tottenham et al., 2009). For calm faces the closed-mouth versions were my preferred choice to provide a fairly neutral and non-arousing control condition (open-mouth expressions tend to be more arousing as established in pilot work). My decision to use happy and angry faces was based on two reasons: (1) their rater agreement, intensity ratings and reaction times were relatively similar (Palermo & Coltheart, 2004b) and (2) a sufficiently large number of well-matched words corresponding to these emotions could be identified (see Stevenson, Mikels, & James, 2007).[9] All faces were cropped to an identical elliptical form to remove hair, shape and background cues. Adobe Photoshop version 6 (Adope Systems Inc., San Jose, CA) was used for stimulus preparation. Scrambled versions were devised for each angry and happy face based on the

[9] These criteria of stimulus selection differ slightly from those for subsequent experiments as the pilot experiment had not yet been completed at this stage.

procedure from Conway, Jones, DeBruine, Little, & Sahraie (2008). Thus, the face images were divided into blocks of 8 x 8 pixels, which were then randomized in order to produce the scrambled images. This yielded a total of 18 scrambled faces (for examples see Figures 8 and 9).

My word stimuli were taken from the Affective Norms for English words database (ANEW; Bradley & Lang, 1999). The ANEW comprises a list of 1034 English words that were rated on the affective dimensions of valence, arousal and dominance using the Self-Assessment Manikin (SAM; Bradley & Lang, 1999). The SAM, initially reported by Lang (1980), consists of graphic representations that are arranged along 9-point bipolar scales for each of these dimensions. That is, for the valence dimension there are displays ranging from happy, satisfied figures at one end to unhappy, unpleasant ones at the other end; equivalent figures, depicting the relevant dimension, are presented for the other scales (arousal: figures ranging from "excited" to "calm"; dominance: figures varying from "dominant" to "in control"). Based on the categorical emotion ratings of the ANEW word list by Stevenson et al. (2007) a subset including words that were either assigned to the specific emotions of anger and happiness or not assigned to any emotional category (neutral) by both male and female raters was identified. The words from my neutral subset are not commonly associated with a specific gender and I therefore used these words for my non-gender trials, too. I also selected a set of common male and female forenames from UK census data (http://www.statistics.gov.uk/specials/babiesnames_boys.asp; http://www.statistics.gov.uk/specials/babiesnames_girls.asp). Using the norms from the English Lexicon Project (Balota et al., 2007), all words were balanced on word length, the Kučera and Francis (1967) frequency norms, the log-transformed Hyperspace Analogue to Language (HAL) frequency norms (Lund & Burgess, 1996), orthographic neighbourhood (Coltheart, Davelaar, Jonasson, & Besner, 1977), the number of syllables, the mean lexical decision latency, the proportion of accurate responses for a particular word in a lexical decision and in a naming task, and the mean naming latency. Treating each of the foregoing lexical characteristics as the dependent variable, I conducted Between-Subjects ANOVA's with word type as factor (angry-related, happy-related, neutral, male-related and female-related). None of these tests reached statistical significance (all ps > .1), suggesting that the different word types from my set are comparable on these lexical criteria. Two Between-Subjects ANOVA's with emotional word-type as factor (angry-related, happy-related and neutral) revealed statistically significant effects of arousal ($F(2,23) = 43.05$, $p < .001$, $\omega = .88$) and valence ($F(2,23) = 135.81$, $p < .001$, $\omega = .96$). Pairwise comparisons with Bonferroni correction showed that angry (Mean = 6.64 (arousal); Mean = 3.05 (valence)) and happy (Mean = 6.44 (arousal); Mean = 8.14 (valence)) words exhibited similar arousal ratings ($p = 1.0$; 95% CI -.10; .61), but differed from each other on valence ($p < .001$, 95% CI 4.29; 5.90). Neutral words (Mean = 4.04 (arousal); Mean = 5.51 (valence)) differed significantly from angry and happy words on arousal (ps < .001; 95% CIs: -3.19; -1.58 (happy); -3.38; -1.77 (angry)) and valence (ps < .001, 95% CIs: -3.39; -1.79 (happy); 1.70; 3.31 (angry)). Overall, these analyses yielded a final set with eight words for each word type (i.e. angry-related, happy-related, neutral, male-related, and female-related words; see appendix 2 for full list and ratings).

The word-face Stroop stimuli were created by overlaying a word in the central area of a face (i.e. around the nose, which is known for not being a critical region of the face for recognition and discrimination of angry and happy faces (Fox & Damjanovic, 2006; Smith, Cottrell, Gosselin, Schyns, & Gosselin, 2005)). Each face type (angry (male/female), happy (male/female), calm (male/female) and scrambled was paired with each word type (angry-related, happy-related, neutral, male-related, and female-related words). In the emotion decision task only angry-related, happy-related and neutral words were overlaid on the face stimuli, whereas in the gender decision task only male-related, female-related and neutral words were used for this purpose. The target words were capitalized in grey Arial Font (point size 30) and rendered in a smooth pillow emboss style to enhance their legibility (Figures 8 and 9). Stimuli subtended 10.96°x 7.84° of visual angle (in height and width, respectively).




a) b) c) d)

**Figure 8.** Example stimulus display for the emotion decision task (no male faces shown due to copyright). a) compatible for angry target, b) incompatible affect for angry target, c) compatible for neutral target and d) incompatible scrambled for happy target.

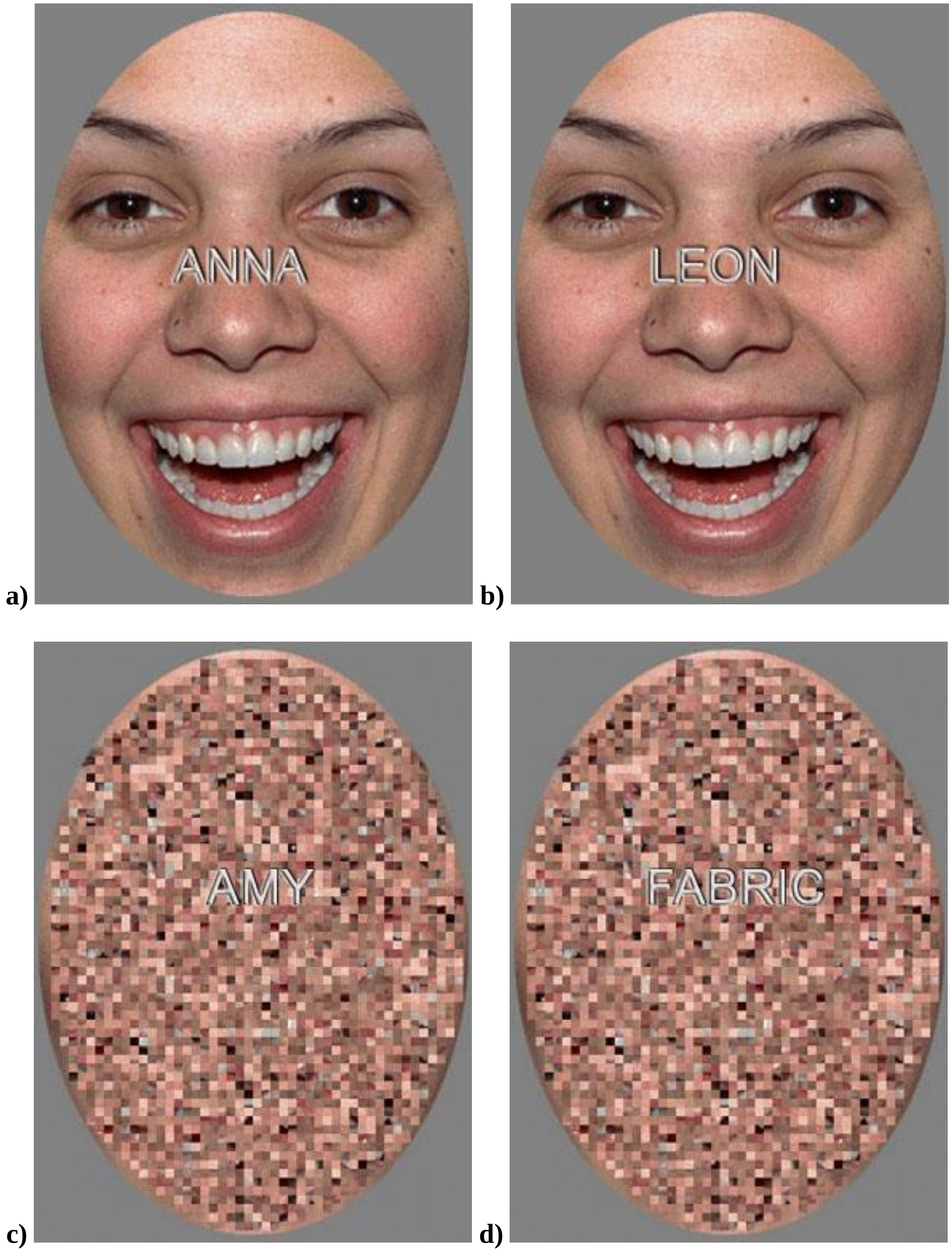



**Figure 9.** Example stimulus display for gender decision task (no male faces shown due to copyright). a) compatible happy for female target, b) incompatible happy for male target, c) incompatible scrambled for female target and d) compatible scrambled for neutral target.

The same questionnaires as in the Face Flanker paradigm were used with the addition of several other measures, including the Attentional Control Scale (ACS; Derryberry & Reed, 2002; the remaining measures were for the purpose of another study and are thus not reported here). Broadly speaking, the ACS assesses, on a scale from 1 (almost never) to 4 (always), an individual's ability to focus attention and ignore distracters; more specifically, it measures one's overall capacity for attentional control (e.g. "When concentrating, I can focus my attention so that I become unaware of what's going on in the room around me"; maximum score: 80; minimum score: 20), but can also provide measures for three subfactors (attentional focus, attentional shift and flexible thought control; Derryberry & Reed, 2002). My analyses concentrated on the overall capacity factor, which was computed by summing the scores for all items (i.e. high score = high attentional control). The ACS has been shown to have good internal reliability (i.e., $\alpha = .88$) and to predict resistance to interference in Stroop-like spatial conflict tasks as well as attentional disengagement from threat stimuli among highly anxious people (Derryberry & Reed, 2002). Furthermore, Sulik et al. (2010) demonstrated that self-report and performance-based measures (e.g. Stroop task) of attentional control were indicators of a single latent attentional control construct.

**Procedure**

Participants signed up using the online EMS system in exchange for cash or course credit as in the Face Flanker paradigm. This procedure was also followed for all subsequent experiments. For the word-face Stroop task they were instructed to discriminate the target words and to ignore the distractor faces. Responses should be given as fast and accurate as possible and could be indicated using the “c”, “v” and “b” keys – stimulus-response mapping was counterbalanced across participants. In the session pertaining to the emotion decision participants needed to determine whether the target word was “pleasant” (= happy-related[10]), “unpleasant” (= angry-related) or “non-emotional” (= neutral); response labels for the gender decision task were: “male” (= male-related), “female” (= female-related) or “non-gender” (= neutral). These response labels, as opposed to labels such as “angry” or “happy”, were chosen intentionally so that no one target word (e.g. angry or anger) mapped or closely mapped onto the response when others did not (e.g. frustrated). During training, feedback on the accuracy of participants’ decision was provided at the end of each trial and participants were asked to use this to improve the accuracy of emotion/gender labelling.

There were 12 unique trial types derived from the factorial combination of word type (angry-related, happy-related, neutral) and compatibility (compatible, incompatible affect, incompatible calm, incompatible scrambled)[11] for the emotion decision task and 21 separate trial types based on the combination of word type (male-related, female-related, neutral), compatibility (compatible, incompatible) and emotion (angry, happy, calm[12], scrambled[13]) for the gender session. In compatible trials the emotion/gender of the word type and face were part of the same emotion/gender category (e.g. target word: happy-related; distractor face: happy); in incompatible trials word type and face were not part of the same emotion/gender category (e.g.

[10] These label “descriptors” were not made explicit to participants, only those in quotes (e.g. “pleasant”, “unpleasant” etc.) were.

[11] For neutral target words the compatibility labels were as follows: compatible = compatible calm; incompatible affect = compatible scrambled; incompatible calm = incompatible angry; incompatible scrambled = incompatible happy.

[12] Due to calm expressions combining both emotional (calm) and gender (male, female) information, they could, in some cases, be both compatible (e.g. neutral target and calm (male) face) and incompatible (e.g. neutral target and male (calm) face) at the same time – incompatible elements are shown in parenthesis in the examples.

[13] Scrambled faces could not be assigned to a particular face gender type.

target word: happy-related; distractor face: angry). Over the course of the experiment there were 288 compatible trials (33%) and 576 incompatible ones (66%), resulting in 864 trials for the experimental phase per session. In other words, for the emotional decision task there were 72 trials for each of the 12 conditions. Based on this, Stroop intereference scores can be computed by subtracting performance on compatible trials from that of incompatible ones (see Chapter 1 and Introduction for further details).

The gender decision task, by contrast, consisted of 32 trials for each condition with female distractor faces (9 trial types), 40 trials for each condition with male distractor faces (9 trial types) and 72 trials for each condition with scrambled distractor faces (3 trial types). Trials were presented in random order with the randperm function in Matlab® (MathWorks, Natick, MA) and every 144 trials participants were given the chance to take a break for as long as needed. Furthermore, for each session there was one practice block where only the word stimuli were displayed (to improve participants' accuracy in emotion/gender discrimination of the word stimuli) and another practice block consisting of a shortened version of the experimental phase (144 trials per practice block). Thus, participants completed 1152 trials per session (25% compatible trials, 50% incompatible trials; 25% of ambiguous compatibility[14]).

Trials started with the presentation of the fixation cross for 508ms to indicate where participants should focus their gaze followed by the experimental stimuli. Participants' responses to the experimental stimuli were self-paced, but the stimuli were only shown for the duration of 1000 ms. Prior to the next trial feedback in the form of the words “correct”/”incorrect” presented in white upper case letters in Courier New type (font size 25) was displayed for 603ms. The total time for the experimental phase of one session was therefore around 30 minutes. Participants were asked to complete the questionnaires in between sessions 1 and 2; sessions 1 and 2 were

[14] See footnote 10

run on two separate days whereby the order of the session (gender versus emotion) was counterbalanced. Moreover, due to the large number of stimuli with scrambled faces (i.e. each facial expression of emotion had a scrambled counterpart) I counterbalanced the scrambled stimuli for each task whereby half of the stimuli for one word type were shown to one group of participants and the other half to the other group. There was a full debrief at the end of the experiment.

**Results.**

*1) Pre-processing for all Word-Face Stroop tasks*

Three participants were excluded due to technical errors with the experiment and one further participant was removed for failing to complete the second part of the study. I ran an identical pre-processing procedure to that of the Face-Flanker paradigm for the remaining participants with calculation of mean RT, RT SDs and mean ACC, outlier removal at subject and group levels (+/- 2.5 SD from mean; here: less than 15% of outliers) and normalisation. Due to error rates usually being slightly larger than 10%, I, again, computed a measure that linearly accounts for speed accuracy trade-offs (= ART; Townsend & Ashby, 1983). Consequently ART will be my measure of choice for reporting performance in the Word-Face Stroop experiment.[15]

2) ANOVAs

I predicted that a slowing in performance should be observed for threatening information, particularly when the threat poses distracting information. Furthermore, I expected this distraction effect to be attenuated with increased task demand (gender decision task). To test

[15] Largely similar trends are observed for RT and ACC data.

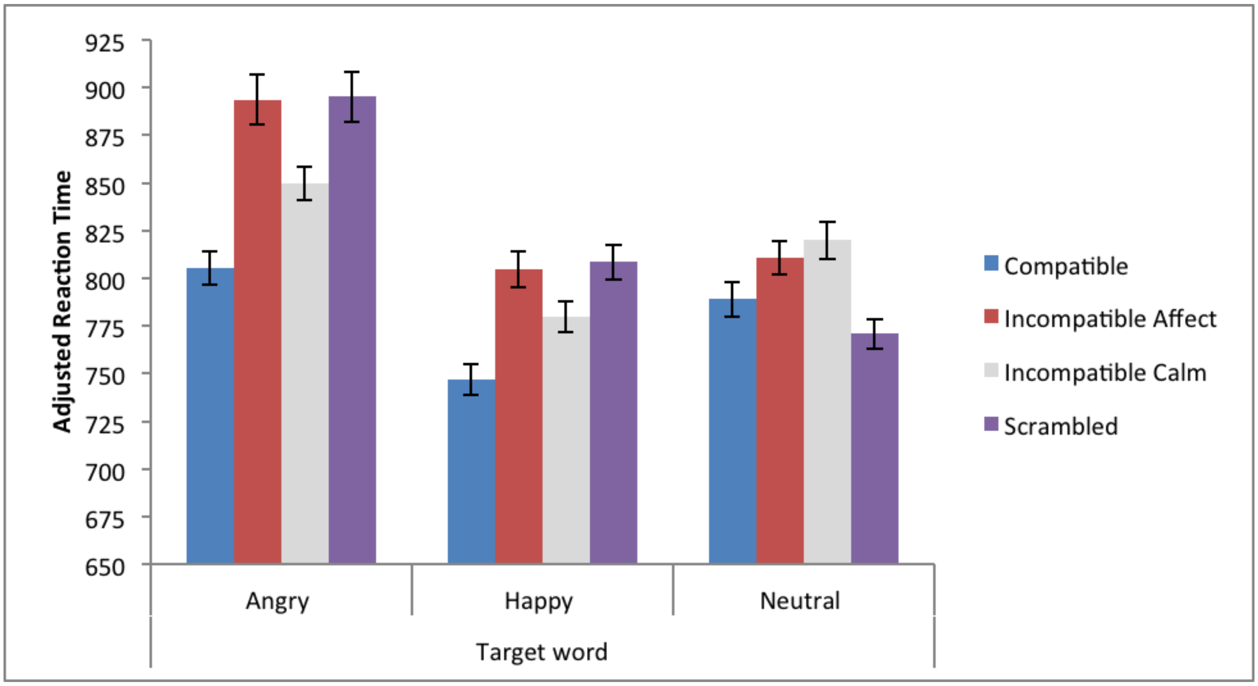
these predictions, first, a Within-Subjects ANOVA was performed on the emotion decision task with word type (angry-related, happy-related, neutral) and compatibility (compatible, incompatible affect, incompatible calm, scrambled) as factors. Results showed statistically significant main effects of word type ($F(2, 114) = 22.13$, $p < .001$, $\eta_p^2 = .28$) and compatibility ($F(3, 171) = 26.66$, $p < .001$, $\eta_p^2 = .32$) as well as a word type X compatibility interaction ($F(6, 342) = 12.63$, $p < .001$, $\eta_p^2 = .18$). Pairwise comparisons using Bonferroni correction revealed that all comparisons of compatibility at the different levels of word type reached statistical significance ($p < .05$), with the exception of incompatible affect versus scrambled trials for both angry ($p = 1$; 95% CI -39.35; 36.34) and happy targets ($p = 1$; 95% CI -37.36; 29.18) as well as incompatible happy versus incompatible angry ($p = 1$; 95% CI -33.20; 14.59) and compatible versus scrambled trials ($p = .34$; 95% CI -7.28; 43.32) for neutral targets.

For the gender decision task, to focus on the key variables of interest, I first performed a 2 (word type: male-related, female-related) X 2 (compatibility: compatible, incompatible) X 2 (distractor emotion: angry, happy) Repeated-Measures ANOVA. Results showed a significant main effect of compatibility ($F(1, 56) = 69.15$, $p < .001$, $\eta_p^2 = .55$), with the main effects of word type ($F(1, 56) = 2.36$, $p = .13$, $\eta_p^2 = .04$) and distractor emotion ($F(1, 56) = .45$, $p = .51$, $\eta_p^2 = .01$) not reaching significance. This main effect was qualified by significant word type X compatibility ($F(1, 56) = 22.96$, $p < .001$, $\eta_p^2 = .29$) and word type X distractor emotion ($F(1, 56) = 11.07$, $p = .002$, $\eta_p^2 = .17$) interactions; the compatibility X distractor emotion ($F(1, 56) = 1.58$, $p = .21$, $\eta_p^2 = .03$) and word type X compatibility X distractor emotion ($F(1, 56) = .50$, $p = .48$, $\eta_p^2 = .009$) interactions were not significant. Pairwise comparisons (Bonferroni corrected) revealed that compatible trial-types were significantly faster than incompatible ones for both male ($p < .001$, 95% CI -92.20; -57.84) and female ($p < .001$, 95% CI -55.69; -27.61) target words.[16] Moreover, whereas happy distracters slowed performance for male targets ($p = .01$, 95% CI -39.61; -4.96), for female targets angry distracters slowed responses ($p < .04$, 95% CI -28.95; -.67).

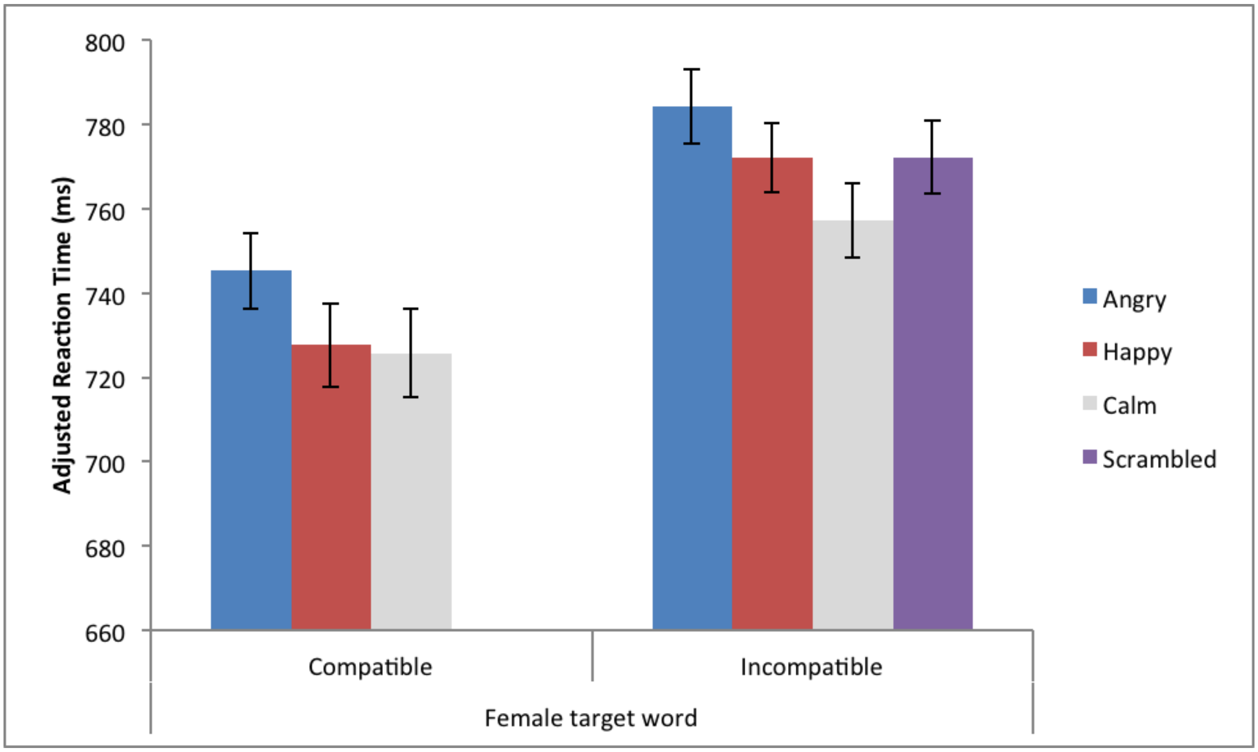
Next, I conducted a full 3 (word type: male-related, female-related, neutral) X 7 (compatibility: compatible angry, compatible happy, compatible calm, incompatible angry, incompatible happy, incompatible calm, scrambled) Repeated-Measures ANOVA including all trial-types for the gender decision task. I obtained a statistically significant main effect of compatibility ($F(6, 336) = 19.8$, $p < .001$, $\eta_p^2 = .26$) as well as a word type X compatibility interaction ($F(12, 672) = 8.8$, $p < .001$, $\eta_p^2 = .14$); the main effect of word type did not reach statistical significance ($F(2, 112) = 1.2$, $p = .31$, $\eta_p^2 = .02$). Pairwise comparisons (Bonferroni corrected) demonstrated that for male and female target words compatible trial-types were significantly faster compared to incompatible trial-types of the same emotion (all $ps < .01$) as well as to scrambled trials (all $ps < .001$). The only exceptions to this trend were the comparisons of compatible calm versus incompatible calm and compatible angry versus scrambled trials (both for female targets), which were marginally significant ($p = .11$, 95% CI -66.35; 3.01) and non-significant ($p = .34$, 95% CI -61.46; 7.60), respectively. Furthermore, for male target words incompatible happy trials were significantly different from scrambled trials ($p = .03$, 95% CI 2.40; 82.99) whereas incompatible angry trials were marginally significantly different from incompatible calm trials for female targets ($p = .06$, 95% CI -.460; 54.10). Finally, for neutral target words performance for both compatible calm female ($p = .01$, 95% CI 3.53; 56.56) as well as incompatible happy female distracters ($p = .03$, 95% CI 1.43; 61.68) was significantly slower than that for scrambled faces while performance for incompatible angry female distracters was

[16] The interaction effects seem to be mainly due to the differences between male versus female targets at compatible and incompatible trial types.

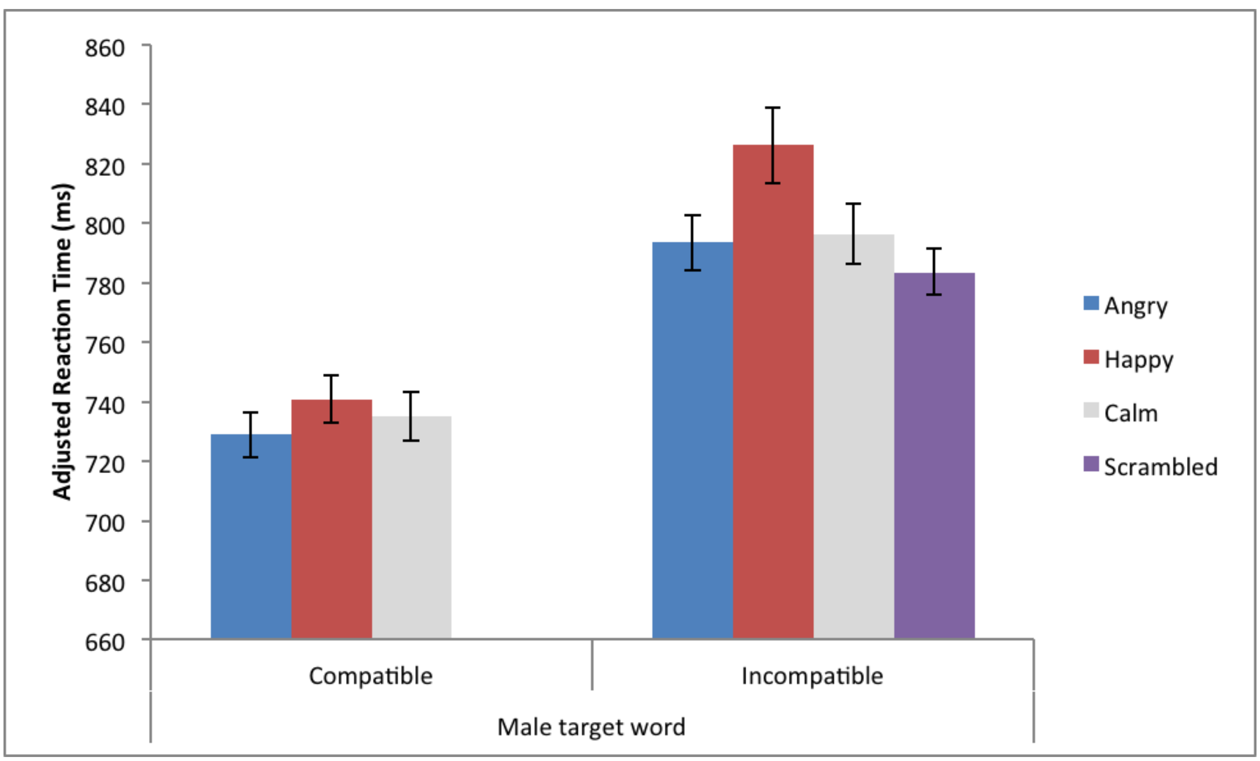
marginally significantly slower (p = .10, 95% CI -2.24; 61.20). All other comparisons with respect to compatibility at neutral targets were statistically non-significant (all ps > .60). Mean (SE) ARTs for both emotion and gender decision tasks are shown in Figure 10.




a)


800
780
760
740
720
700
680
660
Adjusted Reaction Time (ms)
Angry
Happy
Calm
Scrambled
Compatible
Incompatible
Female target word

b)


860
840
820
800
780
760
740
720
700
680
660
Adjusted Reaction Time (ms)
Angry
Happy
Calm
Scrambled
Compatible
Incompatible
Male target word

c)

d)

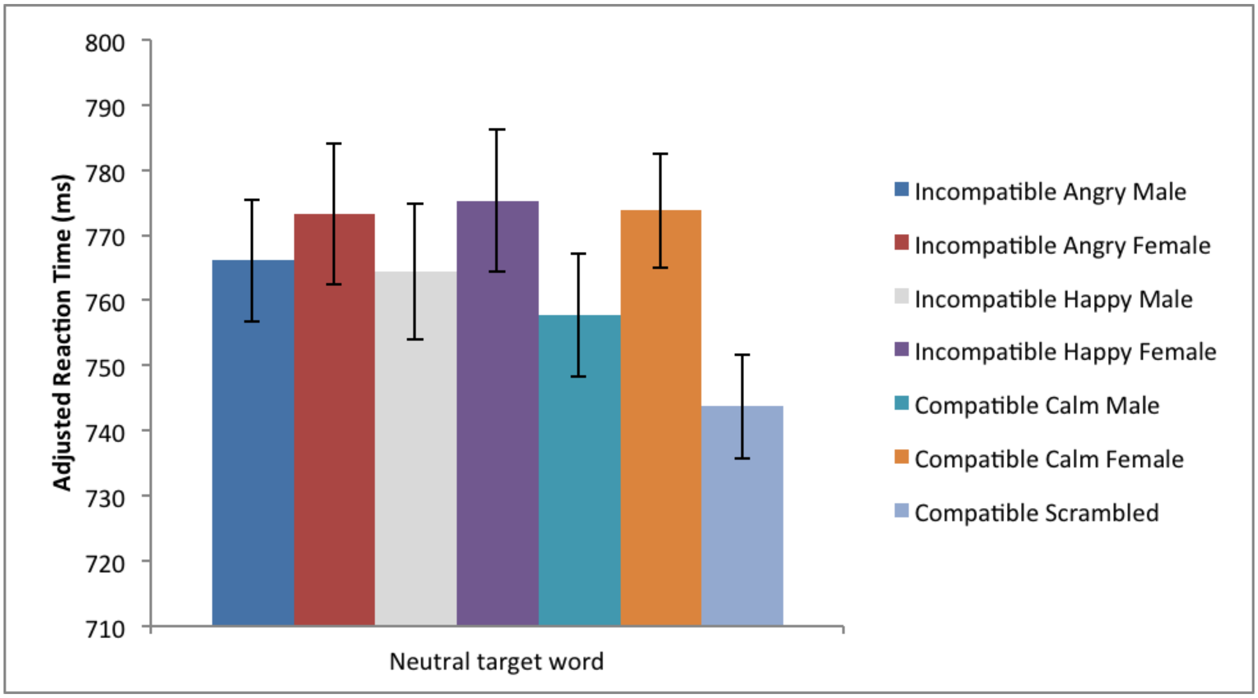



**Figure 10.** Means (SEs) for all conditions of the emotion and gender decision tasks. (a) emotion decision task, (b) gender decision task: female target words, (c) gender decision task: male target words, (d) gender decision task: neutral target words. *Note*: For neutral targets incompatible affect = incompatible happy and incompatible calm = incompatible angry.

*3)* Individual difference analyses

To summarise, analyses for the emotional decision task revealed strong compatibility effects, with performance on incompatible trial-types being slower than that on compatible ones. Of interest was whether threatening (i.e. angry) distracters would impair performance more than other distracter types. Whilst threatening targets exhibited slowed performance, this main effect of word type interacted with compatibility. Threat distracters were found to produce effective interference effects. However, they did not impair performance more than happy distracters for neutral targets and, crucially, happy distracters in fact slowed performance for angry targets more than did angry distracters for happy targets, as revealed in a direct comparison of the relevant angry and happy compatibility scores (see footnote 17 for more details about the scores; paired-samples t-test: $t(57) = 2.24$, $p = .03$, $r = .28$). This suggests that, for this particular task, threat impairs performance when a target, but that happy (relative to angry) distracters produce a similar amount of interference (see results for neutral targets), if not more (see results for angry targets).

For the gender decision task I found that target gender and distracter emotion interacted, with happy distracters impeding performance for male targets and angry distracters similarly for female targets. In an additional, and more elaborate, analysis of this task it was revealed for male and female targets that, generally, compatible trial-types were faster than the incompatible equivalent of the same distracter emotion. Moreover, in tendency the various compatible trials did not differ from each other – likewise for the incompatible ones. For neutral targets, trials with female distracters differed from those with scrambled distracters (this was not found for male distracters, which did not differ from scrambled images). In short, the main finding for the gender decision task is that compatible trial-types were faster than their incompatible counterparts of the same distracter emotion. Also, whilst distracter emotion, largely, did not seem to have an impact on the findings of compatibility, distracter emotion, regardless of compatibility, had an effect on responding to targets.

I predicted that as the level of trait neuroticism rises, interference from threatening material as well as intra-individual variability increase (i.e. greater compatibility scores – see below for further details). Furthermore, I expected that the influence of neuroticism on the appraisal of threat (based on mean response latencies and RT SD measures) is lessened under high task demand and in those with adequate reappraisal (or attentional control) skills. I created Stroop interference scores for each of the various target words by subtracting the mean ART of compatible from that of incompatible trials[17], such that higher scores represented enhanced interference from incompatible material – analogous scores were computed for the RT SD data. Next, I performed a series of Pearson correlation analyses between neuroticism, attentional control, state and trait anxiety and reappraisal versus these Stroop interference effect measures (for both mean ART and RT SD scores). However, against predictions, none of these correlations reached statistical significance (all ps > .05).

Using the MODPROBE macro of Hayes and Matthes (2009) for SPSS® (IBM corp., Armonk, NY), I probed the potential moderating/buffering effect of reappraisal and attentional control (M) on the relationship between neuroticism (focal predictor) and Stroop interference scores (i.e. emotion decision task: affective incompatible angry minus compatible angry (outcome variable 1) and affective incompatible happy minus compatible happy (outcome variable 2) for both mean ART as well as RT SD scores). In an attempt to control for potential confounding factors of this association either the reappraisal or the attentional control measure ($W_1$) was added as a covariate (i.e. whichever of these measures did not act as a moderator in a particular analysis) to the regression model together with the predictors so that its possible impact on regression coefficient estimates could be controlled. The MODPROBE provides the amount of variance in the effect that is solely accounted for by the interaction; it also provides the squared multiple correlation for the full model, which contains the expression of the

[17] For the gender decision task the following interference scores were created: compatible neutral targets (distractor gender: male or female – no gender for scrambled images; distractor emotion: calm or scrambled) were subtracted from incompatible neutral targets (distractor gender: male or female; distractor emotion: angry or happy). Moreover, compatible male targets (distractor gender: male) were subtracted from incompatible male targets (distractor gender: female), with both minuend and subtrahend always having the same distractor emotion (i.e. angry, happy or calm) – this was done analogously for female targets. For the emotional decision task the compatibility scores were: (1) compatible angry targets (distractor emotion: angry) were subtracted from incompatible angry targets (distractor emotion: happy, neutral or scrambled), (2) compatible happy targets (distractor emotion: happy) were subtracted from incompatible happy targets (distractor emotion: angry, neutral or scrambled), (3) compatible neutral targets (distractor emotion: neutral or scrambled) were subtracted from incompatible neutral targets (distractor emotion: angry or happy).

interaction. In addition to generating a general regression output, the MODPROBE determines the impact of the focal predictor on the outcome variable at different scores of the moderator (see Hayes & Matthes, 2009). Predictor and moderator variables were not mean centred as this is only necessary for more complex models involving multiple predictors and interactions (Hayes & Matthes, 2009; Hayes, 2005). By default the MODPROBE macro computes the conditional effects of the focal predictor at three levels of the moderator, that is at high (= + 1 SD on the mean), moderate (= mean) and low (= - 1 SD on the mean) scores. In order to visualize significant interactions the macro, in line with the foregoing procedure, divided participants in my study into three separate groups of high trait reappraisal, moderate trait reappraisal and low trait reappraisal. Counter to my predictions, however, no significant moderation effects were found (mean ART data: reappraisal (M): $b = -.11$, $t(53) = -.10$, $p = .92$ (outcome variable 1); $b = -.18$, $t(53) = -.31$, $p = .76$ (outcome variable 2); attentional control (M): $b = -1.30$, $t(53) = 1.71$, $p = .09$ (outcome variable 1); $b = .51$, $t(53) = 1.26$, $p = .22$ (outcome variable 2); RT SD data: reappraisal (M): $b = .48$, $t(53) = 1.20$, $p = .24$ (outcome variable 1); $b = .04$, $t(53) = .39$, $p = .91$ (outcome variable 2); attentional control (M): $b = .51$, $t(53) = .31$, $p = .11$ (outcome variable 1); $b = -.06$, $t(53) = .31$, $p = .85$ (outcome variable 2)); exploratory analyses with the remaining Stroop interference measures did not yield any significant moderation effects either (all ps > .05).

**Discussion.**

It was hypothesized that threatening information impairs performance, with such interference as well as increased intra-individual variability being particularly prominent in individuals with high trait neuroticism. At the same time, it was expected that attentional bias would be reduced under high task demand as well as for individuals of high reappraisal or attentional control skills. The results demonstrated that response latencies on compatible trials were faster compared to those of incompatible trial types. Moreover, whilst threat diminished target performance, happy distracters exerted at least equally strong (if not, in fact, stronger) interference effects than threatening material when emotion was task-relevant. In contrast, when emotion was task-irrelevant it was found that happy distracters hindered performance for male targets, whereas angry distracters did so for female targets – effects of emotion on interference were not observed under high task demand. Against expectations, no significant links between Stroop measures and individual differences were revealed.

The finding that happy distracters slow responses to male targets and, similarly, angry distracters slow responses to female targets can be considered to be in line with previous research, which finds that male faces tend to be more readily associated with anger, whereas females faces tend to be related to happiness (Becker, Kenrick, Neuberg, Blackwell, & Smith, 2007; Williams & Mattingley, 2006). One could therefore argue that the slowed performance to male targets with happy distracters was observed because happy distracters could be conceived as being incompatible with male targets (male faces would be compatible with angry faces). Likewise for the results with female targets, here angry faces can be considered as incompatible distracters, thereby slowing performance.

Based on theoretical accounts (e.g. Pessoa, 2009) it was unexpected to find that happy distracters impaired performance similarly to angry distracters in some cases and worse in others, although it might be explained, to some degree, by the notion of enhanced early sensory representations for low arousing material. Moreover, it has been shown in various studies that happy faces are particularly salient (e.g. due to the mouth region; Calvo & Lundqvist, 2008; Calvo & Marrero, 2009; Calvo & Nummenmaa, 2008; Calvo, Nummenmaa, & Avero, 2008; Damjanovic et al., 2010; Miyazawa & Iwasaki, 2010; Poirier & Faubert, 2012), thus often leading to enhanced detection. This study tried to address such perceptual factors by selecting angry and happy faces with open mouths, thereby ensuring a similar amount of teeth being displayed. However, the mouth region of angry versus happy faces also differs in other respects (e.g. the shape of the lips). So, even if the stimuli were relatively matched in terms of teeth white, it could be that other aspects of the mouth region (e.g. shape of lips) or face may be responsible for the effects obtained here. This cannot be conclusively answered with the current dataset and will need to be addressed in future work.

As for reappraisal, although late onset of instructed reappraisal has previously been linked to Stroop performance (Sheppes & Meiran, 2008), other research (McRae et al., 2012) has not found any associations between Stroop performance and reappraisal ability. It could thus be that Stroop performance is only linked to late onset of instructed reappraisal, but not necessarily a habitual form thereof. This would also be in line with proposals by Joormann and Siemer (2011) who suggest that cognitive control (e.g. Stroop performance) tends to be associated with late (as opposed to early) forms of reappraisal onset, suggesting that different forms of reappraisal might be differentially linked to cognitive control.

Although the main interference effects were in line with previous research (performance on incompatible trials slower), it was somewhat unexpected that performance for incompatible scrambled images did generally not differ from that of the incompatible affect conditions – previous research has revealed that performance on incompatible neutral trial-types is slower than that for the compatible condition, but faster than the incompatible affective condition (see e.g. Preston & Stansfield, 2008). It is conceivable that because scrambled images did not depict any facial expressions, whereas all other distracter stimuli did, that (a) they were more salient to participants and (b) more clearly identified with neutral targets. So, when exposed to other target types, participants might more readily notice the discrepancy between target and distracter (due to (a) and (b)), thereby leading to greater interference. By contrast, for neutral targets compatible scrambled images might be classified more rapidly as compatible due to (a) and (b), thereby leading to superior performance in this condition. This explanation can also be extended to account for the somewhat more prominent (although in most cases not statistically significantly so) interference effects from incompatible scrambled images in the emotion decision task – as compared to the interference effects in the gender decision task. That is, it seems possible that participants associated scrambled images more with a neutral emotion than with a neutral gender, thus resulting in somewhat greater[18] interference for angry- or happy-related (relative to gender) targets. Indeed, one could say that participants are more likely to encounter relatively neutral emotions in their daily lives compared to a neutral gender, supporting the idea that scrambled images are potentially more closely associated with a neutral emotion as opposed to a neutral gender. Ultimately, this speculation is subject to future investigation, however.

A limitation of these experiments is that calm faces could be perceived as ambiguous in nature in the gender decision task, whereby, for example, a male calm face may be compatible

[18] This possible difference was not tested for statistical significance.

(male distracter) with a male target, but at the same time incompatible (calm distracter). It is believed that this issue has been addressed to some degree in that scrambled images served as alternative controls. However, with scrambled images being rather "non-face-like" it is then difficult to distinguish whether any differential effects of emotion versus scrambled controls arose due emotional or facial features. Future research could address this problem by adopting a different categorisation task where such conflict does not emerge.

A further limitation of this experiment concerns the distribution of compatible versus incompatible trials. In both tasks (emotion and gender) the proportion of compatible trials was substantially lower than that of incompatible ones. This design feature may therefore have prevented a prepotent response tendency from being developed for compatible trials, thereby reducing the interference effects. Previous research has shown that interference effects are sensitive to the proportion of compatible trials, with diminished cost effects found when there is a large proportion of incompatible trials (Casey et al., 2000; Crump et al., 2006, 2008; Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; West & Baylis, 1998). It seems possible that such relatively reduced interference effects may have had an impact on the association (or the lack thereof) between the individual difference variables (particularly neuroticism) and threat appraisal. Future work needs to examine this issue more closely by using a task with a low proportion of incompatible (vs. compatible) trials.

It would be interesting for future research to explore the relationship between the Stroop task and other individual differences in more detail. For example, it could be of interest whether other traits relevant to emotional disorders, such as rumination or mindfulness, moderate the link between neuroticism and attentional bias. Moreover, it seems fruitful to further examine the potential links between Stroop performance and reappraisal. In a recent study Verbruggen, Adams and Chambers (2012) reported that engagement in a stop signal paradigm affected subsequent performance on a gambling paradigm. Applying this to the current task, one could, for instance, test the effect of Stroop performance on a subsequent online reappraisal paradigm, thus further examining the links between reappraisal and cognitive control.

Altogether then, this study revealed that, in line with the Dual-competition model (Pessoa, 2009), performance can be impaired in the face of threatening information. However, it was somewhat unexpected that positive information would lead to a similar, if not stronger, impairment in performance; early sensory representations of low arousing material (Pessoa, 2009) might provide a possible explanation for this finding. As predicted by the Mathews and Mackintosh model (Mathews et al., 1997; Mathews & Mackintosh, 1998), the impact of emotion was diminished under high task demand. Still, emotion was found to interact with performance towards gender targets in a way that can be considered to be in line with existing findings on the link between emotion and gender (Becker et al., 2007; Williams & Mattingley, 2006). Against expectations threat appraisal was not associated with individual differences as measured in this study. A number of reasons may account for this, including a large proportion of incompatible (relative to compatible) trials; several suggestions have been made to address such shortcomings in future studies. This study also adds to the literature on the links between neuroticism, emotion regulation and cognitive control, indicating that, at least under certain circumstances, it may not be possible to demonstrate a relationship between these variables. It will be the task of future research to further examine this issue.

This study has demonstrated that threat affects performance in distracter paradigm involving a prepotent response when only one face cue is displayed per trial. In the following chapter it will be explored if similar effects can be obtained when the distracter cue is spatially separated from the target, as in is the case in a related distracter interference task (Word-Face Flanker paradigm; Bindemann et al., 2005), and how performance on such a task might interact with different emotion-linked traits.

# Chapter 4: Selective attention to emotion in a Word-Face Flanker paradigm

## Introduction.

Encouraged by the findings from the Word-Face Stroop task where single distracting faces were shown to induce reliable interference effects, I set out to examine whether similar effects could also be obtained in an affective Flanker task, using words as targets and faces as distracters. This study would then aid in the interpretation of the affective Face-Flanker task, addressing the question of whether affective interference effects can be obtained when just one emotional face is used per trial.

As mentioned before, related work using photographs of facial expressions of emotion has revealed that the effects from face flanker paradigms are not particularly robust (Palermo and Coltheart, 2004) or even not statistically significant (Bindemann, 2004). Indeed, there is an emerging literature suggesting capacity limits in face processing in the flanker paradigm (e.g. Bindemann, Burton and Jenkins, 2005; Palermo and Rhodes, 2002; Brebner and Macrae, 2008). Notably, Bindemann et al. (2005) demonstrated that a face target-face flanker design did not produce reliable interference effects, whereas the combination word target-face flanker exhibited the strongest effects in a comparison of different combinations of face and non-face stimuli as targets and flankers. They concluded that the processing limits of faces in a flanker paradigm may be that of one face per trial. Similarly, word-face flanker interference effects have been shown in a classification task (e.g. gender classification; Brebner and Macrae, 2008). These findings suggest that an affective word-face flanker task is more likely to yield interference effects than its affective face-face counterparts. To the authors knowledge, such studies have not yet been published, however. Even though affective word-word flanker interference effects have already been reported by other researchers (e.g. Ochsner, Hughes, Robertson, Cooper and Gabrieli, 2009), it seems to be a particularly fruitful avenue to determine the generalisability of these effects to other affective material, such as by extending this work to facial expressions of emotion as in an affective word-face flanker paradigm. Since facial expressions of emotion are widely used in emotion research (e.g. Ekman and Friesen, 1976) and to further inform research on cognitive versions of the word-face flanker paradigm, they constitute a logical choice.

To this end I have devised six affective word-face flanker tasks: three tasks with an emotional decision versus three other tasks with a gender decision. As before, these two decision types were used as manipulations of task demand (higher task demand in the gender decision task). As for the emotional decision tasks, in one task participants were presented with angry-related and happy-related target words that were flanked by angry or happy facial expressions of emotion (Pleasant-Unpleasant task). In a second task angry-related and neutral target words were paired with angry, calm or scrambled faces (Unpleasant-Neutral task) and in a third task happy-related and neutral target words were paired with happy, calm or scrambled faces (Pleasant-Neutral task). In each of these tasks participants had to determine the emotional nature of the target word (depending on the task: pleasant, unpleasant, or neutral) whilst ignoring the distracter face. In contrast, in the gender decision tasks male-related versus female-related words were displayed as targets in one task (Male-Female task), along with male (angry, happy) and female (angry, happy) distracter faces. In a second task (Female-Neutral task) the target words (female-related and neutral) were shown along with various female (angry, happy and calm expressions) and scrambled distracter faces. The third gender decision task, the Male-Neutral task, was created analogously to the Female-Neutral task, only that female(-related) words/faces were replaced by male ones. So, in line with the target stimuli, in the gender decision task participants had to decide whether the targets were male-related, female-related or neutral as well as ignore the distracter faces.

This six-task-design had been adopted in order to avoid one choice component being easier than another, thus addressing a potential shortcoming of the affective Face-Flanker paradigm. To illustrate, if there had been all three word types (angry-related, happy-related and neutral) in a single task, it is conceivable that for neutral word types only a one step decision would be required ("emotional or neutral?"), whereas for the emotional word types at least two decision steps would be needed ("emotion or neutral?" as well as "angry or happy?") – similar arguments can be made regarding the gender decision (e.g. 1. "gender versus neutral?"; 2. "male or female?", with neutral stimuli only involving decision type 1. and gender stimuli involving both decisions, 1. and 2.). Tasks involving only two choices naturally circumvent this problem and were therefore deemed preferrable.

I predicted that threatening information would result in slowed performance. This attentional bias to threat is also expected to be further modulated by individual differences in neuroticism, with elevated levels of neuroticism leading to increased interference from threatening material as well as enhanced intra-individual variability. However, I expect that this is attenuated under high task demand as well as in individuals with high levels of trait reappraisal or attentional control.

**Methods.**
**Participants**

Participant recruitment and requirements were the same as for the Word-Face Stroop paradigm. However, in this study there were 67 participants (33 women) with a mean (SD; range) age of 21.7 (4.7; 18-47).

## Emotional decision tasks

### Stimuli

*Pleasant-Unpleasant task*

Stimulus presentation tools and software (Brainard, 1997; Pelli, 1997) were identical to those of the Word-Face Stroop task. Additionally, E-Prime® 1.0 (Psychology Software Tools Inc, Pittsburgh, PA) was used to run the automated version of the Ospan task (hereafter: Ospan; Unsworth, Heitz, Schrock, & Engle, 2005).

*Faces*

The face stimuli were photographs of angry and happy expressions selected from the NimStim set of facial expressions (Tottenham et al., 2009). Based on my own piloting work I selected 8 Caucasian identities (4 males; ID's: 01, 02, 05, 06, 22, 24, 25, 32) from the angry (open-mouth versions) and happy (exuberant versions) subsets[19]. These specific stimuli were identified for providing the best match on measures of arousal, valence, reaction time, accuracy, emotional intensity and rater agreement (see Appendix).

[19] Due to different selection criteria between this experiment and the Word-Face Stroop task some of the ID's used were different between these two experiments. Hence, full details are provided again.

There were largely three reasons for using happy and angry faces: (1) the results of my pilot study suggesting reasonable matching between these positive and negative emotions, (2) this rendered this task more comparable to the Word-Face Stroop task, facilitating potential comparisons across tasks and (3), same as for the Word-Face Stroop task, a sufficiently large number of well-matched words corresponding to these emotions could be identified (see Stevenson, Mikels and James, 2007). Stimulus preparation (i.e. cropping) was followed as in the Word-Face Stroop task.

*Words*

I utilised the identical matched word set of angry- and happy-related words as in the Word-Face Stroop task. The words were capitalized and presented in white 25-point Courier New font. The height for all words was 0.53˚ of visual angle. Words measured between 4.92° (longest word) and 1.41° (shortest word) of visual angle in width. Face stimuli subtended 3.26° x 2.64° of visual angle (in height and width, respectively). All word types (angry-related and happy-related) were displayed centrally as targets and were paired with each face distractor (angry (male, female) and happy (male, female)). Face distracters were randomly presented to the left or right of the target; the location was determined using the randsample function of the Statistics Toolbox in Matlab® (MathWorks, Natick, MA). A minimum inter-stimulus distance of 1.32˚ of visual angle was maintained on all trials.

*Unpleasant-Neutral task*

Stimulus development and presentation was identical to that of the Pleasant-Unpleasant task apart from the following differences.

*Faces*

The same angry faces as in the Pleasant-Unpleasant task were used as well as a set of 8 calm faces (open-mouth versions). The calm faces were from the same Id's, selected based on the same specifics outlined for the angry and happy faces above and underwent an identical stimulus preparation procedure. Calm faces were chosen to serve as a neutral face baseline whereas the scrambled stimuli constituted a purer non-emotional baseline that was otherwise identical to the emotional stimuli on perceptual characteristics. The scrambled faces of angry facial expressions were prepared in the same manner as for the Word-Face Stroop task by following the procedure from Conway et al. (2008).

*Words*

The angry-related and neutral words from the Word-Face Stroop task comprised my word stimuli in this experiment. Words measured between 4.92° (longest word) and 1.41° (shortest word) of visual angle in width. All word types (angry-related and neutral) were displayed centrally as targets and were paired with each face flanker (angry (male, female), calm (male, female) and scrambled).

*Pleasant-Neutral task*

This task is identical to the Unpleasant-Neutral task with the exception of the differences noted below.

*Faces and Words*

The happy faces from the Pleasant-Unpleasant task were selected as well as the calm faces from the Unpleasant-Neutral task. Moreover, for this experiment I prepared scrambled versions of happy faces (see Word-Face Stroop task for details of the procedure to devise scrambled images).

The happy and neutral word sets were used that had been identified for the two preceding tasks. Word width varied between 3.96° (longest word) and 1.41° (shortest word) of visual angle. Each of the target words (happy-related and neutral) was presented in the screen centre and was flanked by each face type (happy (male, female), calm (male, female) and scrambled).

**Questionnaire measures and Ospan**

I administered the same paper-based measures as in the Word-Face Stroop task. Additionally, participants were assessed on an automated version of the Ospan task (Unsworth, Heitz, Schrock, & Engle, 2005), which is a performance-based measure of attentional control, thus complementing the self-report data of the attentional control questionnaire with a measure that is less prone to response bias, for example. Here, participants needed to remember sets of 3-7 letters in the correct order for subsequent recall. Prior to the presentation of each letter (letters were shown individually) participants were required to solve simple math problems (e.g. (2*3) + 1 = ?). The main measures of interest were the absolute and the total Ospan scores, the former of which represents the number of correctly recalled sets, whereas the latter constitutes the number of correctly recalled letters. To illustrate, a set of 5 letters where 3 letters are correctly recalled and a set of 4 letters with perfect recall would yield an absolute Ospan score of 0 + 4, but a total Ospan score of 3 + 4. Thus, the higher the Ospan score (absolute or total) is, the higher is the measured working memory (WM) capacity. As revealed by Unsworth et al. (2005), the Ospan exhibited a reasonable convergence validity (mean r = .42) of a magnitude that would be expected based on correlations between other WM span measures. The Ospan further loaded substantially on a WM capacity factor (.68) and manifested decent alpha (α = .78) and test-retest (r = .83) reliabilities.

**Verbal intelligence: National Adult Reading Test (NART)**

The NART was also administered as a proxy-measure of verbal intelligence (Crawford, Stewart, Cochrane, Parker, & Besson, 1989; Nelson, 1982). The NART consists of 50 “untypical” English words in terms of their adherence to standard grapheme-phoneme correspondence rules (e.g. abstemious or debt). Participants’ task is to read out loud each of these words. The total number of errors in pronunciation is then used to estimate verbal IQ. The NART possesses excellent test-retest (Smith, Roberts, & Pantelis, 1998), split-half (Crawford, Stewart, Garthwaite, Parker, & Besson, 1988; Crawford, Parker, Stewart, Besson, & Lacey, 1989; Nelson, 1982), and high inter-rater reliabilities, as well as high construct validity and strong cross-validation with other measures of intelligence or verbal fluency (Bright, Jaldow, & Kopelman, 2002; Crawford, Moore, & Cameron, 1992; Crawford et al., 1989; Crawford et al., 1989). Furthermore, it has been linked to demographic indicators of intelligence, such as education and social class (Crawford, Allan, Cochrane, & Parker, 1990), although age, when controlled for by these other demographic variables, and sex do not particularly seem to affect NART performance (Crawford et al., 1988). The NART has been used in other studies of individual differences and cognitive control (e.g. Horn, Dolan, Elliott, Deakin, & Woodruff, 2003).

## Procedure

*Pleasant-Unpleasant task*

For the Pleasant-Unpleasant task participants were instructed to discriminate the target words and to ignore the face distractors. Participants needed to determine whether the word type was “pleasant” or “unpleasant”. Responses should be made as fast and accurately as possible by pressing the “H” and “J” keys with the index and middle fingers (one key was assigned to each finger).[20] Stimulus-response mapping was counterbalanced across participants. During training, feedback on the accuracy of their decision was provided at the end of each trial and participants were asked to use this to improve the accuracy of emotion labelling.

There were four different trial types derived from the factorial combination of word type (angry-related, happy-related) and compatibility (compatible, incompatible). In compatible trials the emotional valence of the word type and face was identical whereas in incompatible trials it was not. Each trial type was repeated 128 times in the experimental task, amounting to a total of

[20] It was deemed that this key arrangement might be somewhat more comfortable for participants as it was not on the “edge of the keyboard” as in the foregoing experiment (i.e. c, v, b).

512 trials (50% compatible trials; 50% incompatible trials). As described before, Flanker compatibility scores were computed by subtracting performance on compatible trials from that on incompatible ones (see Chapter 1 and 2 for further details). Trials were presented in random order, as determined by the randperm function. There was one practice block (100 trials) where only the word stimuli were displayed (to improve participants' accuracy in emotion discrimination of the word stimuli) and another practice block consisting of the actual experimental task (also 100 trials). Thus, participants completed 712 trials for this task altogether.

Trials started with the presentation of the fixation cross for 500ms, followed by the target-distractor display. Participants' responses to the experimental stimuli were self-paced, but the stimuli were only shown for a duration of 600 ms. Prior to the next trial feedback was displayed for 250 ms. This was accomplished by presenting the fixation cross in green font colour (correct response) or red font colour (incorrect response), respectively. On completion of every 128 trials participants could take a break for as long as needed. The total time required for this task was approximately 16 minutes.

*Unpleasant-Neutral task*

The procedure for this task was identical to that of the Pleasant-Unpleasant task, except for the following differences. Here, the task was to decide whether the target words were “unpleasant” or “neutral”. The potential response keys were “H”, “J” and “Space”, with “Space” (always being mapped onto neutral target words) and one of the other two keys was selected for each participant. The selection of keys was carried out such that across the three emotional decision tasks no single key was mapped onto more than one target stimulus per participant. For example, if in the Pleasant-Unpleasant task the “H” key was associated with unpleasant target words, this would also be the case for the Unpleasant-Neutral task. Moreover, the “Space” bar was to be pressed using the thumb, whereas the “H” and “J” keys were to be pressed using the index and middle fingers respectively or vice versa depending on participants’ handedness. To illustrate, a right-handed participant would always press the “H” key using the index finger and the “J” key using the middle finger, this mapping was reversed for left-handed participants. I adopted this procedure for ease and speed of responding and to maximise recording participants’ “true” performance ability, thus avoiding, for example, that participants would need to respond with their non-dominant hand or fingers.

There were 6 unique trial types based on the factorial combination of word type (angry-related or neutral) and compatibility (compatible, incompatible calm, incompatible scrambled[21]). To ensure an even split between angry and neutral (including calm and scrambled faces) stimuli in the experimental task, trial types including angry faces were repeated 128 times and scrambled and calm faces were repeated 64 times. Overall, this, again, amounted to 512 experimental trials and 712 trials in total (16 minutes). Of all trials 50% were compatible and 50% incompatible. However, given the split of trials between angry versus neutral (i.e. calm and scrambled) distracter types, 25% of all angry distracters were compatible and 25% incompatible. For calm distracters 12.5% were compatible and 12.5% incompatible – likewise for scrambled distracters, therefore also resulting in, altogether, 25% compatible and 25% incompatible trials for neutral distracters.

[21] For neutral stimulus types the compatibility categories were as follows: compatible = compatible scrambled, incompatible calm = compatible calm, incompatible scrambled = incompatible.

*Pleasant-Neutral task*

This procedure was the same as the Unpleasant-Neutral task, except that this time participants decision on targets was between “pleasant” and “neutral” word types and that the angry faces were replaced by happy expressions. The Pleasant-Unpleasant, Unpleasant-Neutral and Pleasant-Neutral tasks were presented in random succession, the order of which was established using the randsample function. For examples of the different trial types in the emotional decision tasks, see Figure 11.

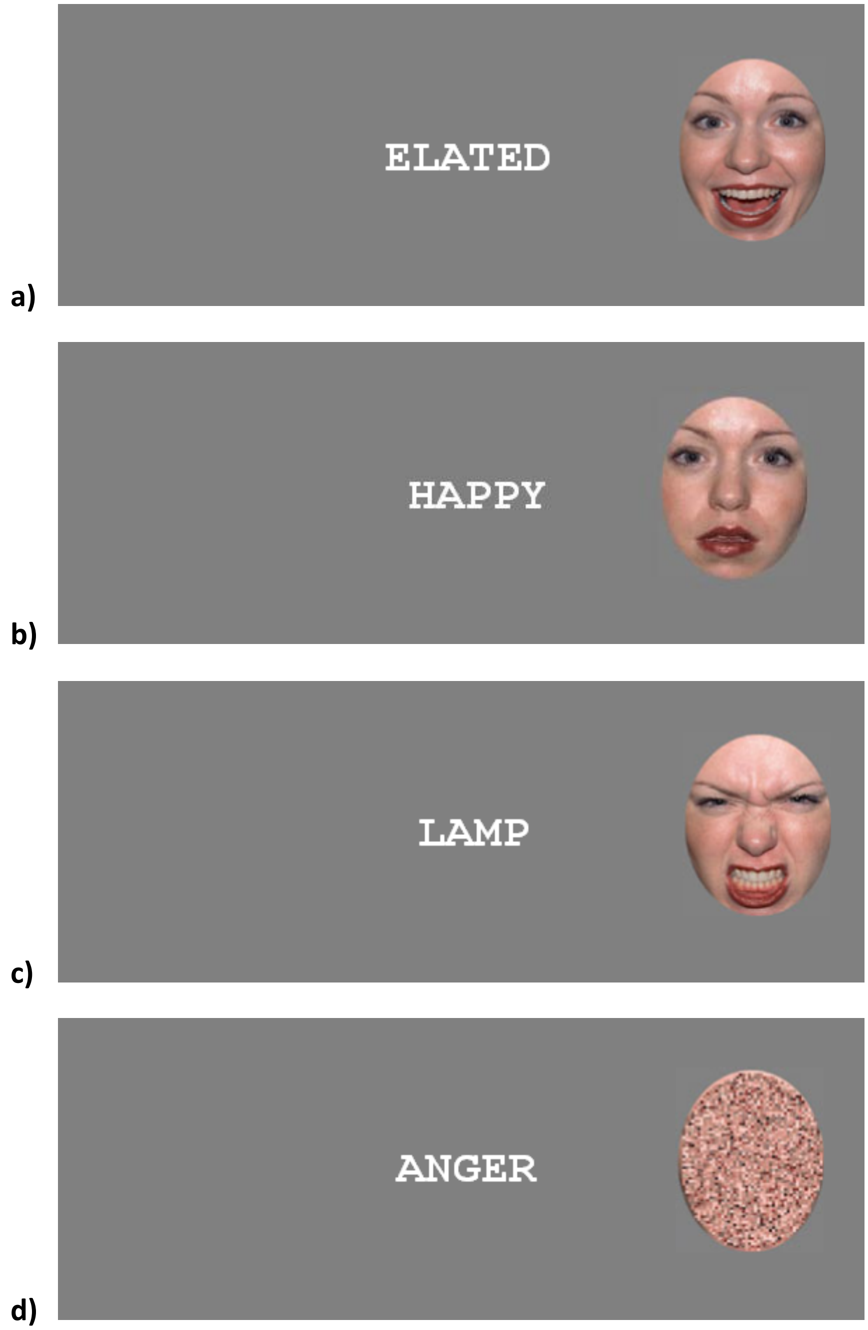



**Figure 11.** Example displays of trial types in the emotional decision tasks (flankers were presented to the left or right of the target on any one trial). a) happy-related target word flanked by a happy, female distractor face (compatible), b) happy-related target word with a calm, female distractor face (incompatible calm), c) neutral target word flanked by an angry, female distractor face (incompatible), d) angry target word with a scrambled distractor face (incompatible scrambled). *Note:* Male faces are not shown due to copyright issues

## Gender decision tasks

### Stimuli

*Male-Female task*

In the Male-Female task I followed the same steps in stimulus preparation and display as in the Pleasant-Unpleasant task. Any differences of the procedure are noted below.

*Faces and Words*

Male and female faces (angry as well as happy expressions) were taken from the Pleasant-Unpleasant task whereas the male- and female-related words from the Word-Face Stroop task constituted the word set of the current experiment. Words measured between 4.40° (longest word) and 1.41° (shortest word) of visual angle in width. All word types (male- and female-related) were displayed centrally as targets and were paired with each face flanker (male (angry, happy) and female (angry, happy)).

*Female-Neutral and Male-Neutral tasks*

*Faces and Words*

This task was designed identically to the Male-Female task, except that only the female faces of the latter task were used as well as the calm and scrambled faces based on the female ID's from the Pleasant-Neutral and Unpleasant-Neutral tasks. Furthermore, the female-related and neutral word sets from the Word-Face Stroop task served as target stimuli. The longest word of this set subtended a visual angle of approximately 4.40° in width as opposed to 1.41° of visual angle for the shortest word. Target words (female-related and neutral) were displayed centrally on the screen and were flanked by the various distractor faces (female (angry, happy and calm expressions) and scrambled).

The Male-Neutral task followed the design of the Female-Neutral task only that instead of selecting the female word and face stimuli from the respective aforementioned tasks the relevant male versions were taken. This change was also reflected in the width of the target stimuli whereby the longest word now measured 3.52° of visual angle with the shortest word, due to the identical neutral word set being used, remaining unchanged. Thus, male-related and neutral word types functioned as targets and these, in turn, were flanked by male (angry, happy and calm expressions) and scrambled faces.

**Procedure**

*Male-Female task*

The procedure for the Male-Female task was virtually identical to that of the Pleasant-Unpleasant task. Any differences in this regard are noted in the following.

Instructions were to discriminate the target words as either “male” or “female”. Training over two practice blocks was provided to enhance participants’ accuracy of gender labeling. In the first practice block (100 trials) only the gender-related target words were presented (= no distractor faces); the second practice block consisted of the actual experimental task, but, again, with only 100 trials. The factorial combination of word type (male-related, female-related), compatibility (compatible, incompatible) and face emotion (angry, happy) yielded 8 unique trial-types. Each trial type was repeated 64 times, resulting in 512 trials overall (50% compatible trials; 50% incompatible trials). Hence, including both practice blocks, participants performed a total of 712 trials. Compatible trials were those where target word and face gender corresponded (e.g. female-related target word and a female distractor face); incompatible trials were those where there was no correspondence on gender (e.g. female-related target word and a male distractor face).

*Female-Neutral task*

The procedure of this task was based on the Male-Female task; any departures from the latter procedure are stated below.

The response options in this task were “female” versus “neutral”. Response keys (“Space” (= neutral), “H”, “J”) and mapping were analogous to the Unpleasant-Neutral task, but this time care was taken that each of the various target words in the three gender tasks (male-related, female-related, neutral) was associated with only one response key per participant. There were 8 distinct trial-types according to the combination of word type (female-related, neutral), compatibility (compatible, incompatible) and face emotion (angry, happy, calm, scrambled)[22]. To ensure an even split between face and scrambled distracters, the 2 trial-types with scrambled faces amounted to 192 trials each (total: 384), whereas the remaining 6 trial-types with facial expressions consisted of 64 trials each (total: 384), resulting in 768 experimental trials and 968 trials (including practice) overall. Altogether, compatible versus incompatible trials were

[22] All angry, happy and calm expressions were from female models in this task and therefore could not be incompatible with the female-related word type as such. At the same time angry and happy faces could not be compatible with neutral targets and scrambled distracters not with female targets. Calm expressions, same as in the Word-Face Stroop paradigm, were in the unique position of being compatible with female targets based on the face gender and compatible with neutral targets based on the emotion of the face.

displayed equally often (41.7% each), with the remainder (16.7%) being of ambiguous compatibility (see footnote 22). More specifically, 16.7% of all trials were compatible trials involving face distracters; an equal percentage (16.7%) was allocated to the equivalent incompatible trials with face distracters. Compatible versus incompatible trials with scrambled images were each presented 25% of the time, with the remaining 16.7% of all trials, as mentioned above, being of ambiguous compatibility. The duration of this task was approximately 22 minutes.

*Male-Neutral task*

The procedure of the Male-Neutral task was analogous to the Female-Neutral task, with the change that the response choice was “male” versus “neutral” and the female words and faces were exchanged for male ones. All 3 gender decision tasks (Male-Female, Female-Neutral and Male-Neutral) were run in random order with the randsample function. These three tasks were run jointly with the emotional decision ones. Both the emotional and gender versions were presented in counterbalanced order across two sessions separated by at least one day in order to minimize any carry-over effects of the response mapping from the previous session. The Ospan task was always completed in the first testing session after the word-face flanker tasks and then followed by the questionnaire measures. Participants were debriefed by the end of the second session. Examples of the trial types of the gender decision tasks are given in Figure 12.

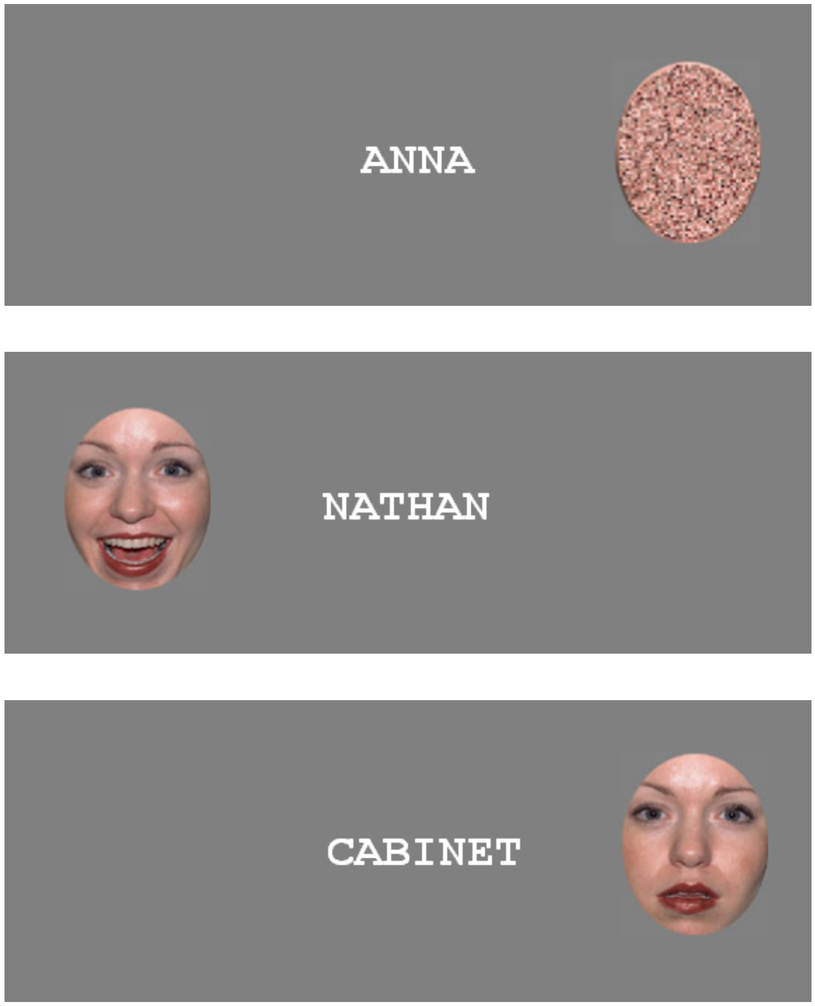



**Figure 12.** Example displays of trial types in the gender decision tasks. a) female-related target word flanked by a scrambled distractor face (incompatible scrambled), b) male-related target word with a happy, female distractor face (incompatible happy), c) neutral target word flanked by a calm, female distractor face (in-/compatible, see footnote 22). *Note:* Male faces are not shown due to copyright issues.

**Results.**

*1) Pre-processing for all Word-Face Flanker tasks*

One participant was excluded from the analyses due to technical errors during testing. The same pre-processing steps as in the Word-Face Stroop paradigm were followed for the remaining participants with computation of mean RT, RT SDs and mean ACC, outlier removal at subject and group levels (+/- 2.5 SD from mean; here: less than 10% of rejections) and normalisation. Eight participants (8.25%) were also excluded from the Ospan data for not maintaining a minimum accuracy of 85% in the maths problems. Again, since some error rates were marginally above 10% ART was used for all subsequent analyses with this paradigm.[23]

2) ANOVAs

*Pleasant-Unpleasant task*

Overall, it is expected that threatening material, especially when distracting, impairs performance. Such effects are, however, expected to be reduced with elevated task demands (gender decision task). To assess the effect of flankers on ART performance a Within-Subjects ANOVA was performed with word type (angry-related, happy-related) and compatibility (compatible, incompatible) as factors. There were significant main effects of target word (happy targets faster; $F(1, 59) = 7.52$, $p = .008$, $\eta_p^2 = .11$) and compatibility (compatible trials faster; $F(1, 59) = 13.919$, $p < .001$, $\eta_p^2 = .19$), but no significant target word X compatibility interaction ($F(1, 59) = 1.92$, $p = .17$, $\eta_p^2 = .03$). The means (SEs) for ART are presented in Figure 13.

[23] The RT and ACC data generally exhibited comparable trends.

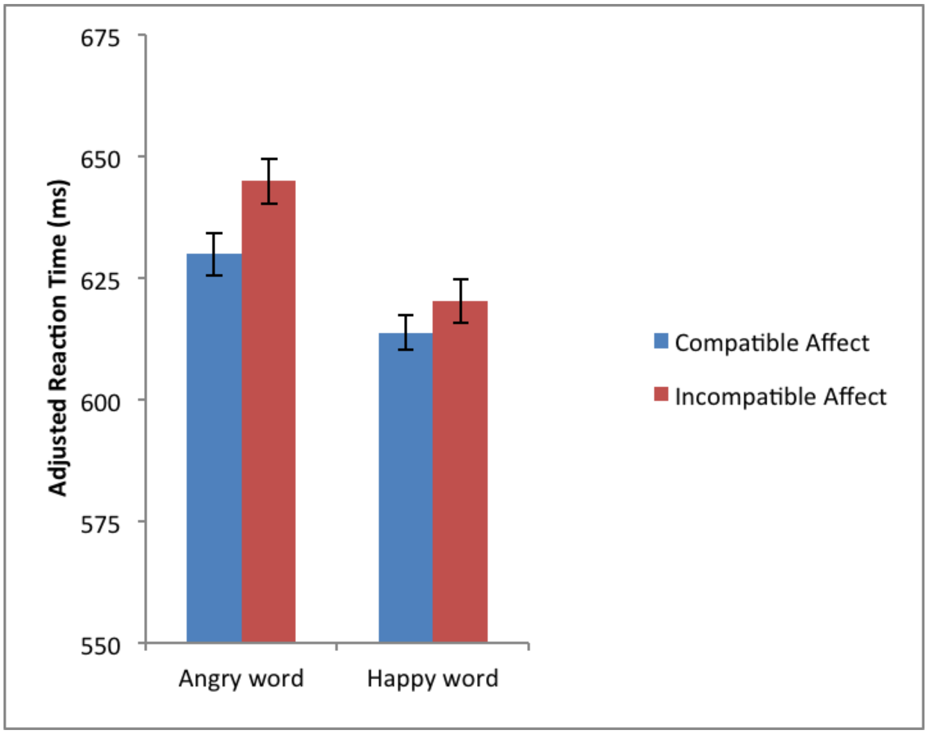



**Figure 13.** The means (SEs) for ART for the different types of stimuli.

*Unpleasant-Neutral task*

I examined the effect of flankers with a Within-Subjects ANOVA where word type (angry-related or neutral) and compatibility (compatible, incompatible, scrambled) served as factors. Results showed a significant main effect of compatibility ($F(2, 120) = 7.36$, $p = .001$, $\eta_p^2 = .11$) as well as a significant word type X compatibility interaction ($F(2, 120) = 16.09$, $p < .001$, $\eta_p^2 = .21$), but no significant main effect of word type ($p = .44$, $\eta_p^2 = .01$). Pairwise comparisons using Bonferroni correction revealed that responses on incompatible, as opposed to scrambled, trial-types were significantly faster for angry-related targets ($p < .001$, 95% CI -61.317; -16.19), whereas the reverse pattern (= incompatible slower) was true for neutral-related targets ($p = .01$, 95% CI 3.33 ; 33.31). Additionally, response latencies for scrambled faces were significantly slower than those for compatible stimulus-types for angry targets (p < .001, 95% CI 24.31; 70.09); all other comparisons of compatibility at the different levels of word type did not reach significance (p > .05). Mean ART and SEs are displayed in Figure 14.

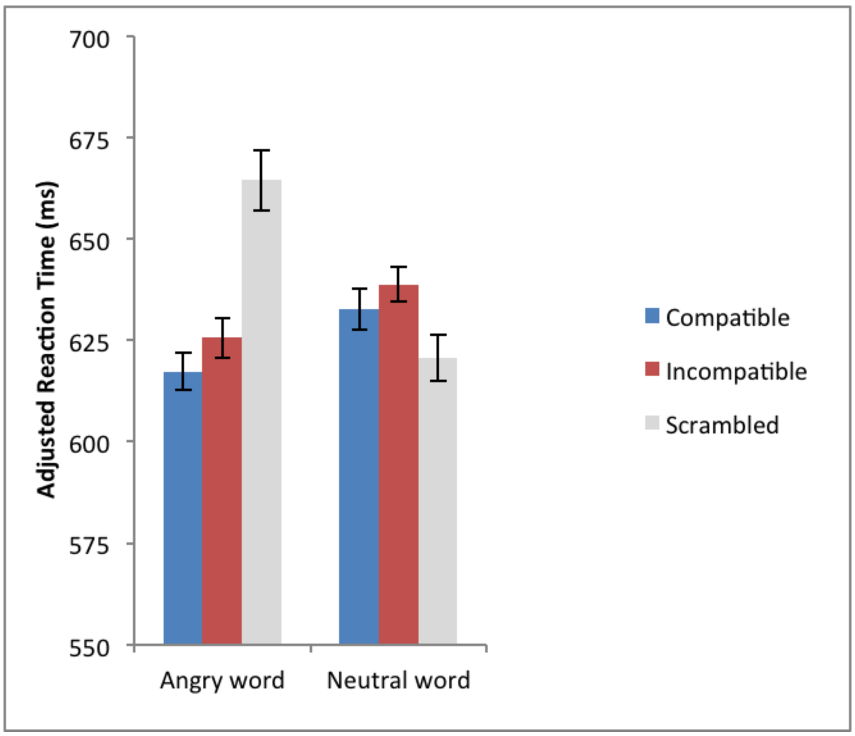



**Figure 14.** The means (SEs) for ART for the different types of stimuli.

*Pleasant-Neutral task*

I conducted a 2 (word type: happy-related or neutral) X 3 (compatibility: compatible, incompatible, scrambled) Within-Subjects ANOVA. I found significant main effects of word type ($F(1, 62) = 17.62$, $p < .001$, $\eta_p^2 = .22$), compatibility ($F(2, 124) = 3.73$, $p = .03$, $\eta_p^2 = .06$) as well as a significant word type X compatibility interaction ($F(2, 124) = 7.81$, $p = .001$, $\eta_p^2 = .11$). Pairwise comparisons using Bonferroni correction indicate that, for happy targets, responses on trials with compatible ($p < .001$, 95% CI -44.25; -11.62) or incompatible expressions[24] ($p = .07$, 95% CI -30.49; 1.03) were significantly faster than on trials with scrambled images – none of the other comparisons of compatibility at the different levels of word type reached significance ($p > .05$). An overview of the ART performance in this task is provided in Figure 15.

[24] The comparison between incompatible and scrambled trials was only marginally significant.

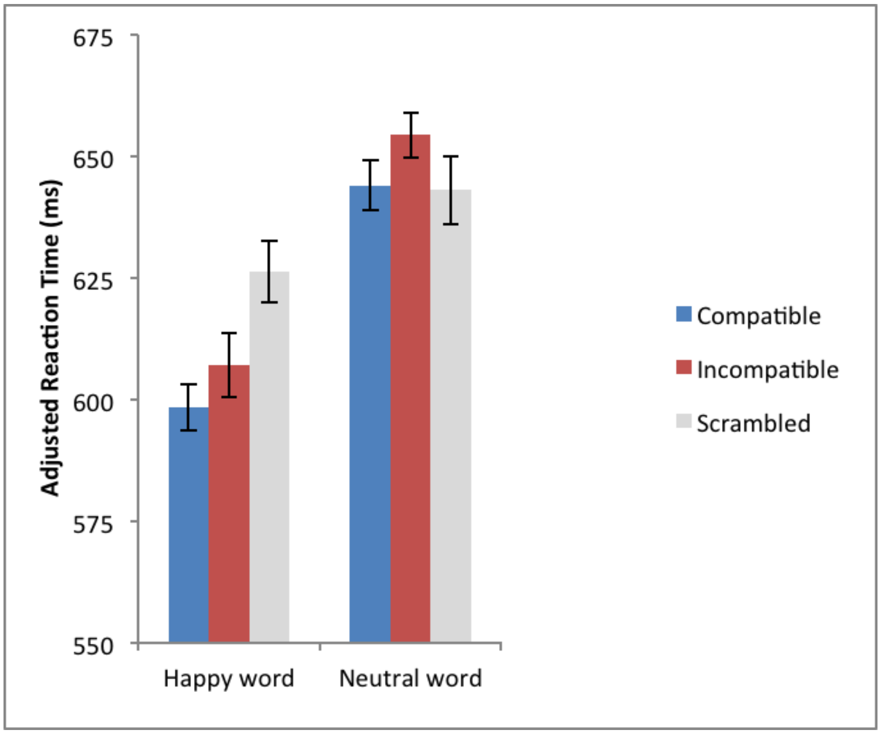



**Figure 15.** Overview of the ART means (SEs) for the various trial-types.

*Male-Female task*

A Repeated-Measures ANOVA was run with word type (male-related, female-related), compatibility (compatible, incompatible) and face emotion (angry, happy) as factors. I obtained significant main effects of word type (female faster; $F(1, 61) = 5.84$, $p = .02$, $\eta_p^2 = .09$) and compatibility (compatible faster; $F(1, 61) = 32.21$, $p < .001$, $\eta_p^2 = .35$) and a marginally significant main effect of face emotion, with responses to happy faces being faster than angry faces ($F(1, 61) = 3.58$, $p = .06$, $\eta_p^2 = .06$) – none of the interactions yielded significant effects (all ps > .05). The ART results of the Male-Female task are presented in Figure 16.

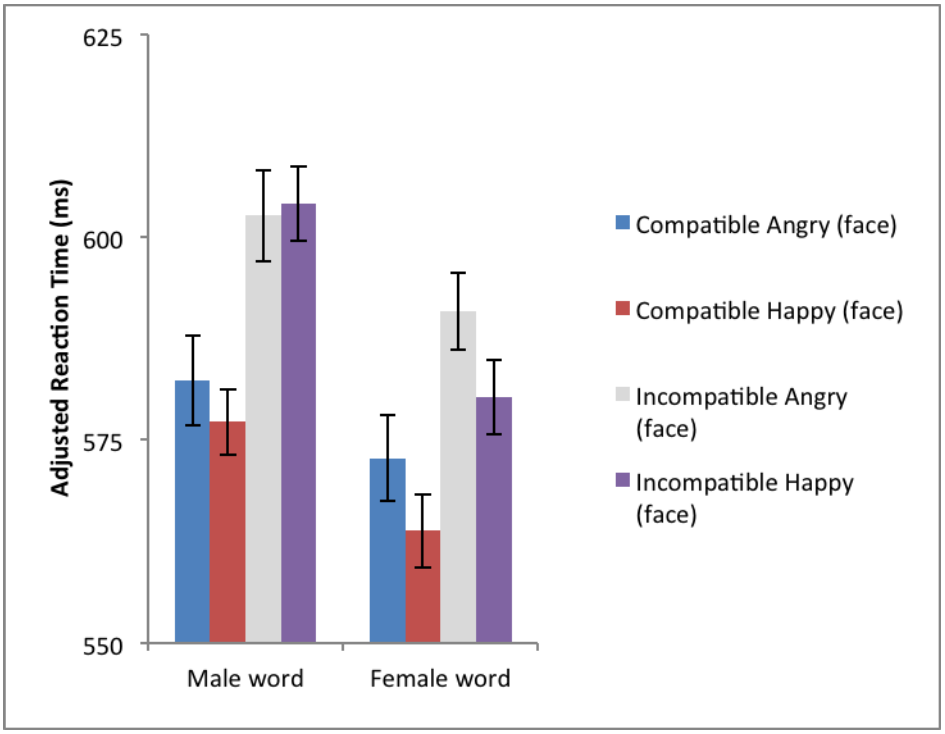



**Figure 16.** Means (SEs) for all stimulus-types of the Male-Female task.

*Female-Neutral task*

Given the uneven distribution of compatible versus incompatible trial-types across the two target words, I administered two separate Repeated-Measures ANOVAs, one for each word type. Using a Within-Subjects ANOVA for female target words with face emotion (angry, happy, calm, scrambled) as factor, the differences between the means were found to be statistically significant ($F(3, 180) = 6.87$, $p < .001$, $\eta_p^2 = .10$). Pairwise comparisons using Bonferroni correction produced significant differences between scrambled images and each of the other distracters, whereby scrambled faces yielded slower ARTs than angry ($p < .001$, 95% CI 39.97; 10.01), happy ($p = .016$, 95% CI 2.27; 33.41) and calm ($p = .002$, 95% CI 6.16; 39.09) distractors; any other comparisons did not reach significance (all ps = 1). For neutral targets I also conducted a

Within-Subjects ANOVA with face emotion (angry, happy, calm, scrambled) as factor. Similar to female target words, I found the differences between the means to be significant ($F(3, 180) = 8.40$, $p < .001$, $\eta_p^2 = .12$). However, this time follow-up tests (with Bonferroni correction) demonstrated that scrambled distracters exhibited significantly faster ARTs compared to the other face distracters: angry ($p = .006$, 95% CI -40.34; -4.64), happy ($p < .001$, 95% CI -50.90; 13.85), calm ($p < .001$, 95% CI -45.04; -12.56) – all other comparisons were non-significant ($ps = 1$). These results are shown in Figure 17.

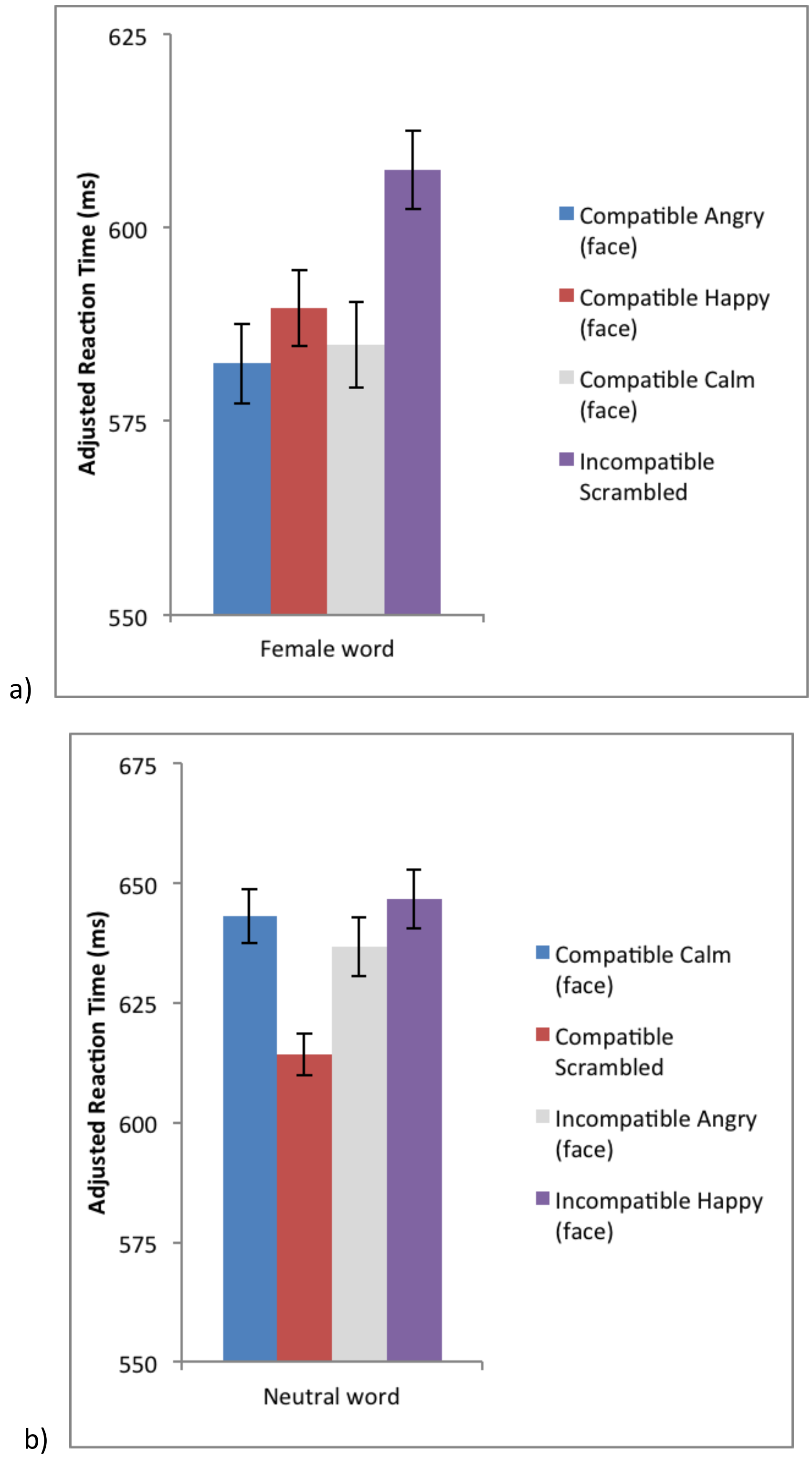
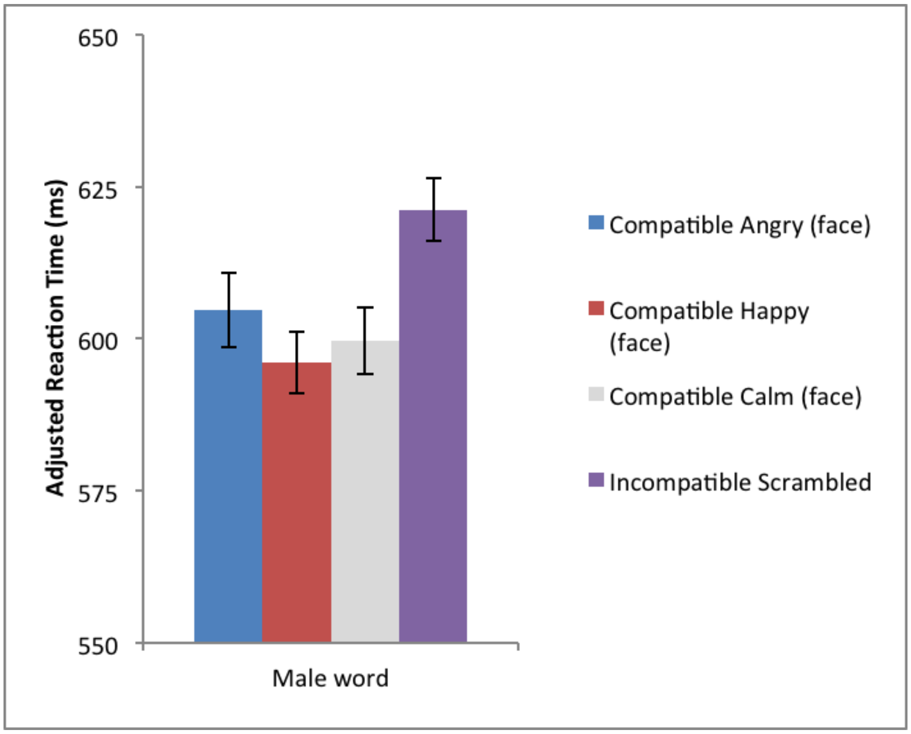


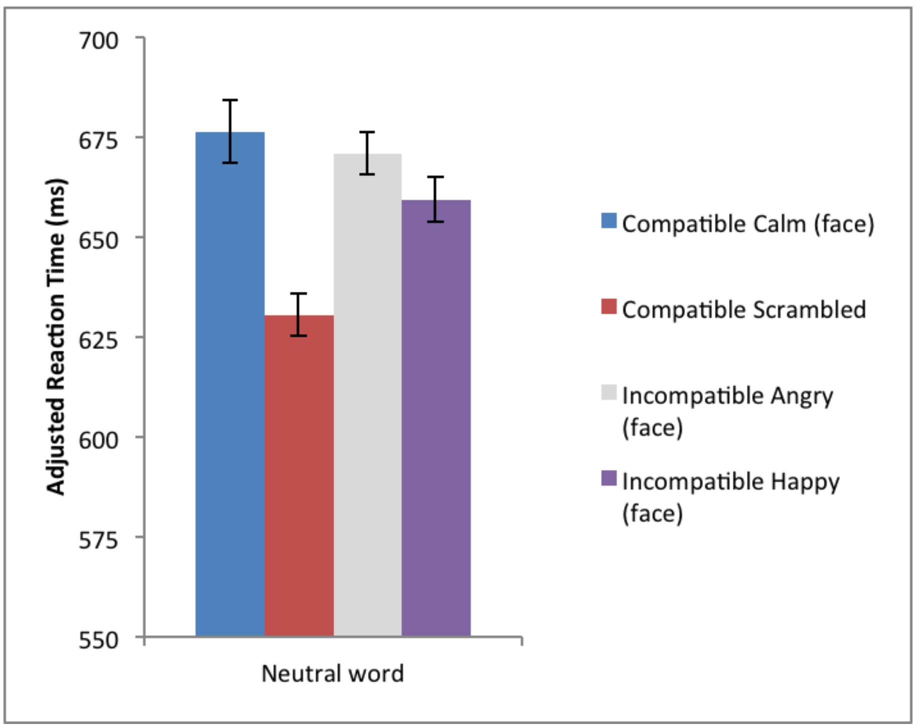

**Figure 17.** Mean (SE) ART findings for all types of stimuli split across word type. (a) female target words; (b) neutral target words.

*Male-Neutral task*

As for the female-neutral task above, I split the Repeated-Measures ANOVA here into two separate ones according to word type. Thus, I ran a Repeated-Measures ANOVA on the conditions concerning male target words, that is with face emotion (angry, happy, calm, scrambled) as a factor. Results showed that the differences between the means were statistically significant ($F(3, 183) = 7.83$, $p < .001$, $\eta_p^2 = .11$). Pairwise comparisons (corrected with Bonferroni adjustment) revealed that, again, as for female words, scrambled trial-types differed significantly from all other distractor faces, that is angry ($p = .02$, 95% CI 1.93; 31.06), happy ($p < .001$, 95% CI 9.24; 40.96), calm ($p = .001$, 95% CI 7.57; 35.57), whereas the remaining comparisons were non-significant ($ps > .70$). The second Repeated-Measures ANOVA, this time for neutral target words, was also carried out with face emotion (angry, happy, calm, scrambled) as a factor. There was a main effect of face emotion ($F(3, 183) = 16.35$, $p < .001$, $\eta_p^2 = .21$). Only the pairwise comparisons between scrambled stimuli and the remaining face flankers reached significance (angry: $p < .001$, 95% CI -58.97; -22.10; happy: $p < .001$, 95% CI -45.97; -11.63; calm: $p < .001$, 95% CI -66.95; -24.62; all other comparisons, $ps > .27$). ART means (SEs) are displayed in Figure 18.




a)




b)

**Figure 18.** Overview of the means (SEs) for the different trial-types. (a) males target words; (b) neutral target words.

*3) Individual difference analyses*

To summarise, compatible (compared to incompatible) trial-types were found to be faster and this was also true for compatible scrambled trials. By contrast, scrambled images, when incompatible, tended to produce slower performance than compatible and other incompatible stimulus types. The findings for calm distracters (the other control stimulus set) were less clear in terms of compatibility, possibly due to their ambiguous nature in the gender decision task. Happy targets were faster than angry ones and female targets than male ones. It was of interest whether angry distracters exhibited more interference than other distracter types. Relevant analyses revealed that there was a hint of a speeded performance of happy distracters over angry ones when task demand was high (gender decision task), although this did not reach conventional levels of significance. Moreover, unlike in the Word-Face Stroop task, angry and happy distracters did not seem to have any differential effects on target performance when task load was low (emotion decision task; paired-samples t-test between the relevant compatibility scores: $t(59) = 1.29$, $p = .17$, $r = .17$; for details on these compatibility scores, see Pleasant-Unpleasant task in footnote 25). In general then, whilst there was a trend for greater interference of threatening distracters under high task demand, when task demand was low this trend was not replicated and instead a speeding effect for happy targets was found.

As for the individual difference measures, I expected that elevated trait neuroticism is paired with increased attentional bias to threat as well as greater intra-individual variability (i.e. greater compatibility scores – see below for further details). Moreover, high trait reappraisal (or attentional control) can attenuate the impact of neuroticism on threat appraisal and intra-individual variability, respectively. For each of the 6 Word-Face Flanker tasks I computed flanker compatibility effect scores by subtracting the mean ART performance level in the compatible from that in the incompatible trial type, such that higher scores denote faster responses to the compatible material – equivalent scores were calculated for the RT SD data.[25] I then ran a series of Pearson correlation analyses between neuroticism, state and trait anxiety, verbal intelligence, reappraisal, attentional control along with the absolute and total Ospan scores versus these flanker compatibility effect measures. None of these correlations, however, survived correction for multiple comparisons (minimum p = .02).

Following the same procedure as in the Word-Face Stroop paradigm, I employed the MODPROBE macro of Hayes and Matthes (2009) to examine the potential moderating roles of reappraisal or attentional control (M) on the link between neuroticism (focal predictor) and flanker compatibility scores (i.e. those for Pleasant-Unpleasant and Male-Female tasks; outcome variables[26]). The analyses also controlled for working memory capacity (= the absolute and total Ospan scores) and either reappraisal or attentional control (as before, whichever of these did not act as a moderator in a particular analysis). Contrary to my predictions the results did not reveal any significant interaction effects of neuroticism and reappraisal/ attentional control on the flanker compatibility measures (maximum: t(53) = 2.22; minimum p = .03)[27] after correction for

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[25] The following compatibility scores were created. *Pleasant-Unpleasant task*: (1) compatible angry targets (distracter emotion: angry) were subtracted from incompatible angry targets (distracter emotion: happy) – equivalent steps were taken for happy targets. *Pleasant-Neutral task*: compatible happy targets (distracter emotion: happy) were subtracted from incompatible happy targets (distracter emotion: neutral or scrambled) – this was done analogously with angry targets for the *Unpleasant-Neutral task*. *Male-Female task*: compatible male targets (distracter gender: male) were subtracted from incompatible male targets (distracter gender: female), with both minuend and subtrahend always having the same distracter emotion (i.e. angry or happy) – an equivalent procedure was adopted for female targets. *Male-Neutral task*: compatible neutral targets (distracter gender: male – no gender for scrambled images; distracter emotion: calm or scrambled) were subtracted from incompatible neutral targets (distracter gender: male; distracter emotion: angry or happy) – for the *Female-Neutral task* a similar procedure was followed with neutral targets.

[26] See footnote 25

[27] Only 1 (out of 12) moderation analysis for the Pleasant-Unpleasant and Male-Female tasks reached the conventional level of significance (p < .05) – i.e. that involving the compatibility score for female targets with happy distracters. This interaction was no longer significant after correcting for multiple comparisons and is therefore not reported in further detail – all other interactions, p > .05.

multiple comparisons; exploratory analyses with the remaining flanker compatibility scores did not show statistically significant moderation effects either (all ps > .05).

**Discussion.**

It was expected that response times would be impeded in the face of threatening information. This bias as well as intra-individual variability was thought to be particularly strong in individuals with enhanced trait neuroticism, but expected to be reduced under high task demand or in individuals with high trait reappraisal or attentional control. Results showed that for compatible trial-types, relative to incompatible ones, speeded performance was observed. While happy targets improved performance, threatening distracters impaired performance under high (but not low) task demand. As for the individual difference analyses, against expectations (Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998; Pessoa, 2009; Robinson & Tamir, 2005), no significant effects were obtained. These results indicate that, similar to the findings from the Face Flanker paradigm, happy targets accelerate performance compared to other target types. This is suggestive of a facilitatory effect of early sensory representations for low arousing or positive content in target stimuli (Pessoa, 2009). Against predictions (Mathews et al., 1997; Mathews & Mackintosh, 1998; Pessoa, 2009), threatening information did not lead to an increased impairment in performance when task demands are low. If anything, performance to happy distracter faces is particularly slowed in this context, albeit not significantly so when compared to angry ones. By contrast, under high task demand, where the effect of threat was expected to be attenuated (Mathews et al., 1997; Mathews & Mackintosh, 1998), threatening distracters significantly slowed performance. This finding could be seen to suggest that sensitivity to threat has attained priority in our system through evolution (Öhman & Mineka, 2001), whereby threat has an advantage in detection over other emotions at an unconscious level, but not at a conscious level. However, this reading seems to be in conflict with numerous studies reporting robust effects of threat at a conscious level (Mathews et al., 1997; Mathews & Mackintosh, 1998; Pessoa, 2009). Future studies will need to further examine the effect of task difficulty or awareness on threat in this type of task to address this issue. Moreover, it should be noted that targets (words) and distracters (faces) consisted of different stimulus types, with speeded performance only being observed for happy target words, but not for happy distracter faces. Hence, it will be crucial to further test these findings using other stimulus modalities (e.g. auditory) or by switching the stimulus types of targets and distracters (e.g. target faces versus distracters words) to see if similar effects are still observed.

As hypothesized, the results yielded significant compatibility effects (unlike in the Face-Flanker task). This extends previous non-emotional Word-Face Flanker tasks (Bindemann et al., 2005; Brebner & Macrae, 2008), demonstrating that compatibility effects can also be obtained using affective stimuli in this paradigm.

Given the similarities between the Word-Face Stroop and Word-Face Flanker paradigms, many of the issues raised the discussion of the Word-Face Stroop task apply here too. In particular, it seems plausible that the lack of a relationship between the Flanker measures and individual differences in the Word-Face Flanker studies reported here is due to comparable reasons, such as the different forms of reappraisal (early vs. late onset reappraisal; Joormann & Siemer, 2011). Although the proportion of compatible versus incompatible trials was largely kept equal across the different tasks, thereby strengthening the dominance of compatible trials somewhat compared to the two preceding paradigms (Face Flanker and Word-Face Stroop tasks), this proportion may nevertheless have been insufficient to create a prepotent response for the compatible trials. This design feature may thus have affected the strength of the interference effects (Casey et al., 2000; Crump et al., 2006, 2008; Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; West & Baylis, 1998) and, in turn, the associations between the individual difference variables and threat appraisal. Moreover, the data also seem to be in line with the interpretation that scrambled images are more salient and more closely associated with (a) neutral targets/emotion. This Flanker experiment also has similar limitations in terms of calm faces (i.e. ambiguity in the gender decision tasks).

On a more theoretical level it is also unclear what produced the interference effects. Compatible and incompatible trials differ in that the distracter image is non-identical as well as associated with a different button press. The current findings therefore do not allow the distinction as to whether an interference effect is due to response conflict or stimulus compatibility (e.g. different valence). This issue could be explored in future research by systematically associating two stimulus types to each response button (e.g. happy faces of high vs. low arousal: response button A; angry faces of high vs. low arousal: response button B). Such a scenario would then permit the comparison of incompatible trials where both target and distracter differ on only one dimension (e.g. they are associated with the same response button, but differ in level of arousal; for instance, target: high arousing happy face, distracter: low arousing happy face) vs. incompatible trials where they differ on more than one dimension (e.g. they differ on the response button and on valence; for instance, target: high arousing happy face, distracter: high arousing angry face). Given the already fairly complex nature of this study such an approach was not adopted in order to reduce the overall amount of trials/ testing time. However, it seems fruitful to further investigate this issue in future research.

Whilst similar future studies could be conducted as suggested for the Word-Face Stroop paradigm, it could also be of interest to future researchers to vary the onset time of emotional distracters, which could elucidate the temporal impact unique to a particular emotion. Moreover, whilst this was not conducted for this thesis, it could be of interest to examine the effects of 3-way interactions (e.g. with reappraisal and attentional control as simultaneous moderators) in predicting attentional bias. It should also be noted that even though the self-report measures employed throughout this thesis demonstrate respectable validity and reliability, comparing well to behavioural results, response bias could nevertheless have been a problem. Future investigators should therefore where possible complement such measures with additional behavioural, physiological or neural measures, as was done here, for example, with the Ospan task.

Overall, these findings are in line with proposals of the capacity limits for face processing (Bindemann et al., 2005) in that with only one face per trial display flanker compatibility effects were obtained, demonstrating for the first time that emotion has an impact on performance in a Word-Face Flanker task. The results also suggest that early sensory representations of low arousing or positive cues (Pessoa, 2009) may facilitate target processing. Against predictions, threat impeded performance under high (but not low) task demand, indicative of an advantange in threat processing at an unconscious (as opposed to conscious) level (Öhman & Mineka, 2001). Threat appraisal, counter my hypotheses, was not associated with the various individual difference measures employed in this study. This might be due to a number of limitations of this study concerning the proportion of compatible versus incompatible trials, amongst others. A number of recommendations for future studies have been made, which might help in disentangling the interpretation of these effects.

The work reported up until this point has explored the effect of personality traits and threat on distracter interference in a number of different paradigms. The next chapter will examine the impact of these variables on a slightly different type of cognitive control: response inhibition.

# Chapter 5: Impact of emotional expressions on response inhibition in the Stop signal paradigm

## Introduction.

Response inhibition is a well-known feature of cognitive control, denoting the suppression of behaviours that have become obsolete (Verbruggen & Logan, 2008). As outlined in the General Introduction, cognitive control is presumed to consist of three unique, but inter-related mechanisms: shifting, updating and inhibition (Miyake et al., 2000; Pessoa, 2009), with response inhibition forming part of the inhibition component (Friedman & Miyake, 2004; Pessoa, 2009). Several lines of evidence have lend support to this perspective of unity and diversity in cognitive control (Miyake & Friedman, 2012; Munakata et al., 2011; Verbruggen et al., 2004). Pessoa (2009) draws on this idea in his Dual-Competition model, proposing that the joint, inter-related mechanism of cognitive control, which he refers to as a common resource pool, is affected by use from the cognitive control functions, threatening material as well as individual differences. So, for example, recruitment of this resource pool for an updating task or the presentation of high threats would also affect the resources available for the response inhibition mechanism. Whilst traditionally response inhibition has been associated with motor inhibition (Verbruggen & Logan, 2008), recent findings suggest that it may instead be related to context-monitoring, which serves the detection and interpretation of the stop signal (Chatham et al., 2012).

To date there have been only a small number of studies investigating the impact of emotional material on response inhibition. An affective stop-signal task where emotional images preceded the target stimuli revealed that response and stop latencies were slowed as a function of the high arousal content, but not the valence (positive, negative) of the images (Verbruggen &

De Houwer, 2007). Hare, Tottenham, Davidson, Glover, and Casey (2005), however, revealed an effect of valence in an emotional Go/ NoGo task when affective items functioned as targets. The researchers demonstrated that response latencies to fearful faces were slower than comparison stimuli (i.e. happy and neutral), but participants were less accurate at inhibiting responses for happy items, an effect that can also be modulated by individual differences (e.g. Ladouceur et al., 2006).

Studies have shown that stop signal performance is not only affected by the stimulus (Pessoa et al., 2012; Verbruggen & De Houwer, 2007; Wilkowski, 2012), but also by situational or trait variables (Krypotos, Jahfari, Van Ast, Kindt, & Forstmann, 2011; Logan et al., 1997; Padmala & Pessoa, 2010). Logan et al. (1997) demonstrated, for example, that stopping performance is slowed in individuals with high trait impulsivity, a personality facet linked to neuroticism (DeYoung, 2010c). Padmala and Pessoa (2010), in turn, showed that stop signal inhibition can be increased in a reward scenario. Moreover, findings from Krypotos et al. (2011) suggest that individuals with adaptive emotion regulation skills, as measured by heart rate variability, exhibit better execution and inhibition performance when confronted with negative images in a stop signal task. These findings indicate that trait measures as well as emotional states have an influence on response inhibition. Furthermore, of particular note are the findings that impulsivity and heart rate variability are linked with performance in the stop signal paradigm. This could be relevant to the mental noise hypothesis (Robinson & Tamir, 2005), which stipulates that intra-individual variability in response latencies is positively associated with neuroticism. One could thus speculate that neuroticism might be related to intra-individual variability in response latencies of this task (i.e. RT SDs of go trials).

Based on this evidence and the affective stop signal task by Verbruggen & De Houwer (2007) in particular, I devised 6 experimental stop signal tasks, in three of which emotion was task-relevant (emotional decision task) and in three of which gender was task-relevant (gender decision task), with emotional cues acting as distracters. Stimuli were angry (high and low arousal), happy (high and low arousal) as well as scrambled images thereof. Participants typically engaged in a binary choice task on each trial (e.g. "is the target image pleasant or unpleasant?"; go trial). However, on a small subset of the trials (stop signal trials), a signal appeared (here: a blue rectangle), indicating that they should refrain from responding on this trial. The stop signal trials served as a measure of response inhibition, as indexed by SSRTs (see Methods for more details), whereas the go trials provided an executive response, indexed by response latencies (Choice Reaction Time, CRT). Participants were also assessed on emotional and regulatory individual difference measures (neuroticim, reappraisal, attentional control) to assess the impact of trait measures on threat appraisal or stop signal performance more generally. Based on Pessoa's (2009) Dual-competition model I predicted that threatening stimuli impair stop signal performance, as indexed by a longer CRTs and SSRTs (see methods), with this bias being more pronounced at high levels of trait neuroticism and when more than one cue is displayed per trial. Moreover, as outlined above, in line with the mental noise hypothesis (Robinson & Tamir, 2005), high levels of trait neuroticism were expected to be linked with greater intra-individual variability on go trials. Furthermore, elevated levels of voluntary control (reappraisal or attentional control) decrease the impact of neuroticism on threat appraisal and intra-individual variability (Blechert et al, 2012).

**Methods.**

**Participants**

Participant recruitment and requirements was as for the Word-Face Stroop paradigm. I tested 66 students (33 females) in this study who had a mean (SD; range) age of 20.6 (3.9; 18-47).

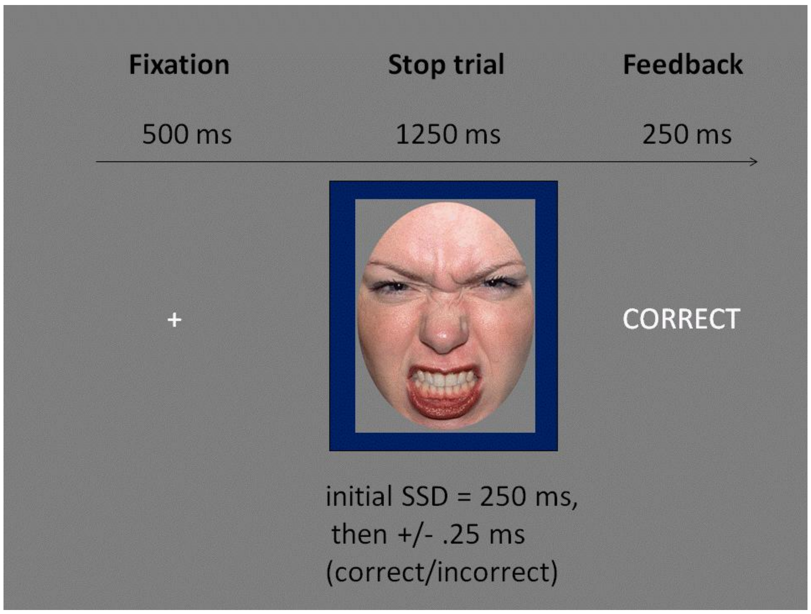
**Stimuli, Questionnaire measures and Ospan**

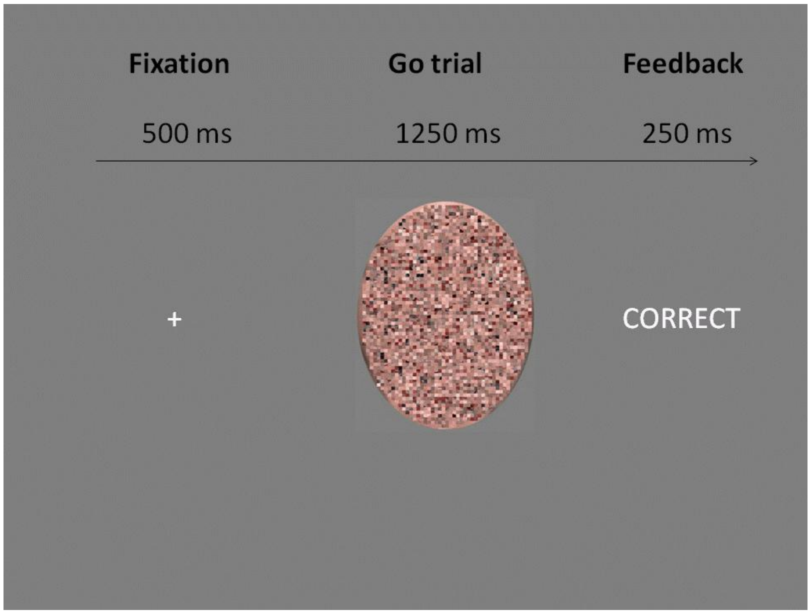
*Pleasant-Unpleasant task*

I employed the same experimental set up (stimulus presentation tools and software) as in the two preceding paradigms (Word-Face Stroop and Word-Face Flanker tasks).

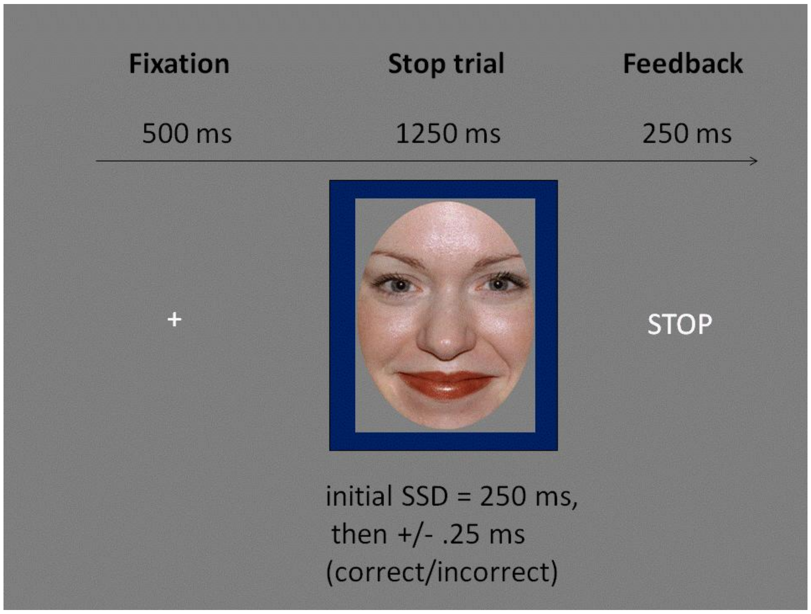
My target stimuli corresponded to the distractor faces from the Pleasant-Unpleasant task of the Word-Face Flanker paradigm (same actors as well as the same angry and happy expressions) with the addition of also including the closed-mouth counterpart for each target face. The closed mouth versions had undergone the identical matching procedure as their open-mouth equivalents on measures of arousal, valence, reaction time, accuracy, emotional intensity and rater agreement (see Appendix). As my pilot work has shown (Appendix), the open- and closed-mouth expressions of the NimStim differ in arousal, with faces with a closed-mouth tending to be less arousing compared to faces with an open-mouth. Hence, these two face sets (open- versus closed-mouth) constituted my manipulations of arousal (high versus low).
I selected emotional faces of high and low arousal in line with previous work on the affective stop signal paradigm (Frederick Verbruggen & De Houwer, 2007) where arousal and valence

had been manipulated. Moreover, happy and angry expressions were chosen for (1) being particularly well matched compared to other specific emotion pairs (see Appendix) and (2) for rendering this task more comparable to my previous experiments (Word-Face Stroop and Flanker tasks), thereby facilitating potential comparisons. Stimulus development (i.e. cropping) of the faces was followed as in the Word-Face Flanker task. My stop signal consisted of a dark blue rectangle of 35 pixel units in width framing the target face shortly after its onset. An illustration of the various trial sequences in the emotional and gender decision tasks is provided in Figure 19.

a)





b)




c)

**Figure 19.** Typical trial sequences of the affective stop signal task. a) sample stop signal trial (angry, female, high arousal) in tasks 1., 3., 4., and 6.; b) sample go trial (scrambled) in tasks 2., 3., 5., 6.; c) sample stop signal trial (happy, female, low arousal) in tasks 1., 2., 4., 6. *Tasks:* 1. Pleasant-Unpleasant, 2. Pleasant-Scrambled, 3. Unpleasant-Scrambled, 4. Male-Female, 5. Male-Scrambled, 6. Female-Scrambled.

For the stop signal experiment I employed the same self-report measures as for my previous experiments, including the Ospan (Unsworth et al., 2005) as used in the Word-Face Flanker experiment.

*Other emotion and gender tasks*

The remaining emotion and gender tasks were largely the same in terms of stimulus selection and preparation as the Pleasant-Unpleasant task. Any departures from this are noted below.

The Pleasant-Scrambled task utilised all happy expressions (male and female) from the Pleasant-Unpleasant task as well as scrambled controls, which were created out of the happy faces, following the scrambling procedure in the Word-Face Flanker task. The Unpleasant-Scrambled task presented angry expressions instead of the happy ones for both the emotional and scrambled images.

Experimental stimuli of the Male-Female task were identical to the Pleasant-Unpleasant task. Moreover, the Female-Scrambled task consisted of all female face images (angry and happy) from the Pleasant-Scrambled and Unpleasant-Scrambled tasks as well as the scrambled counterparts thereof. The Male-Scrambled task was equivalent to the Female-Scrambled task, but contained the relevant male faces and scrambled images.

**Procedure**

*Pleasant-Unpleasant task*

I instructed participants to (a) determine whether the target face was “pleasant” or “unpleasant”, (b) to attempt to withhold their responses whenever a stop signal appeared and (c) to respond as fast and accurately as possible. Those trials where participants responded are commonly referred to as go trials. The RTs recorded on these trials are known as the go RT or Choice Reaction Time (CRT). Those trials where a stop signal appeared are referred to as stop signal trials and allow computation of the stop signal RT (SSRT – see below for further details). To prevent waiting strategies, I further informed participants of the tracking procedure, emphasizing that the onset time of the stop signal would be adjusted such that their probability of stopping would approach .50, regardless of their performance. Response keys were “h” and “j”, to be pressed with the index and middle fingers, respectively. Stimulus-response mapping was counterbalanced across participants. Feedback was provided at the end of every trial during training as well as during the experiment so that participants could improve the accuracy of their stopping and going responses. On stop trials the word “correct” was presented when participants correctly refrained from pressing a response key whereas the word “stop” appeared whenever a response key was (incorrectly) pressed. On go trials the words “correct” and “incorrect” were shown depending on the accuracy of the response choice and the word “respond” was displayed when (erroneously) no key press was made. Feedback was always presented in white upper case letters in Courier New type (font size 25).

Based on the factorial combination of emotion (angry vs. happy), arousal (high vs. low) and gender (male, female) there were 8 separate trial-types. The order of trials was random as determined with the randperm function. Each trial-type appeared 96 times during the experimental phase, resulting in 768 trials. The prior practice phase consisted of two training blocks; the first block comprised a go-task (no stop signals shown) so that participants could familiarise themselves with the response choices (128 trials), the second block was a shortened version of the experimental task and served as preparation for it (128 trials). Thus, participants completed a total of 1024 trials for the Pleasant-Unpleasant task.

The fixation signal was displayed for 500 ms at the beginning of a trial, followed by the target face. Participants had to make a speeded response within 1250 ms in order for the stop trials to be challenging and, on correct stop trials, to keep the waiting interval until the next trial minimal. Next, feedback was provided for a duration of 250 ms. Self-paced breaks were provided every 192 trials. This experiment lasted approximately 34 minutes. Fixation, target faces and feedback were all displayed in the screen centre.

Stop signals were randomly presented, by means of the randsample function, on 25% of all trials for each stimulus-type (= 24 stop trials per trial-type). The initial stop signal delay (SSD) was set at 250 ms and thereafter adapted regularly in line with discrete staircase tracking procedures (Levit, 1971) to achieve a probability of stopping of .50 for each stimulus-type. The SSD was increased by 25 ms after a correct response on a stop trial (inhibition success) and decreased by the same time interval after an incorrect response (inhibition failure).

Following the guidelines by Verbruggen, Chambers and Logan (in revision) I used the integration method (Logan, 1994; Verbruggen et al., 2010) to estimate the SSRT. Since I did not employ a block-variant design, however, I used the experiment-wide integration method, which, as Verbruggen et al. (in revision) note, is still considered reliable and provides unbiased estimates if no gradual increase in RT is observed.

In the integration method goRTs for a particular stimulus-type are ranked and the nth RT, which represents the finishing time of the stop process, is identified. To obtain the nth RT the number of the goRT trials is multiplied by the probability of responding on stop trials for this type of stimulus. The SSRT is then computed by deducting mean SSD from the finishing time (nth RT). To illustrate, with P(respond | signal) = .52 and 84 goRT trials for stimulus type A, the nth RT is ranked $44^{th}$ (0.52 x 84). Hence, mean SSD is subtracted from the $44^{th}$ fastest goRT to arrive at the SSRT for stimulus type A.

*Other emotion and gender tasks*

Bar the following modifications, I copied the procedure of the Pleasant-Unpleasant stop signal task for the other emotion and gender tasks (Pleasant-Scrambled, Unpleasant-Scrambled, Male-Female, Male-Scrambled, Female-Scrambled).

In the Pleasant-Scrambled task participants' needed to determine whether a target was "pleasant" or scrambled". As for the Affect-Neutral tasks of the Word-Face Flanker paradigm the potential response keys for the "pleasant" responses were one of either "h" or "j", depending on which of the two keys was associated with this response in the Pleasant-Unpleasant task. The second response key (= "space") was always allocated to the neutral response-choice and required a thumb press; "h" and "j" were to be pressed with either the index or middle fingers, depending on handedness. Across the three emotional decision tasks each response key ("h", "j" or "space") was only mapped onto a single response choice. For example, if "h" was linked to "pleasant" targets in one task it would be linked to this response choice in other tasks, too.

The task consisted of 5 unique types of stimuli as derived from the combination of emotion (happy), arousal (high, low), gender (male, female) and scrambled[28]. This resulted in 96 trials for each arousal and gender type and because all stimulus-types of arousal and gender were simultaneously happy in this task the total number of happy trials amounted to 384 (4 x 96). In order to balance the number of happy versus control trials there were also 384 trials for scrambled faces. As a consequence there were 24 stop signal trials for each of the gender and arousal types, which resulted in 96 stop trials for happy expressions and 96 stop trials for scrambled faces. Overall, the number of trials in the Pleasant-Scrambled task totalled 768 for the experimental phase and 1024 when including the trials from both practice blocks.

The Unpleasant-Scrambled task followed the procedure of the Pleasant-Scrambled task with the happy target stimuli being replaced by angry faces, along with the corresponding change in response choice ("unpleasant" in lieu of "pleasant"). The Pleasant-Unpleasant task was completely replicated in the Male-Female task, but with the response choice now being gender related ("male" versus "female"). Furthermore, the Female-Scrambled task comprised 5 different stimulus-types, resulting from the combination of gender (female), emotion (angry, happy), arousal (high, low) and scrambled. Each type of emotion and arousal consisted of 96 trials resulting in an overall amount of 384 female trials. Again, in order to maintain a balance between female and control trials, scrambled faces also totalled 384. There were 24 stop signal trials for all the different types of emotion and arousal (= combined 96 stop trials for female faces) and 96 stop trials for scrambled faces.

[28] Scrambled faces were not manipulated along the factors of emotion, arousal and gender, but constituted a separate category of trial-types.

Instructions were to discriminate targets as either “Female” or “Scrambled”. According to the same principle as in the Pleasant-Scrambled task, “space” was assigned as response key for scrambled images whereas either “h” or “j” functioned as response keys for female targets, depending on which of the two keys had been allocated to the female response option in the Male-Female task – again any one response key was assigned to only one gender target (i.e. male, female or scrambled) across the three gender decision tasks.

The Male-Scrambled task followed the procedure of the Female-Scrambled task with male stimuli and responses replacing the female ones. The three gender decision tasks (Male-Female, Female-Scrambled and Male-Scrambled) were presented in random order, using the randsample function – likewise for the three emotion decision tasks (Pleasant-Unpleasant, Pleasant-Scrambled, Unpleasant-Scrambled). Testing order of the emotional and gender versions was counterbalanced across two sessions with a minimum gap of one day in between so that any carry-over effects of the response mapping from the previous session would be reduced. Subsequent to the set of stop signal experiments in the first testing session participants performed the Ospan study, which was followed by the self-report measures. Debriefing occurred at the end of the second session.

## **Results**

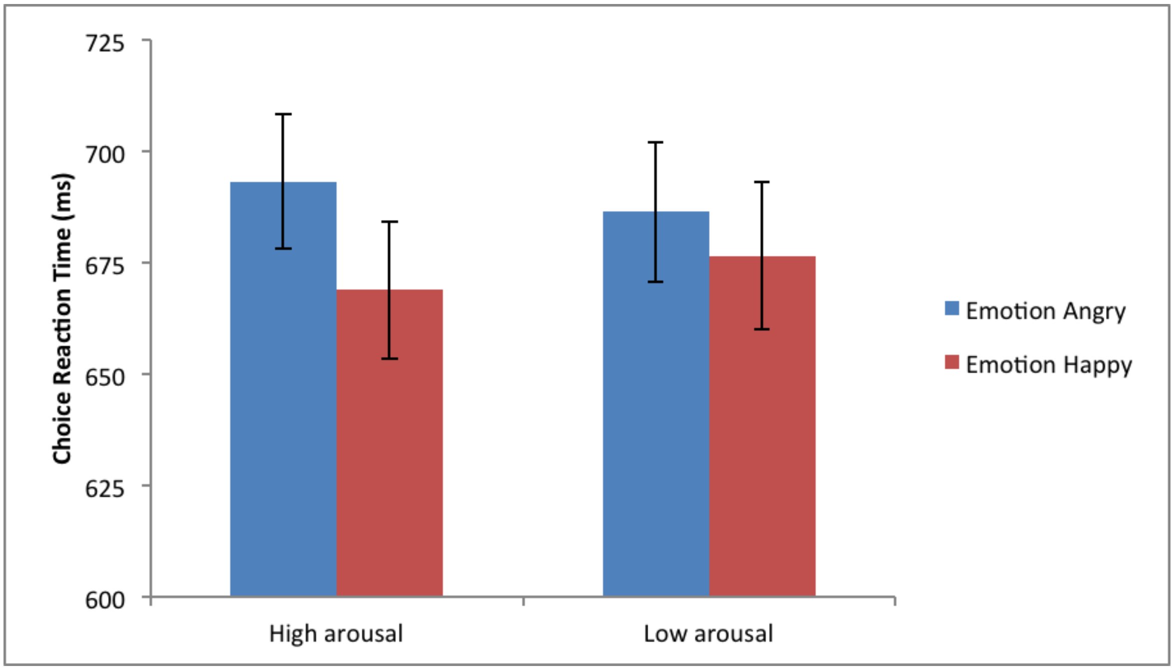
### *1) Pre-processing for all Stop signal tasks*

I pre-processed CRT and SRT (i.e. signal response time, which is the RT for those stop signal trials where participants failed to inhibit their key press) data in accordance with the procedure from the Word-Face Flanker paradigm, involving calculation of the respective mean (here: CRT and SRT) and standard deviation (here: CRT SD) scores, exclusion of outliers at subject and group levels (+/- 2.5 SD from mean; stop signal data: less than 9% of rejections; Ospan data: 8.25% removed) and normalisation. To focus on only the key conditions of interest all trial-types were collapsed across gender (e.g. male angry high arousing stimuli were combined with female angry high arousing stimuli to yield a combined condition of angry high arousing stimuli, which is then made up of both male and female faces). All p-values of pairwise comparisons were adjusted using Bonferroni correction.

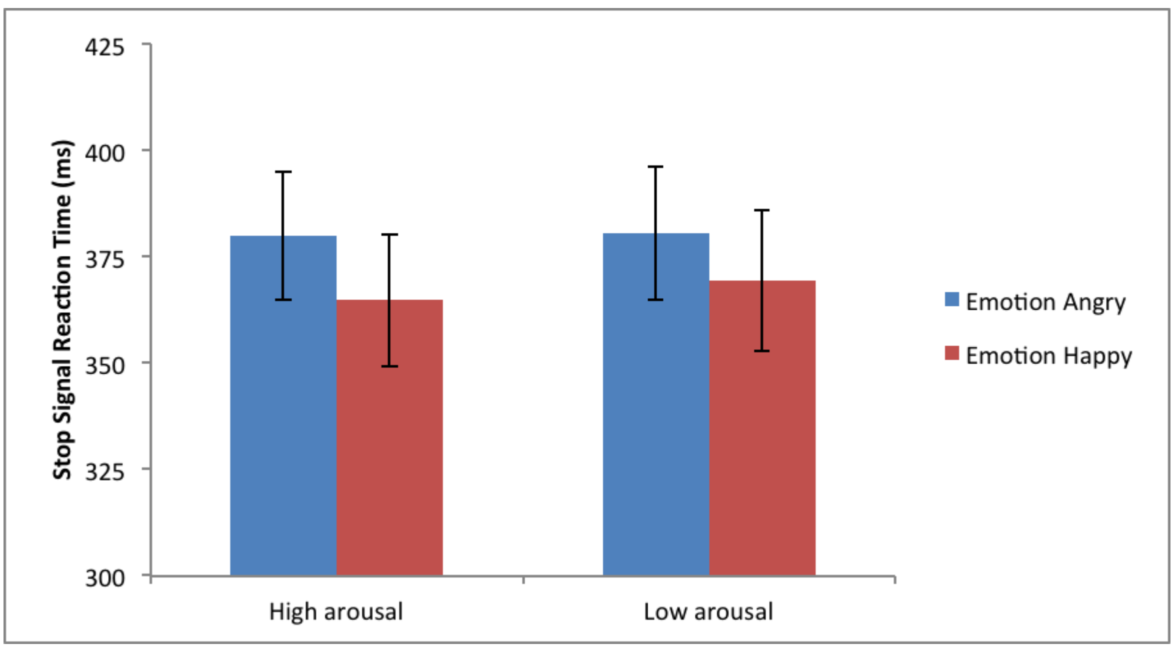
### 2) *ANOVAs*

*Pleasant-Unpleasant task*

For the stop signal task, I predicted that threatening information slows responding. To test this, Within-Subjects ANOVAs were run on CRT and SSRT data with emotion (angry, happy) and arousal (high, low) as factors. For CRTs I observed a statistically significant main effect of emotion ($F(1, 64) = 14.24$, $p < .001$, $\eta_p^2 = .18$) and an emotion X arousal interaction ($F(1, 64) = 9.26$, $p = .003$, $\eta_p^2 = .13$), but no significant main effect of arousal ($F(1, 64) = .05$, $p = .83$, $\eta_p^2 < .01$). Pairwise comparisons indicated that response latencies to angry (compared to happy) faces were significantly slower on both low ($p = .06$, 95% CI -.26; 19.93; marginally significant) and high arousal ($p < .001$, 95% CI 13.99; 34.67) trials, with the difference between angry and happy faces being larger for high arousing stimuli. For stop latencies I obtained a statistically significant main effect of emotion ($F(1, 64) = 4.10$, $p = .047$, $\eta_p^2 = .06$), showing that SSRTs were slower to angry than happy faces. However, the main effect of arousal ($F(1, 64) = .60$, $p = .44$, $\eta_p^2 = .01$) and the interaction ($F(1, 64) = .22$, $p = .64$, $\eta_p^2 < .01$) did not reach statistical significance. Results of the Pleasant-Unpleasant task are presented in Figure 20.




a)

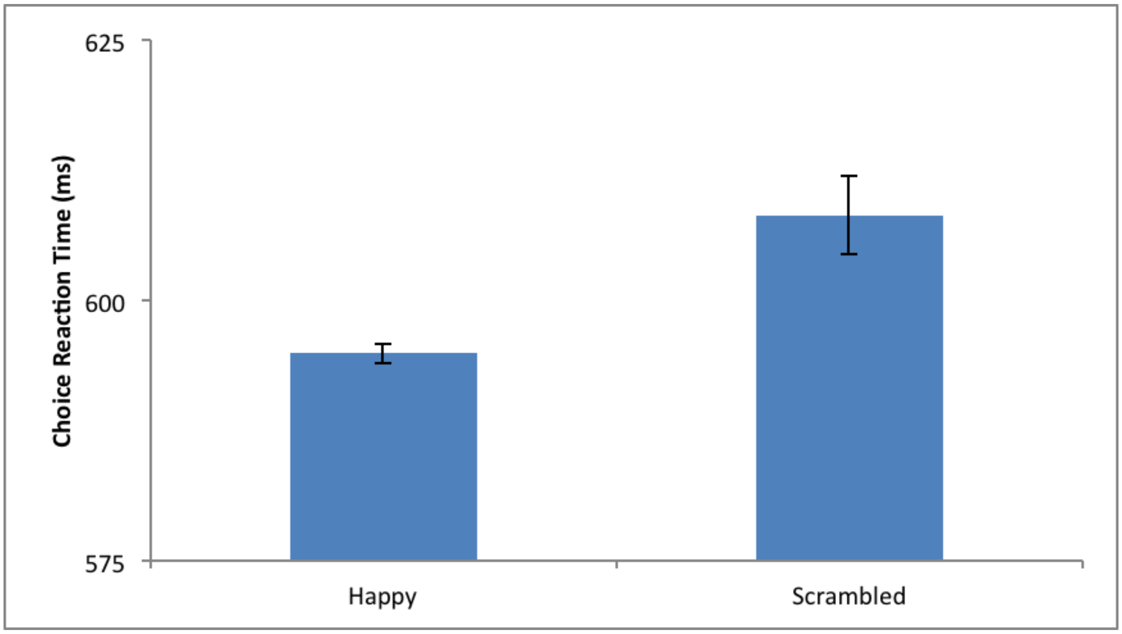



b)

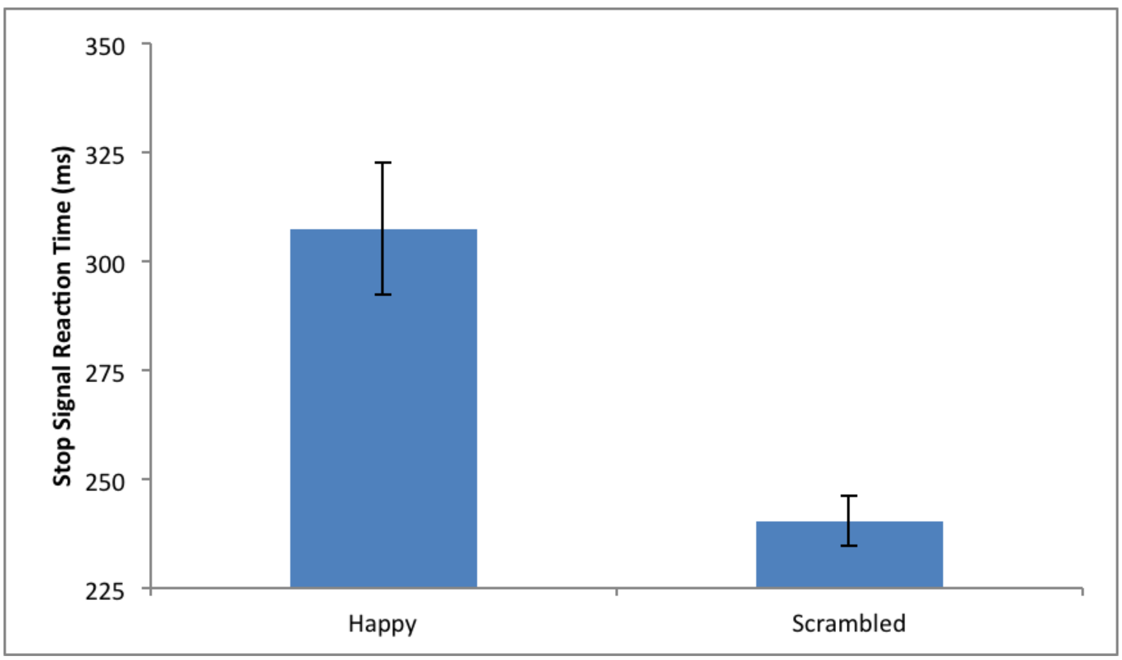
**Figure 20.** (a) CRTs and (b) SSRTs, both with SEs for all trial types of emotion and arousal.

*Pleasant-Scrambled and Unpleasant-Scrambled tasks*

Following the significant effect of emotion in the Pleasant-Unpleasant task, comparisons in all subsequent tasks involving scrambled trial-types focused on the comparison between emotion (angry or happy) versus scrambled stimuli. For this purpose all relevant trial-types were collapsed across arousal, to examine the main effects of angry vs. happy faces vs. scrambled images, depending on the task. Separate paired samples t-tests were used to examine differences in CRT and SSRT between happy vs. scrambled (Pleasant-Scrambled task) and angry vs. scrambled faces (Unpleasant-Scrambled task). Results demonstrated that response latencies for CRTs of happy targets were significantly faster compared to scrambled targets, $t(63) = -.2.81$, $p = .007$, $r = .33$, whereas the reverse (performance for happy targets slower) was found for SSRTs, $t(63) = 5.61$, $p < .001$, $r = .58$ (Pleasant-Scrambled task; see figure 10). My analyses for the Unpleasant-Scrambled task indicated that response times for angry faces did not significantly differ from those for scrambled stimuli as regards to CRTs, $t(64) = -.96$, $p = .34$, $r = .12$. By contrast, angry targets exhibited slower SSRTs than scrambled stimulus-types, $t(64) = 6.48$, $p < .001$, $r = .63$. The three significant findings above for both Pleasant-Scrambled and Unpleasant-Scrambled tasks also survived correction for multiple comparisons using Bonferroni adjustment – the corrected p-value for each of the two tasks was .03. Figure 21 displays mean (SE) CRTs and SSRTs for these results.


625
600
575
Choice Reaction Time (ms)
Happy
Scrambled

a)


350
325
300
275
250
225
Stop Signal Reaction Time (ms)
Happy
Scrambled

b)

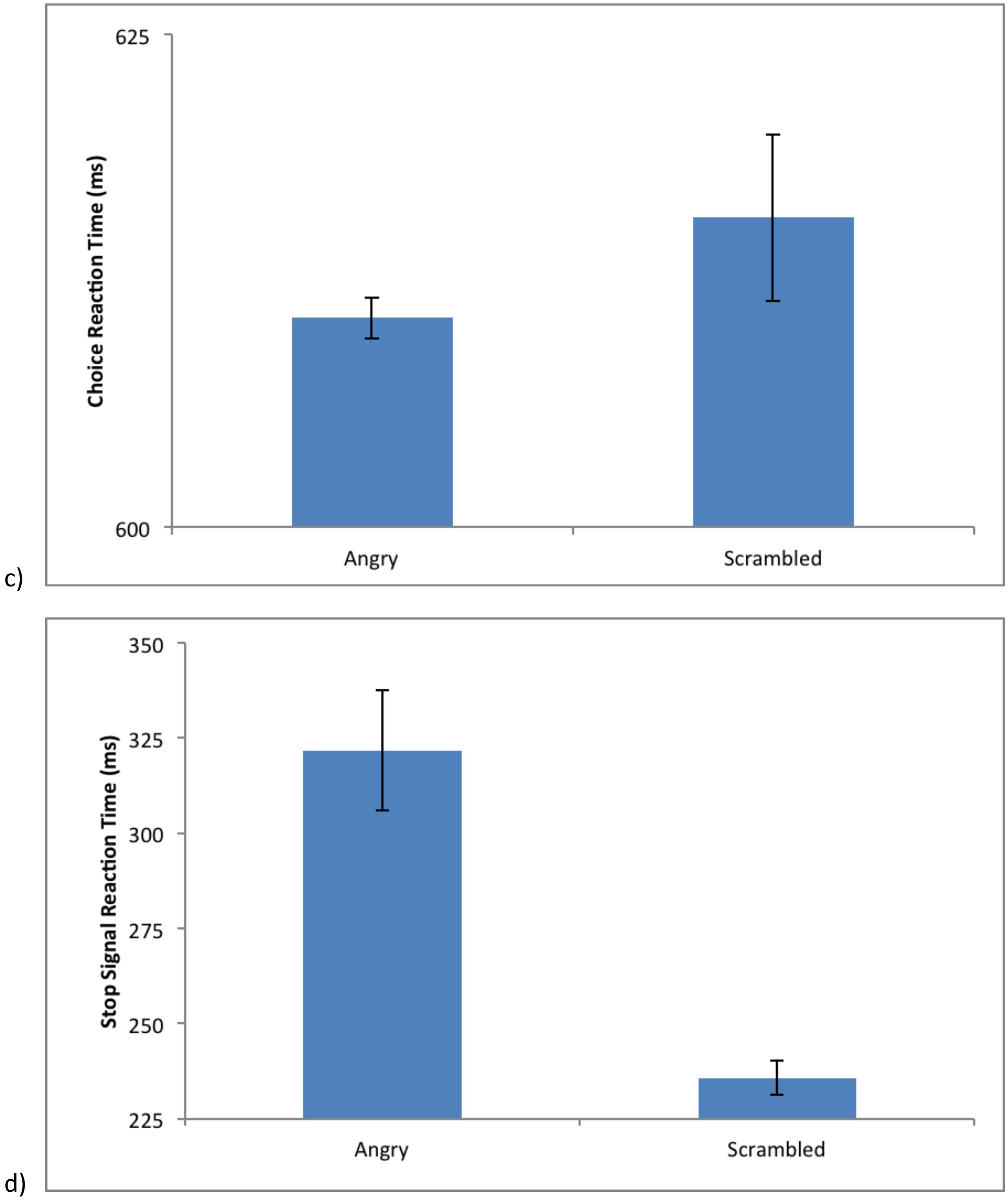



**Figure 21.** Mean (SE) CRT and SSRT for the Pleasant-Scrambled (a and b, respectively) and Unpleasant-Scrambled tasks (c and d, respectively).

*Male-Female task*

To examine the main effects of emotion and arousal, when these were not the focus of attention, 2 (emotion: angry versus happy) X 2(arousal: high versus low) Repeated-Measures ANOVAs were performed on CRT and SSRT scores to allow direct comparisons with the findings from the Pleasant-Unpleasant task. For CRT there was a statistically significant main effect of arousal ($F(1, 64) = 4.39$, $p = .04$, $\eta_p^2 = .06$), suggesting that response latencies on low arousal trials were faster than on high arousal trials. However, there was no significant main effect of emotion ($F(1, 64) = 1.00$, $p = .32$, $\eta_p^2 = .02$) nor an emotion X arousal interaction ($F(1, 64) = 2.04$, $p = .16$, $\eta_p^2 = .03$). For SSRTs this pattern of results was replicated in that there was a marginally significant main effect of arousal ($F(1, 64) = 3.11$, $p = .08$, $\eta_p^2 = .05$; low arousal trials shorter SSRTs) and, again, no main effect of emotion ($F(1, 64) = 1.95$, $p = .17$, $\eta_p^2 = .03$) and no statistically significant interaction ($F(1, 64) = .06$, $p = .80$, $\eta_p^2 < .01$). Figure 22 displays CRTs (SEs) and SSRTs (SEs) to make a gender decision for the different trial-types.

Next, to focus on the key condition of interest (i.e. emotion) and following on from the four tasks including scrambled trial-types I collapsed trial-types over arousal in the Pleasant-Unpleasant and Male-Female tasks, resulting in two final trial-types of angry and happy. Following Pessoa, Padmala, Kenzer and Bauer (2012) I then created CRT, CRT SD and SSRT difference scores for each of the six stop signal tasks. Scores from happy trial types were subtracted from the corresponding scores of angry trial-types (A-H CRT score, A-H CRT SD score and A-H SSRT score hereafter)[29]. Moreover, scores from scrambled stimulus-types were

[29] These scores were created for the Pleasant-Unpleasant, the Male-Female, the Female-Scrambled and the Male-Scrambled tasks. Section subheadings or clarifications in the actual sentence denote which of these four tasks a score was derived from (e.g. a subheading for the Pleasant-Unpleasant task means that scores discussed in this particular section are based on this task). A similar logic is applied to the A-SC and H-SC scores, which are derived

subtracted from trial-types of emotion (angry and happy; A-SC CRT score, A-SC CRT SD score, A-SC SSRT score, H-SC CRT score, H-SC CRT SD score, H-SC SSRT score hereafter). These new measures were created to account for individual differences in general response speed.

I then performed two paired-samples t-tests on the A-H CRT and A-H SSRT scores of the Pleasant-Unpleasant versus the Male-Female tasks. Results showed that the A-H CRT score for the Pleasant-Unpleasant task (mean: 17.12, SD: 36.78) was significantly greater than that for the Male-Female task (mean: 1.86, SD: 14.23; $t(63) = 3.10$, $p = .003$, $r = .36$). Similar findings were obtained for the A-H SSRT score, with that for the Pleasant-Unpleasant task (mean: 13.35, SD: 52.76) being significantly larger than the one for the Male-Female task (mean: -3.35, SD: 21.69; $t(63) = -2.50$, $p = .02$, $r = .30$). This suggests that the difference between angry and happy trial-types was more pronounced when emotion was directly task-relevant (Pleasant-Unpleasant task) as opposed to when it was distracting information (Male-Female task).

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from the Pleasant-Scrambled, the Unpleasant-Scrambled, the Female-Scrambled and the Male-Scrambled tasks. Again, section subheadings or clarifications in the sentence denote which of these four tasks a score is based on.

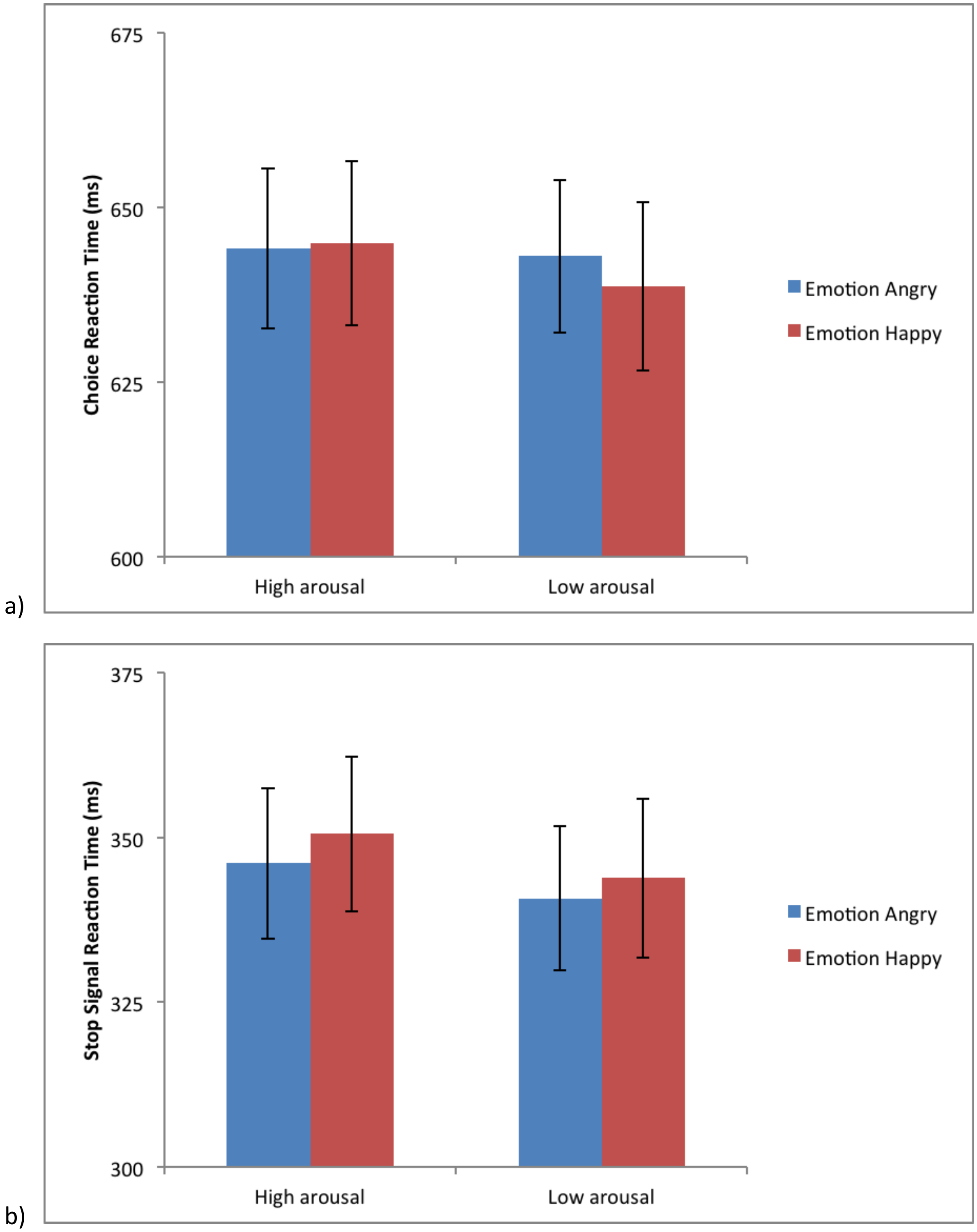


**Figure 22.** CRTs (a) and SSRTs (b) with SEs for all trial-types of the Male-Female task.

*Male-Scrambled and Female-Scrambled tasks*

A series of One-way Repeated-Measures ANOVAs was run for the Male-Scrambled and Female-Scrambled tasks with emotion (angry, happy, scrambled) as factor; all pairwise comparisons were adjusted using Bonferroni correction. For the Female-Scrambled task I found statistically significant differences between the means for CRTs ($F(2, 130) = 3.77$, $p = .03$, $\eta_p^2 = .06$). However, pairwise comparisons showed that only the difference in response times between happy (faster) and scrambled stimuli reached marginal significance ($p = .09$, 95% CI -21.71; 1.05) – all other comparisons were non-significant ($ps > .29$). There were also statistically significant differences between the means for SSRTs ($F(2, 130) = 43.49$, $p < .001$, $\eta_p^2 = .40$). Pairwise comparisons indicated that stop latencies of angry ($p < .001$, 95% CI 66.13; 142.68) and happy trial-types ($p < .001$, 95% CI 64.63; 138.32) were statistically significantly slower compared to those of scrambled trials, but angry versus happy stimulus-types did not significantly differ from each other ($p = 1.0$, 95% CI -8.14; 14.00). These results are presented in Figure 23.

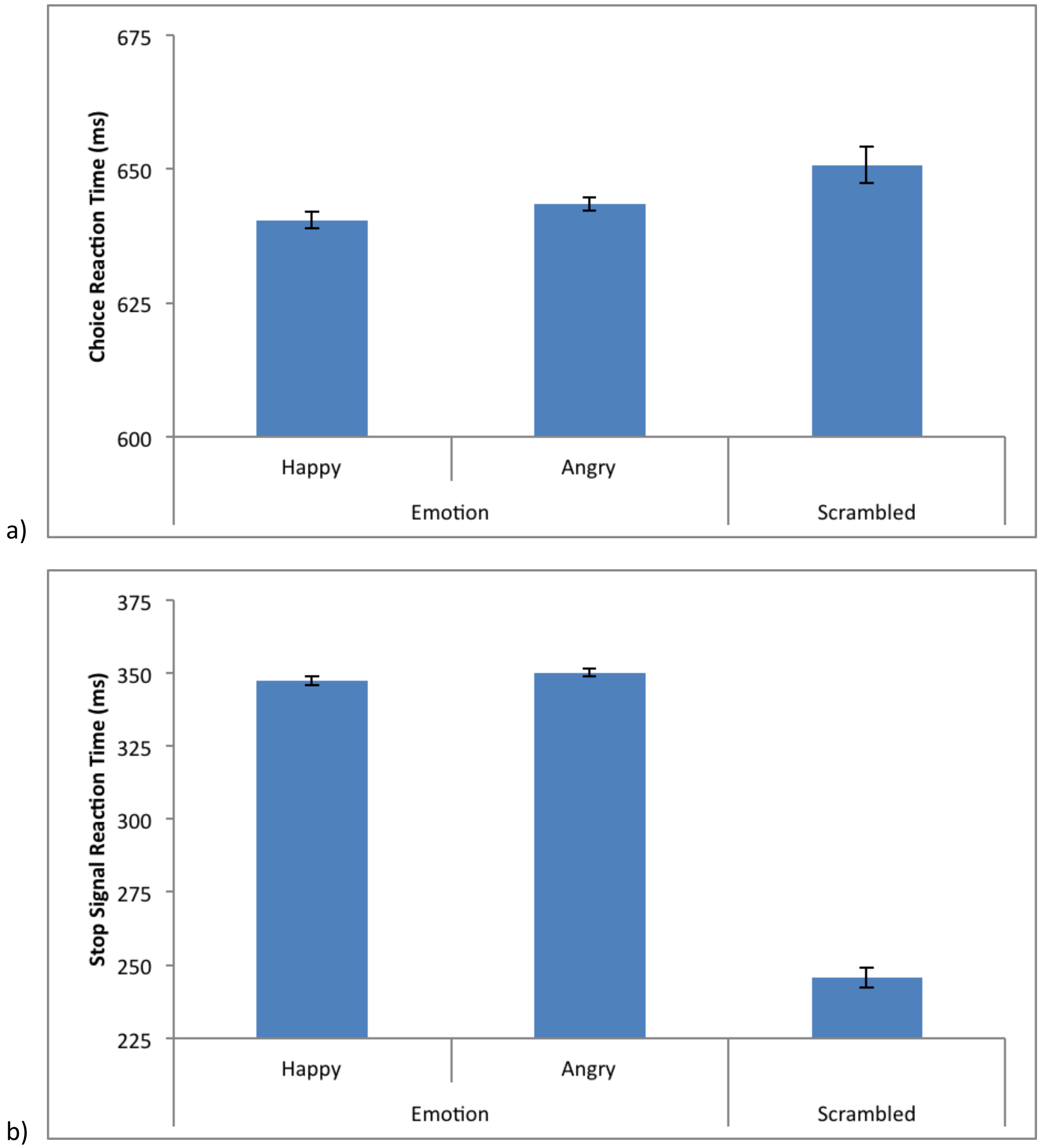


**Figure 23.** Mean CRTs (a) and SSRTs (b) with SEs for the Female-Scrambled task.

For the Male-Scrambled task the tests also revealed statistically significant differences between the means for CRTs ($F(2, 130) = 3.57$, $p = .03$, $\eta_p^2 = .05$). Again, pairwise comparisons only detected a marginally significant difference on performance for happy versus scrambled trial-types ($p = .09$, 95% CI -20.48; .93), the other comparisons did not reach significance (all ps > .24). Statistically significant differences between the means were also observed for stopping latencies ($F(2, 130) = 50.18$, $p < .001$, $\eta_p^2 = .44$). Similar to the Female-Scrambled task, pairwise comparisons demonstrated that this effect was explained by differences between angry ($p < .001$; 95% CI 68.03; 135.89) and happy ($p < .001$; 95% CI 68.59; 139.69) versus scrambled trial-types – angry versus happy targets did not differ from each other on stopping performance ($p = 1.0$, 95% CI -14.10; 9.74). These findings are shown in Figure 24.

a)
b)

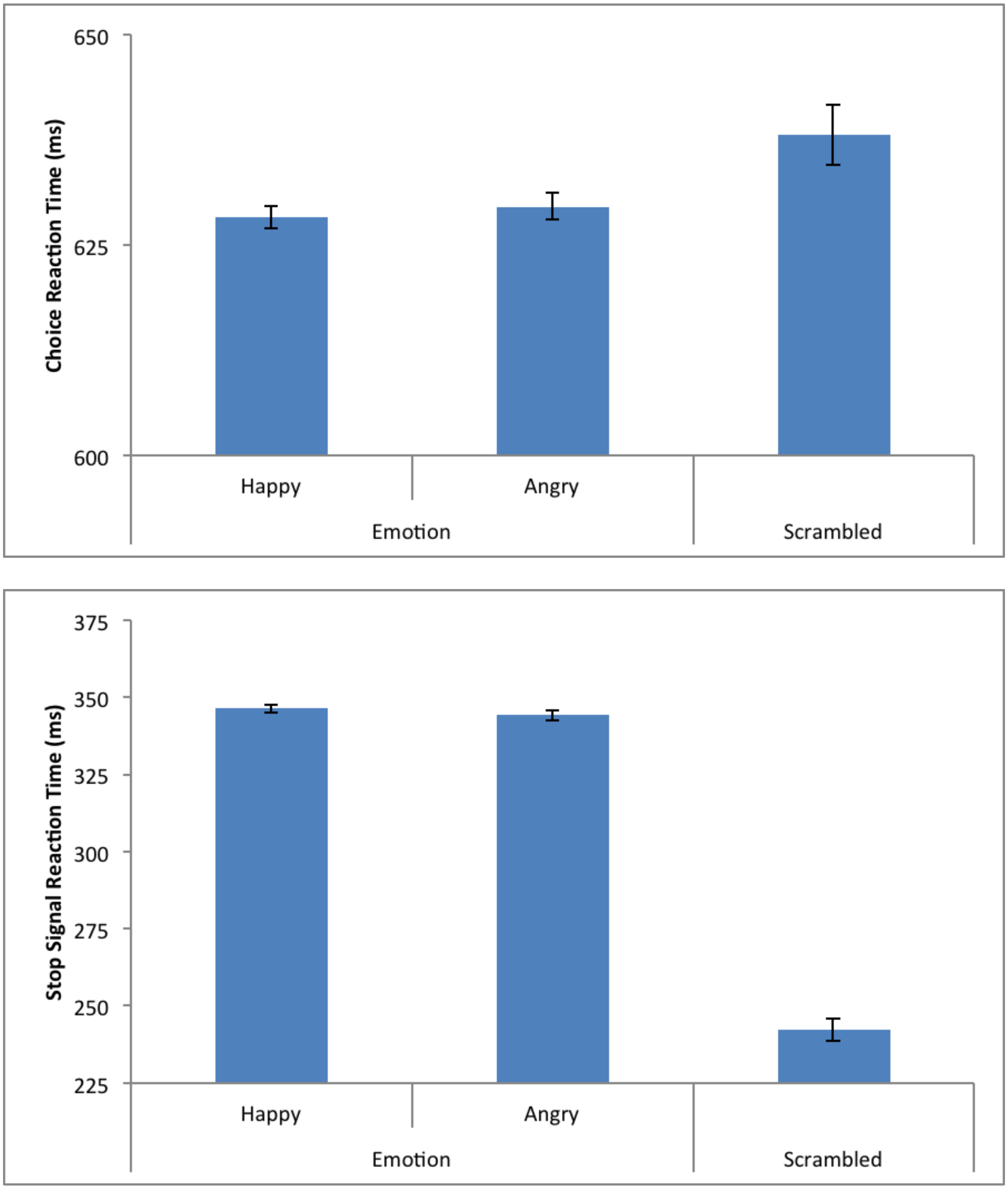


**Figure 24.** Means and SEs for CRT (a) and SSRT (b) data for the Male-Scrambled task.

3) Individual difference analyses

In summary, the results for the stop signal task have shown so far that angry and happy cues produce slower SSRTs compared to scrambled images, regardless of whether the former are target cues or distracter cues. By contrast, happy cues are faster than scrambled stimuli for CRT, whereas angry cues do not differ in such response latencies from scrambled ones – again, these effects hold true for both when the emotional cues are targets versus distracters. In a direct comparison, performance for angry targets is shown to be slower than that for happy targets (CRT and SSRT), albeit these emotional cues do not differ from each other when functioning as distracters (CRT and SSRT). So, in other words, the difference in performance between angry and happy trial-types was more striking when emotion was the target (Pleasant-Unpleasant task) as compared to when it was distracting information (Male-Female task). Indeed, for gender targets, distracters differ on arousal (low arousal cues faster; both CRT and SSRT) and, interestingly, when emotional cues are targets, for CRTs they interact with arousal distracter cues – angry targets produce a stronger slowing effect with high arousing distracter cues. In short, these findings suggest that the interference from threatening relative to happy faces is most salient when these cues are targets, although general effects of emotion over control stimuli (here: scrambled images) were observed for both emotional target as well as distracter cues.

As for the individual difference measures, based on the Mathews and Mackintosh model (Mathews et al., 1997; Mathews & Mackintosh, 1998) and the mental noise hypothesis (Robinson & Tamir, 2005), I expected that attentional bias to threat as well as intra-individual variability are increased (as reflected in large positive difference scores) at elevated levels of trait neuroticism. This effect should, according to the Mathews and Mackintosh model, be more prominent when threat acts as a distracting cue amongst a set of other cues, as in the gender decision task, but be lessened on trials where there is only one main cue (emotion decision task). Furthermore, I predicted that heightened voluntary control (reappraisal or attentional control) diminishes the effect of neuroticism on the appraisal of threat as well as intra-individual variability.

In line with these predictions, first, a series of Pearson correlations was conducted between the difference scores (involving mean CRTs, CRT SDs and SSRTs) from all six stop signal tasks versus neuroticism, state and trait anxiety, verbal intelligence, reappraisal, attentional control and the two Ospan measures (i.e. total and absolute scores). I found weak-to-moderate negative correlations between the A-H SSRT score for the Pleasant-Unpleasant task and the absolute and total Ospan scores ($r = -.30$, $p = .023$ and $r = -.28$, $p = .04$, respectively). Moreover, the A-H SSRT score for the Male-Female task produced significant weak-to-moderate correlations with reappraisal (negative association) and trait anxiety (positive association; $r = -.29$, $p = .02$ and $r = .26$, $p = .04$, respectively). Trait anxiety also exhibited weak-to-moderate positive correlations with the A-H CRT score of the Female-Scrambled task ($r = .25$, $p = .04$), the A-H CRT SD score of the Pleasant-Unpleasant task ($r = .30$, $p = .02$) as well as the H-SC CRT SD score of the Male-Scrambled task ($r = .32$, $p = .01$). Finally, neuroticism was weak-to-moderately correlated with the A-H CRT SD score of the Pleasant-Unpleasant task (positive association: $r = .28$, $p = .03$), whereas the H-SC SSRT score of the Pleasant-Scrambled task showed a weak-to-moderate negative correlation with state anxiety ($r = -.27$, $p = .04$). It should be noted, however, that the aforementioned correlations for the stop signal paradigm were only significant at the conventional significance level. When correcting for multiple comparisons none of these correlations remained statistically significant.

Consistent with the procedure from the Word-Face Stroop paradigm and, again, using the MODPROBE macro of Hayes and Matthes (2009) for this purpose, I explored the prediction that reappraisal or attentional control (M) moderate the strength of the association between neuroticism (focal predictor; F) and the A-H CRT, A-H CRT SD and A-H SSRT scores of the Pleasant-Unpleasant and Male-Female tasks (outcome variables). As before, the absolute and total Ospan scores as well as either reappraisal or attentional control were entered as covariates in each regression model. This prediction was, on the whole, supported with some significant, albeit weak in terms of variance accounted for, interaction effects. Each of these moderation effects will be discussed in turn for each outcome variable.

*Pleasant-Unpleasant task*

*CRT, CRT SD and SSRT*

The interaction between neuroticism and reappraisal/ attentional control with regard to the A-H CRT and A-H CRT SD scores as respective outcome variables was not significant (A-H CRT score – reappraisal: b = -.68, t(49) = -1.93, p = .06; see Table 1a, column 2; attentional control: b = -.18, t(49) = -1.01, p = .32; see Table 2a, column 2; A-H CRT SD score – reappraisal: b = -.21, t(49) = -1.23, p = .23; see Table 3, column 1; attentional control: b = -.05, t(49) = -.57, p = .57; see Table 4, column 1), neither was the moderation effect between neuroticism and attentional control concerning the A-H SSRT score (b = -.63, t(49) = -1.88, p = .07; see Table 2a, column 1). However, as can be seen from Table 1a (column 1), my results show a statistically significant interactive effect of neuroticism and reappraisal on the A-H SSRT score (b = -1.42, t(49) = -2.15, p = .04). Whereas 21% of the variance in the A-H SSRT score was accounted for by the regression model, an additional 8% of the variance was solely explained by the interaction (see Table 1a). An effect size of this magnitude for the interaction is not entirely unexpected, given that the variance explained by moderation effects is usually comparatively small (Chaplin, 1991). The interaction suggests that the level of reappraisal affects the impact of neuroticism. So, in individuals with low levels of reappraisal (mean: 23.89; b = 11.65, SE = 5.12, t(49) = 2.28, p = .03, 95% CI = 1.36; 21.94), neuroticism was related to the A-H SSRT score as expected (high neuroticism = large positive difference, low neuroticism = large negative difference; see thin smooth line, figure 15) – a positive A-H SSRT score indicates that responses to angry expressions were slower. In other words, the higher the level of neuroticism, the more participants are slowed by angry expressions.[30] For individuals of medium and high levels of reappraisal this association was not statistically significant, however (medium reappraisal: mean: 29.00; b = 4.41, SE = 4.73, t(49) = .93, p = .36, 95% CI = -5.10; 13.92; high reappraisal: mean: 34.11; b = -2.83, SE = 6.42, t(49) = -.44, p = .66, 95% CI = -15.73; 10.07). Next, I used the Johnson–Neymann (J-N) technique of the modprobe macro to examine the features of the interaction in more detail (Hayes & Matthes, 2009). This technique determines the thresholds(s) to significance on the spectrum of the moderator variable, i.e. the transition point(s) or value(s) of the moderator variable where the association between the predictor and the outcome reaches significance. Here, at a reappraisal sumscore of 25 (out of a maximum of 42), the conditional effect of neuroticism on the A-H SSRT score shifted in significance (i.e. significant below this point and non-significant above; b = 9.61, SE = 4.78, t(49) = 2.01, p = .05, 95% CI = .00; 19.21) – this score (i.e. 25) was at the 21$^{st}$ percentile in our sample distribution. The interaction is displayed in Figure 25.

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[30] Given the observed slowing effect of performance towards angry targets and that both angry and happy SSRTs were slower compared to scrambled SSRTs (see ANOVAs), it seems unlikely that a large, positive A-H SSRT score would be due to a facilitation effect of responses to happy faces.

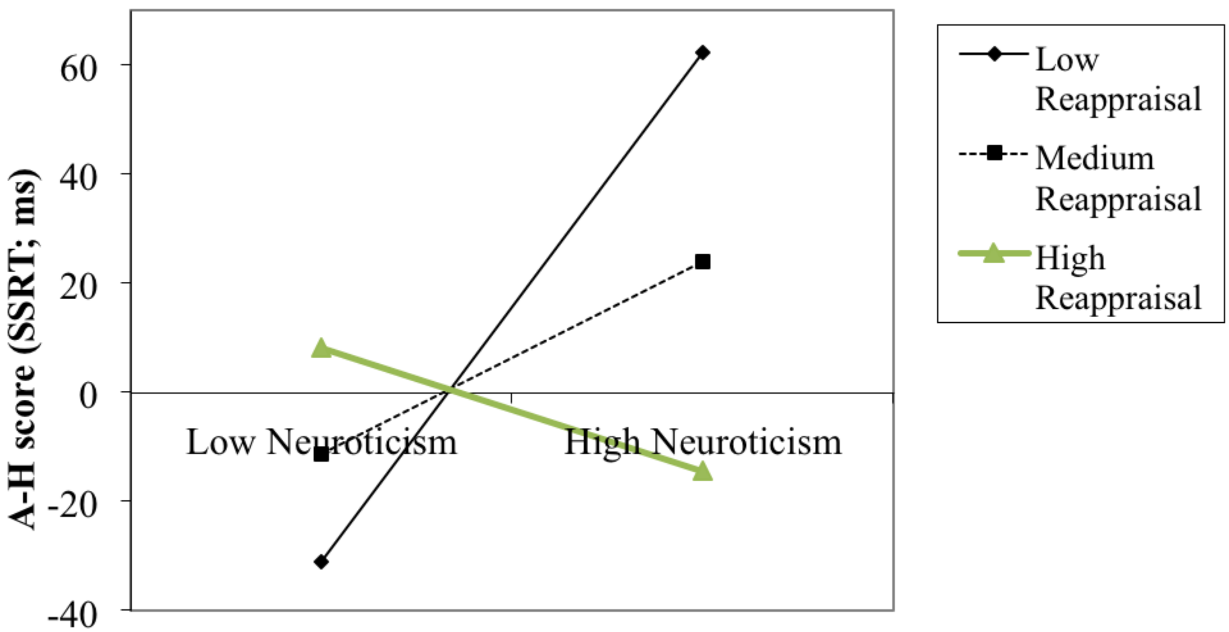


**Figure 25.** The A-H SSRT score was plotted against neuroticism. Participants were split into subgroups of high (+1SD), medium (mean) and low (-1SD) reappraisal for the purpose of displaying the interaction.

*Male-Female task*

*CRT, CRT SD and SSRT*

In line with my predictions the interaction effect of neuroticism and reappraisal was statistically significant with the A-H CRT score (b = -.41, t(50) = -2.53, p = .02; see Table 1b, column 2), accounting for 11% of unique variance in this outcome variable. It should be noted though that the conditional effects of the focal predictor at different levels of the moderator variable were only marginally significant at best. In particular, results showed a marginally significant association for individuals of low reappraisal, whereby, similar to the Pleasant-Unpleasant task, the higher the level of neuroticism of a person was, the slower were his/her responses to targets with angry distracters (mean: 23.97; b = 2.02, SE = 1.27, t(50) = 1.59, p = .12, 95% CI = -.54; 4.56). Once more, the conditional effects were not significant for medium and high levels of reappraisal, but showed, with a weak trend, some resemblance to the pattern of results from the Pleasant-Unpleasant task (mean: 29.04; b = -.08, SE = 1.18, t(50) = -.07, p = .94, 95% CI = -2.45; 2.28; mean: 34.10; b = -2.18, SE = 1.59, t(50) = -1.37, p = .18, 95% CI = -5.38; 1.02, respectively). To further probe the interaction I, as before, employed the J-N technique using the modprobe macro (Hayes & Matthes, 2009). This revealed a transition in significance at a reappraisal sumscore of ~ 22/42 (i.e. the $4.5^{th}$ percentile in our sample distribution; again, scores below this threshold reached significance, scores above did not; b = 2.95, SE = 1.47, t(50) = 2.01, p = .05, 95% CI = .00; 5.89).

The moderation effect of neuroticism and reappraisal on the A-H CRT SD score also reached statistical significance (b = -.43, t(50) = -3.36, p < .01; see Table 3, column 2), explaining 17% of distinct variance in this outcome variable. This time the conditional effects were not significant at low and medium levels of reappraisal (mean: 23.97; b = .84, SE = .99, t(50) = .85, p = .40, 95% CI = -1.15; 2.83; mean: 29.04; b = -1.33, SE = .92, t(50) = -1.45, p = .15, 95% CI = -3.18; .52), with a significant association between neuroticism and the A-H CRT SD score at high levels of reappraisal (mean: 34.10; b = -3.50, SE = 1.24, t(50) = -2.82, p < .01, 95% CI = -6.00; -1.00). Employing the J-N technique of the modprobe macro (Hayes & Matthes, 2009), I further probed this interaction. Results showed a transition in significance at a reappraisal sumscore of ~20/42 (i.e. the 3rd percentile in our sample distribution; again, scores below this threshold reached significance, scores above did not up until a second transition point; b = 2.64, SE = 1.32, t(50) = 2.01, p = .05, 95% CI = .00; 5.29) as well as ~31/42 (i.e. the 68th percentile in our sample distribution; here, scores above this threshold reached significance, scores below did not up until the former transition point (i.e. ~20/40); b = -1.97, SE = .98, t(50) = -2.01, p = .05, 95% CI = -3.95; .00). Thus, at low levels of reappraisal, the higher the level of neuroticism, the more variable participants' performance was towards threatening information, whereas, at elevated levels of reappraisal, the higher the level of neuroticism, the less variable participants' performance was towards threatening information.

Against my expectations, there was no interaction effect of neuroticism and reappraisal/attentional control on the A-H SSRT score (reappraisal: b = -.25, t(49) = -.93, p = .36; see Table 1b, column 1; attentional control: b = -.13, t(49) = -1.00, p = .32; see Table 2b, column 1), nor was there an interaction effect between neuroticism and attentional control concerning the A-H CRT and A-H CRT SD scores (A-H CRT: b = -.09, t(49) = -1.10, p = .28; see Table 2b, column 2; A-H CRT SD: b = -.09, t(49) = -1.25, p = .22; see Table 4, column 2). Figure 26 presents the interaction effect of the A-H CRT score, and Figure 27 the interaction effect of the A-H CRT SD score.

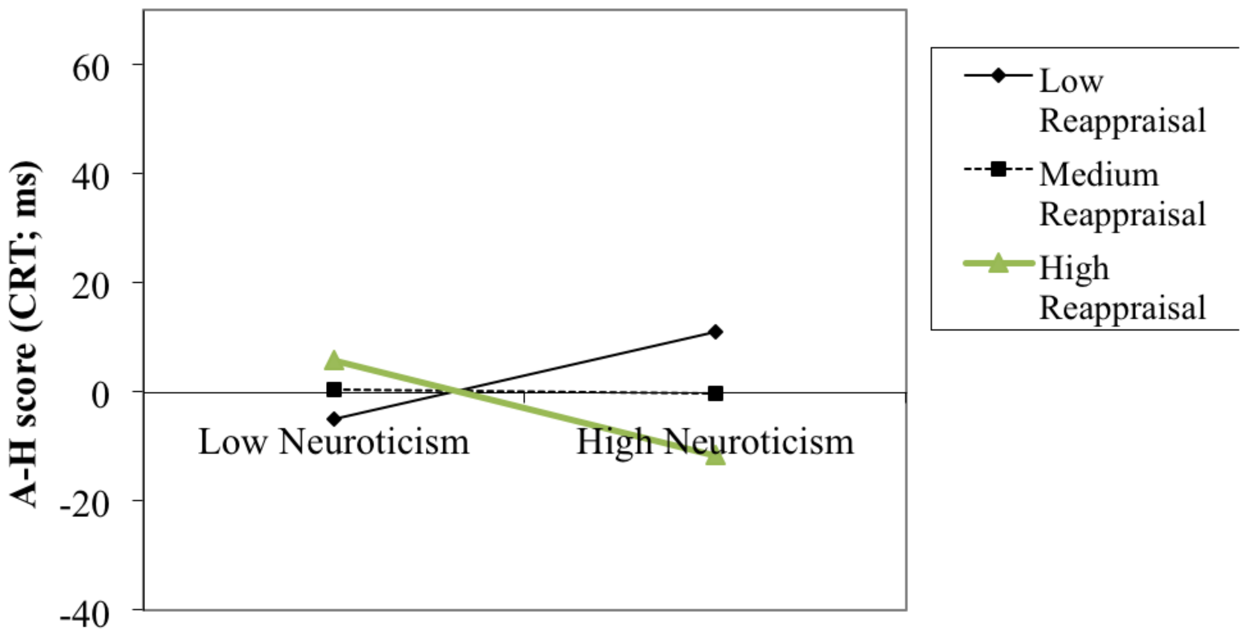


**Figure 26.** Neuroticism plotted against the A-H CRT score for three different subgroups of reappraisal (low, medium, high).

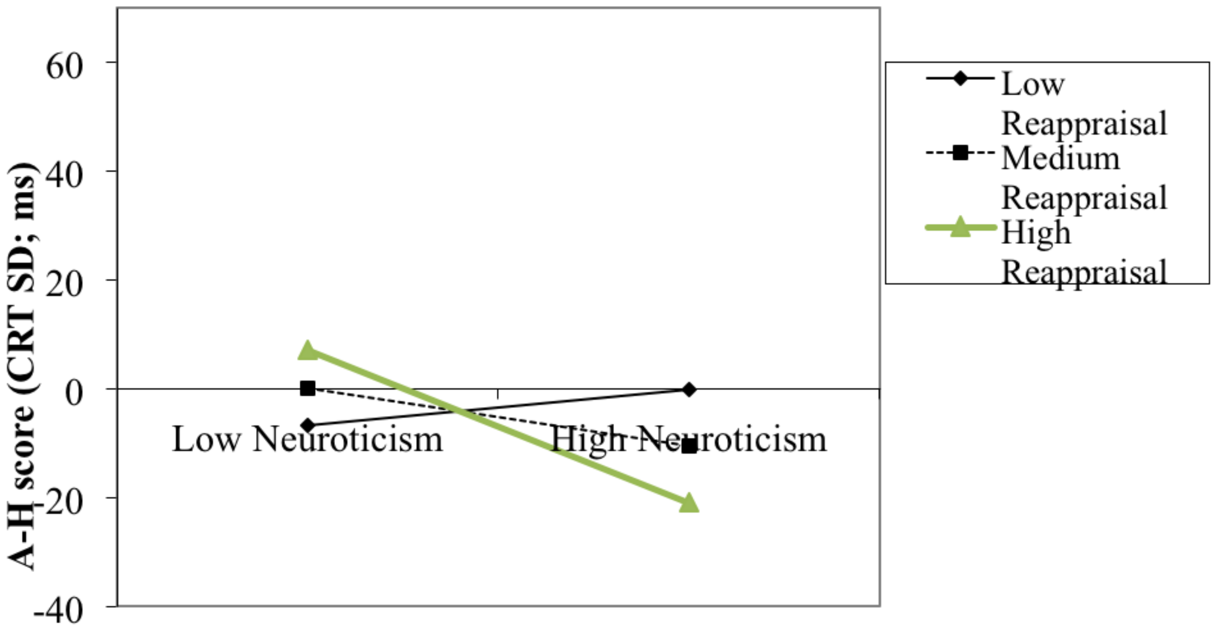


**Figure 27.** Neuroticism plotted against the A-H CRT SD score for three different subgroups of reappraisal (low, medium, high).

These moderation effects were unique to A-H scores from the Pleasant-Unpleasant and Male-Female tasks. Exploratory analyses with the remaining difference scores did not yield any statistically significant effects after correcting for multiple comparisons.[31]

[31] Only 3 (out of 48) exploratory moderation analyses reached the conventional level of significance: the interaction of neuroticism and attentional control with regard to the H-SC CRT SD score of the Pleasant-Scrambled task ($b = .28$, $t(49) = 1.07$, $p = .01$) and the interactions of neuroticism and reappraisal with regard to the H-SC CRT SD score ($b = -.48$, $t(49) = -2.28$, $p = .03$) as well as the A-H CRT SD score ($b = .58$, $t(49) = 2.92$, $p < .01$) of the Female-Scrambled task, all other ps > .05).

**Table 1.** OLS regression estimating indicators of the A-H scores from neuroticism, reappraisal, as well as their interaction, with attentional control and the absolute and total Ospan scores as covariates.

a)

| | Pleasant-Unpleasant task | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A-H SSRT score | | | | A-H CRT score | | | |
| | *b* | *SE* | *t* | *p* | *b* | *SE* | *t* | *p* |
| Constant | -184.03 | 120.03 | -1.53 | 0.13 | -40.38 | 63.96 | -0.63 | 0.53 |
| Attentional Control ($W_1$) | 0.42 | 1.10 | 0.38 | 0.70 | -0.71 | 0.59 | -1.21 | 0.23 |
| Absolute Ospan score ($W_2$) | -0.45 | 0.81 | -0.56 | 0.58 | 0.07 | 0.43 | 0.16 | 0.88 |
| Total Ospan score ($W_3$) | -0.59 | 1.04 | -0.57 | 0.57 | -0.53 | 0.56 | -0.95 | 0.35 |
| Neuroticism (F) | 45.54 | 18.57 | 2.45 | 0.02 | 20.90 | 9.90 | 2.11 | 0.04 |
| Reappraisal (M) | 6.69 | 3.75 | 1.78 | 0.08 | 3.69 | 2.00 | 1.85 | 0.07 |
| *F x M* | **-1.42** | **0.66** | **-2.15** | **0.04** | -0.68 | 0.35 | -1.93 | 0.06 |

b)

| | Male-Female task | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A-H SSRT score | | | | A-H CRT score | | | |
| | *b* | *SE* | *t* | *p* | *b* | *SE* | *t* | *p* |
| Constant | -67.40 | 48.52 | -1.39 | 0.17 | -38.76 | 29.59 | -1.31 | 0.20 |
| Attentional Control ($W_1$) | 0.75 | 0.44 | 1.69 | 0.10 | -0.04 | 0.27 | -0.15 | 0.88 |
| Absolute Ospan score ($W_2$) | -0.19 | 0.33 | -0.57 | 0.57 | 0.01 | 0.20 | 0.06 | 0.96 |
| Total Ospan score ($W_3$) | 0.36 | 0.42 | 0.85 | 0.40 | -0.26 | 0.26 | -1.00 | 0.32 |
| Neuroticism (F) | 9.49 | 7.56 | 1.25 | 0.22 | 11.94 | 4.61 | 2.59 | 0.01 |
| Reappraisal (M) | -0.04 | 1.53 | -0.03 | 0.98 | 1.91 | 0.93 | 2.05 | 0.05 |
| *F x M* | -0.25 | 0.27 | -0.93 | 0.36 | **-0.41** | **0.16** | **-2.53** | **0.01** |

*Note*: (a) *Pleasant-Unpleasant* task: **A-H score (SSRT): $R^2$ = 0.21, F(6, 49) = 2.20, p = 0.6, $R^{2inter}$ = 0.08, F = 4.63, p = 0.036**; A-H score (CRT): $R^2$ = 0.18, F(6, 49) = 1.78, p = 0.12, $R^{2inter}$ = 0.06, F = 3.73, p = 0.06; (b) *Male-Female task*: A-H score (SSRT): $R^2$ = 0.18, F(6, 50) = 1.77, p = 0.12, $R^{2inter}$ = 0.01, F = .86, p = 0.36; **A-H score (CRT): $R^2$ = 0.18, F(6, 50) = 1.87, p = 0.11, $R^{2inter}$ = 0.11, F = 6.42, p = 0.02.**

**Table 2.** OLS regression estimating indicators of the A-H scores from neuroticism, attentional control, as well as their interaction, with reappraisal and the absolute and total Ospan scores as covariates.

a)

| | Pleasant-Unpleasant task | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A-H SSRT score | | | | A-H CRT score | | | |
| | *b* | *SE* | *t* | *p* | *b* | *SE* | *t* | *p* |
| Constant | -122.88 | 108.46 | -1.13 | 0.26 | 7.97 | 58.73 | 0.14 | 0.89 |
| Reappraisal ($W_1$) | -1.52 | 1.69 | -0.90 | 0.37 | -0.06 | 0.91 | -0.07 | 0.95 |
| Absolute Ospan score ($W_2$) | -0.18 | 0.86 | -0.20 | 0.84 | 0.09 | 0.47 | 0.19 | 0.85 |
| Total Ospan score ($W_3$) | -0.87 | 1.10 | -0.79 | 0.43 | -0.52 | 0.60 | -0.88 | 0.38 |
| Neuroticism (F) | 35.46 | 15.90 | 2.23 | 0.03 | 10.74 | 8.61 | 1.25 | 0.22 |
| Attentional Control (M) | 4.05 | 1.94 | 2.09 | 0.04 | 0.46 | 1.05 | 0.43 | 0.67 |
| *F x M* | -0.63 | 0.33 | -1.88 | 0.07 | -0.18 | 0.18 | -1.01 | 0.32 |

b)

| | Male-Female task | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A-H SSRT score | | | | A-H CRT score | | | |
| | *b* | *SE* | *t* | *p* | *b* | *SE* | *t* | *p* |
| Constant | -61.31 | 43.74 | -1.40 | 0.17 | -7.28 | 28.03 | -0.26 | 0.80 |
| Reappraisal ($W_1$) | -1.54 | 0.67 | -2.28 | 0.03 | -0.38 | 0.43 | -0.89 | 0.38 |
| Absolute Ospan score ($W_2$) | -0.12 | 0.35 | -0.34 | 0.74 | 0.01 | 0.22 | 0.03 | 0.98 |
| Total Ospan score ($W_3$) | 0.30 | 0.44 | 0.68 | 0.50 | -0.22 | 0.28 | -0.80 | 0.43 |
| Neuroticism (F) | 8.76 | 6.36 | 1.38 | 0.17 | 4.92 | 4.07 | 1.21 | 0.23 |
| Attentional Control (M) | 1.51 | 0.78 | 1.93 | 0.06 | 0.61 | 0.50 | 1.21 | 0.23 |
| *F x M* | -0.13 | 0.13 | -1.00 | 0.32 | -0.09 | 0.09 | -1.10 | 0.28 |

*Note*: (a) *Pleasant-Unpleasant* task: A-H score (SSRT): $R^2 = 0.20$, $F(6, 49) = 1.99$, $p = 0.09$, $R^{2inter} = 0.06$, $F = 3.55$, $p = 0.07$; A-H score (CRT): $R^2 = 0.14$, $F(6, 49) = 1.27$, $p = 0.29$, $R^{2inter} = 0.02$, $F = 1.03$, $p = 0.32$; (b) *Male-Female task*: A-H score (SSRT): $R^2 = 0.18$, $F(6, 50) = 1.80$, $p = 0.12$, $R^{2inter} = 0.02$, $F = 1.00$, $p = 0.32$; A-H score (CRT): $R^2 = 0.10$, $F(6, 50) = .93$, $p = .49$, $R^{2inter} = 0.02$, $F = 1.22$, $p = 0.28$.

**Table 3.** OLS regression estimating indicators of the A-H scores from neuroticism, reappraisal, as well as their interaction, with attentional control and the absolute and total Ospan scores as covariates.

| | **A-H CRT SD score** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Pleasant-Unpleasant task** | | | | **Male-Female task** | | | |
| | *b* | *SE* | *t* | *p* | *b* | *SE* | *t* | *p* |
| Constant | -17.09 | 31.62 | -0.54 | 0.59 | -36.75 | 23.10 | -1.59 | 0.12 |
| Attentional Control ($W_1$) | -0.44 | 0.29 | -1.50 | 0.14 | -0.17 | 0.21 | -0.83 | 0.41 |
| Absolute Ospan score ($W_2$) | 0.30 | 0.21 | 1.41 | 0.17 | 0.15 | 0.16 | 0.93 | 0.36 |
| Total Ospan score ($W_3$) | -0.54 | 0.27 | -1.97 | 0.05 | -0.39 | 0.20 | -1.92 | 0.06 |
| Neuroticism (F) | 7.40 | 4.89 | 1.51 | 0.14 | 11.10 | 3.60 | 3.08 | p < .01 |
| Reappraisal (M) | 1.73 | 0.99 | 1.75 | 0.09 | 2.22 | 0.73 | 3.05 | p < .01 |
| *F x M* | -0.21 | 0.17 | -1.23 | 0.23 | **-0.43** | **0.13** | **-3.36** | **p < .01** |

*Note*: (a) *Pleasant-Unpleasant* task: $R^2$ = 0.22, F(6, 49) = 2.31, p = 0.05, $R^{2inter}$ = 0.02, F = 1.50, p = 0.23; (b) *Male-Female task*: $R^2$ = 0.26, F(6, 50) = 2.87, p = .02, $R^{2inter}$ = 0.17, F = 11.26, p < .01.

**Table 4.** OLS regression estimating indicators of the A-H scores from neuroticism, attentional control, as well as their interaction, with reappraisal and the absolute and total Ospan scores as covariates.

| | A-H CRT SD score | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Pleasant-Unpleasant task | | | | Male-Female task | | | |
| | *b* | *SE* | *t* | *p* | *b* | *SE* | *t* | *p* |
| Constant | -0.77 | 28.62 | -0.03 | 0.98 | -2.41 | 22.72 | -0.11 | 0.92 |
| Reappraisal ($W_1$) | 0.56 | 0.45 | 1.25 | 0.22 | -0.14 | 0.35 | -0.39 | 0.70 |
| Absolute Ospan score ($W_2$) | 0.30 | 0.23 | 1.31 | 0.20 | 0.13 | 0.18 | 0.72 | 0.48 |
| Total Ospan score ($W_3$) | -0.53 | 0.29 | -1.83 | 0.07 | -0.34 | 0.23 | -1.49 | 0.14 |
| Neuroticism (F) | 3.89 | 4.20 | 0.93 | 0.36 | 3.35 | 3.30 | 1.02 | 0.31 |
| Attentional Control (M) | -0.10 | 0.51 | -0.20 | 0.84 | 0.44 | 0.41 | 1.09 | 0.28 |
| *F x M* | -0.05 | 0.09 | -0.57 | 0.57 | -0.09 | 0.07 | -1.25 | 0.22 |

*Note*: (a) *Pleasant-Unpleasant* task: $R^2 = 0.20$, F(6, 49) = 2.06, p = 0.08, $R^{2inter} < 0.01$, F = .33, p = 0.57; (b) *Male-Female task*: $R^2 = 0.12$, F(6, 50) = 1.10, p = .38, $R^{2inter} = 0.03$, F = 1.57, p = 0.22.

In summary, there were no consistent correlations between the difference scores and the individual difference variables. However, the association between neuroticism and the A-H scores was moderated by reappraisal for SSRT (but not CRT or CRT SD) when emotion was task-relevant (Pleasant-Unpleasant task) and for CRT and CRT SD (but not SSRT) when emotion served as distracting information (Male-Female task). These interactions indicated that for low levels of reappraisal high neuroticism was related to slowed performance when exposed to angry targets (SSRT) or distracters (CRT). For higher levels of reappraisal this association became non-significant. Additionally, for CRT SD scores (Male-Female task) the results indicated that, at low levels of reappraisal, the higher the level of neuroticism, the more variable participants' performance was towards threatening information, whereas, at elevated levels of reappraisal, the higher the level of neuroticism, the less variable participants' performance was towards threatening information.

**Discussion.**

I predicted that threatening stimuli impair performance, with this bias being more pronounced at high levels of trait neuroticism and when more than one cue is displayed per trial. Moreover, high levels of trait neuroticism were expected to be linked with greater intra-individual variability on go trials. Furthermore, I hypothesized that elevated levels of voluntary control (reappraisal or attentional control) decrease the impact of neuroticism on intra-individual variability on go trials and on threat appraisal. In line with these predictions, I found that angry targets produce greater interference relative to happy ones (SSRT and CRT), with this effect only being significant when emotion is task-relevant. Moreover, for gender targets results showed speeded stop and response latencies for low (versus high) arousal distracter cues, whereas, when emotion is task-relevant, arousal interacts with valence (angry targets exhibit greater interference with high arousing distracter cues). Also in line with my hypotheses, for low levels of reappraisal high neuroticism was related to slowed performance when exposed to angry targets (SSRT) or distracters (CRT). Additionally, at low levels of reappraisal, elevated trait neuroticism was associated with increased variability for angry distracters (CRT SD scores). By contrast, at upper levels of reappraisal, high trait neuroticism was linked with decreased intra-individual variability towards threatening information (CRT SD scores).

These results extend previous findings (Pessoa et al., 2012; Verbruggen & De Houwer, 2007), confirming that arousal does play a role when emotion is task-irrelevant and that effects of valence are obtained when emotion is task-relevant. This is also consistent with proposals that threat impacts on a common resource pool, leading to impaired performance (Pessoa, 2009). According to the Dual-competition model, response inhibition is related to this common resource pool. Recent studies suggest that stop signal performance loads highly on this common factor of cognitive control (Miyake & Friedman, 2012). Indeed, as these authors show, inhibitory functions are particularly strongly linked to the common resources. So, when threatening material taps into the resource pool, this will likely have a substantial impact on diminishing the available resources for exerting response inhibition (Pessoa, 2009).

The data presented in this chapter also supports, at least in some contexts, the regulatory role of reappraisal on the association between neuroticism and A-H scores. This is the first time that reappraisal has been shown to buffer the impact of neuroticism on stop signal performance and provides a useful extension of cognitive models of threat processing (Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998; Pessoa, 2009). The Mathews and

Mackintosh model stipulates that elevated anxiety and neuroticism are linked to a stronger activation of the threat evaluation system, which, in turn, leads to greater processing resources being directed towards the threatening information. Blechert et al. (2012) have demonstrated that reappraisal can substantially reduce the extent to which cortical resources, as measured by ERPs, are activated in the context of threat. My results indicate that individuals high in neuroticism with adequate emotion regulation skills can counter the enhanced sensitivity of the threat evaluation system such that threatening content is stopped from further impinging onto the cortical processing resources, thereby leaving stop signal performance relatively unimpaired in these individuals.

It is of note that angry targets seem to exhaust resources for both going and stopping in the Pleasant-Unpleasant task. However, this is not found for the remaining emotional decision tasks (Pleasant-Scrambled and Unpleasant-Scrambled) nor for any of the gender decision tasks. Here, except for the Male-Female task where no main effect of valence is observed, angry faces produce slower SSRTs and faster CRT compared to scrambled images. One reason for this discrepancy between the results of the Pleasant-Unpleasant and the other tasks involving scrambled stimuli could be that in the former it is necessary for correct task performance to focus on the emotional cue. In all of the tasks involving scrambled images participants might have engaged in a slightly different strategy, however. Namely, instead of basing their decision, as instructed, on either the gender or emotion cue, participants may have decided on each trial whether the image was a face or non-face (scrambled). This strategy would have facilitated their performance on the task as this decision involves less cognitive steps compared to an emotion or gender decision (Bruce & Young, 1986; Young & Bruce, 2011), whilst still allowing them to perform correctly. The consequence of this strategy is that the emotional cue would be rendered task-irrelevant even if, according to the task instruction (Un-/Pleasant-Scrambled tasks), it should be task-relevant. Following on from this argument, the current findings may suggest that when threat is directly task-relevant – and threat meaning is more deeply processed at late stages of processing, as in the Pleasant-Unpleasant task – threat may exhaust the common pool resources (Pessoa, 2009) at both executive (CRTs) and inhibitory (SSRTs) levels. By contrast, when task-irrelevant, as in the other tasks according to this point, its impact would be lessened, hence only leading to interference with SSRTs. This argument, that in all four tasks involving scrambled faces (i.e. two for emotion decision and two for gender decision) the emotional component might have been task irrelevant for participants when making their responses, could also explain why all four tasks have similar findings.

Given that the scrambled faces, which I used as control stimuli, can also be considered non-face stimuli, it is unclear whether any differences between emotional vs. scrambled images arose due to the effects of (a) emotional vs. neutral or (b) face vs. non-face cues. Generally, calm or other neutral face images might be used as control stimuli to address this issue. In this particular paradigm calm or other neutral faces were, however, avoided due to their ambiguous nature in a gender decision task. For example, in a task involving a decision between male vs. calm faces, calm images will be also be of a specific gender (here: male), hence simultaneously being associated with both available response options (calm and male) and thereby creating ambiguity.[32] For this reason, scrambled images were preferred as control images as they are not linked to any specific gender, incurring the disadvantage that any differences between emotional and scrambled images may be due to two reasons (a vs. b, see above). It is thus not possible to

[32] Using calm, female faces would result in a similar dilemma in that the “not male” response option would then be linked to two different cues (calm vs. female), thus not constituting an unambiguous neutral control condition.

unambiguously determine whether any direct interference or facilitation effects are due to the specific emotional or the more general face components of the stimuli.

Typical for stop signal tasks, it is unclear in this study to what degree performance on stop trials can be explained by motor inhibition versus target detection, a process that is activated on stop trials by the fact that an additional, salient cue (= stop signal) appears requiring detection (Hampshire et al., 2010). Behaviourally, these processes are difficult to disentangle. Previous research has tried to address this by, for example, displaying a similar cue to that of the stop signal on each trial (e.g. a blue rectangle), with the colour or another dimension of the cue changing (e.g. from blue to red) to indicate a stop signal trial (Sagaspe et al., 2011). However, even in this case it remains that some features change between go and stop trials (e.g. colour), which, again, will need to be detected to ensure correct task performance. Hence, the issue of target detection versus response inhibition is not conclusively addressed, as the fact remains that stop vs. go trials differ on at least one feature (e.g. colour of the stop signal). Alternatively, analogously to Hampshire et al.'s (2010) imaging study, one could create an additional task that mainly measures target detection and then subtract behavioural performance on this task from that in the stop signal task, thereby potentially controlling for any processes related to target detection. However, such an additional task was not run for this study nor is it clear how exactly such a “subtraction process” might be implemented. It therefore remains subject to future investigations to determine to what degree threat produces a slowing effect on stop signal trials due to affecting motor inhibition or target detection (or both).

A striking feature of the results is that an interaction of neuroticism and reappraisal in predicting threat appraisal was found with SSRTs (but not CRTs or CRT SDs) when emotion was task-relevant and with CRTs and CRT SDs (but not SSRTs) when it was task-irrelevant.

This finding might be accounted for by the effect of these traits on the different underlying processes of these measures (executive response vs. response inhibition) at varying levels of task-relevance of emotion. So, when emotion is task-relevant these traits seem to be mainly associated with threat in the context of response inhibition, whereas when emotion is task-irrelevant they seem to be mainly associated with threat in terms of its effect on the executive response. This might be explained by the effect of task-relevance of emotion on these cognitive control processes. Alternatively, this might be due to the perception of threat as a result of these control processes and task-relevance. For example, one could argue that on stop signal trials in the emotional decision task the emotional cue is task-relevant, due to the emotional decision on the corresponding go trials of this task, but obsolete; on go trials in the gender task the emotional cue is task-irrelevant but not obsolete as the target face cue still needs to be processed (intermediate levels of processing). On go trials in the emotion task, in turn, emotion is directly task-relevant (and not obsolete), whereas on stop trials in the gender task the emotional cue is not only task-irrelevant, but has also become obsolete (= absolute levels of processing). It may be possible that neuroticism and reappraisal interact with threat appraisal mainly at more intermediate, but not at absolute, levels of processing.

Although this study was not conducted on a psychiatric sample, the findings nevertheless have interesting implications for healthy and clinical populations. The data suggest that the impact of neuroticism on threat appraisal can be buffered by good reappraisal skills. Reappraisal has been an integral part of Cognitive Behavioural Therapy in the form of cognitive restructuring since its inception (Beck et al., 1979) and has been shown to be amenable to training (Schartau, Dalgleish, & Dunn, 2009). Future avenues might therefore entail an examination of whether participants (clinical or non-clinical) with initially poor habitual use of reappraisal can be trained to increase their use and whether such increased use of reappraisal might, in turn, be reflected in a more adaptive appraisal of threat (e.g. in a response inhibition paradigm). It will therefore be crucial not only to extend this work to more experimental based methods of reappraisal (Troy et al., 2010), but also to determine if different types of reappraisal maybe more or less suitable for reducing the effect of neuroticism on threat appraisal (vanOyen Witvliet, Knoll, Hinman, & DeYoung, 2010).

A further issue that deserves consideration is which aspect of the stimulus in this study was the subject of reappraisal respectively was attended to. It is, for example, conceivable that individuals of higher trait levels of reappraisal were more adapt at attending to certain features of the face stimuli that allowed them to perform with decent accuracy whilst at the same time avoiding those features that are more closely associated with threat, such as the eye region (Fox & Damjanovic, 2006). Indeed, such a strategy might produce "buffer effects", even if participants did not utilise their reappraisal skills to this end, using strategies of selective attention to regulate their emotions instead. This point could usefully be addressed using eye-tracking methods. It is also unclear what levels of processing participants' reappraisal strategies involved. Research has shown that reappraisal can operate at implicit as well as explicit task levels (Blechert et al., 2012), leaving open the question to what degree reappraisal is necessarily a conscious or deliberate process, especially when in habitual form, or to what degree more semantic processing was involved. It seems unlikely that participants engaged in more deliberative processing because of the relatively brief trial durations and because reappraisal did not significantly buffer the impact of threat when it needed to be directly appraised (go trials in emotion decision task). Future studies might want to further investigate the specific (re)appraisal processes that participants may have employed in order to reduce the impact of threat by means of, for example, post-experiment interviews, targeted self-report measures etc.

To conclude, in line with relevant models of emotional reactivity and threat processing (Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998; Pessoa, 2009; Robinson & Tamir, 2005) results from this study have not only shown that threat, when task-relevant, impairs executive and stopping responses, but also that neuroticism and reappraisal interact in predicting threat appraisal in some circumstances. This is an important and novel extension of these models, particularly in view of the clinical relevance of emotion regulation (Aldao et al., 2010; Gross & Munoz, 1995).

## Chapter 6: General discussion

Cognitive models of threat processing maintain that threat, depending on the task at hand, can speed (when task relevant) or impair (when task irrelevant) cognitive performance (Pessoa, 2009). It is generally assumed that attentional bias to threat is modulated by anxiety, with increased anxiety leading to increased bias (Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998). Evidence suggests that such biases are not actually specific to anxiety, however, and instead are linked to the broader personality spectrum of negative affect or neuroticism (Griffith et al., 2010; Clark & Watson, 1991; Clark, Watson, & Mineka, 1994), of which anxiety, like depression and aggression, is but one facet. Further, according to certain models (Mathews & Mackintosh, 1998), such emotion-linked attentional biases to threat may be modulated both by task demands, and also by individual differences in 'regulatory' traits or cognitive functions, including emotion regulation and attentional control abilities.

The majority of previous studies on cognition-emotion interactions have focused on the influence of threat on spatial and temporal aspects of attention, as assayed by tasks such as dot-probe detection and attentional blink. It has recently been suggested, however (Pessoa, 2009), that threat material may also influence higher-level cognitive control processes, such as response inhibition. In particular, Pessoa (2009) proposed a dual competition framework to describe cognitive-emotional interactions, such that emotional content influences both perceptual and cognitive control competition processes (Pessoa, 2009). Mildly intense emotional stimuli are suggested to have enhanced sensory representation and thereby improve behavioural performance, especially when task relevant. By contrast, high-arousal stimuli (e.g. angry threats) are proposed to generally impair performance on tasks of cognitive control (e.g. response inhibition) since they consume processing resources that are shared with cognitive control tasks (see also Bishop, 2007).

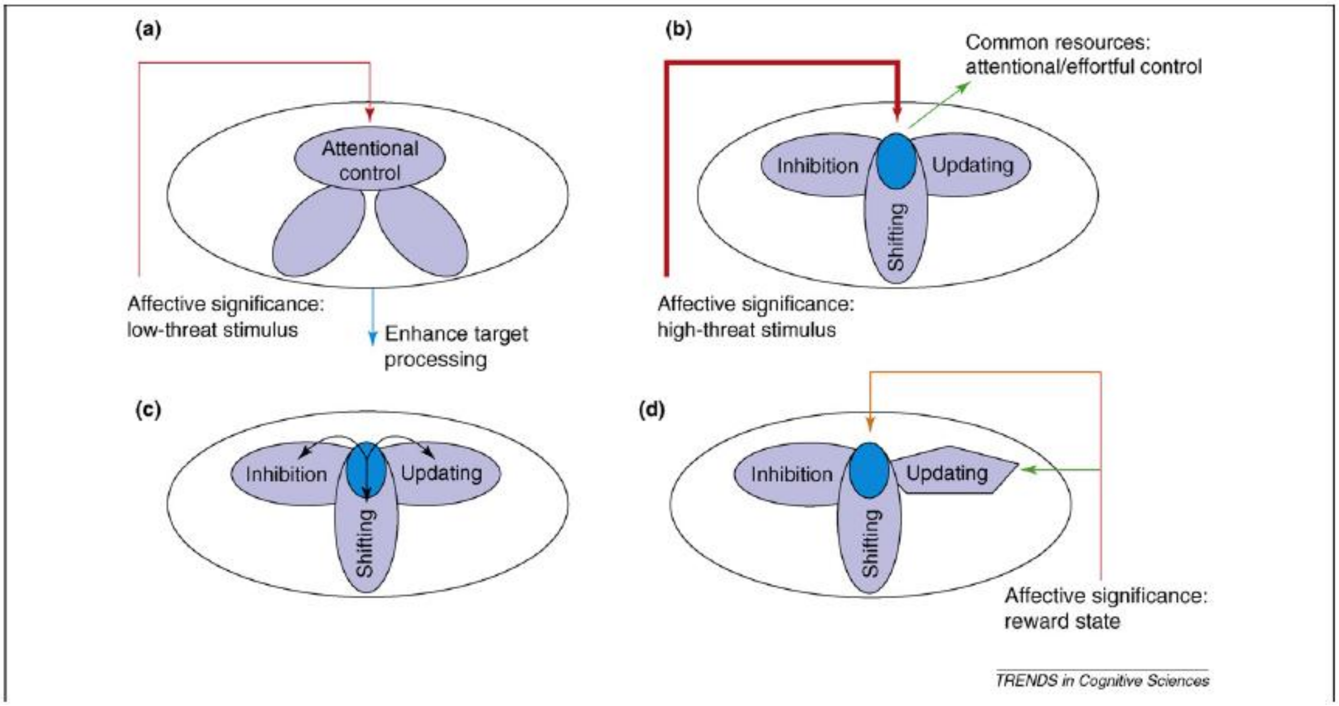


**Figure 28**: Dual competition model illustrating the impact of stimulus-driven and state-dependent effects on cognitive control functions (grey circles) and the common resource pool (blue circle). Thick (thin) arrow denotes stimuli of elevated (lower/state) threat levels (adapted from Pessoa, 2009).

In the present thesis, I examined the influence of emotional content (arousal and valence) on different tasks of selective attention and cognitive control: the Stroop interference task, the Flanker paradigm, and the Stop-signal reaction time task (SSRT). In addition, I examined the influence of 'reactive' trait negative emotion (neuroticism) and 'regulatory' abilities (emotion regulation and attentional control) on selective processing of emotional material, particularly selective processing of threat-related material (angry facial threats). Overall, the results can be taken to provide at least some initial support of Pessoa's dual competition model. An overview of the results from this thesis is provided in Table 5.

**Table 5.** Summary of main findings

| *Task demand* | *Prediction* | **Task**<br>*Face-Flanker* | *Word-Face Stroop* | *Word-Face Flanker* | *Stop signal*<br>CRT | SSRT |
|---|---|---|---|---|---|---|
| **Low task demand** | Impairment to threat | x (speeding for happy targets) | + | x (speeding for happy targets) | + | + |
| | *Positive association: N vs. TB* | | | | | |
| | *mean latency* | - | x | x | x | x |
| | *latency SDs* | - | x | x | x | x |
| | *Moderation: N vs. R vs. TB* | | | | | |
| | *mean latency* | - | x | x | x | + |
| | *latency SDs* | - | x | x | x | - |
| **High task demand** | Impairment to threat attenuated | - | + | + | + | + |
| | *Positive association: N vs. TB* | | | | | |
| | *mean latency* | - | x | x | x | x |
| | *latency SDs* | - | x | x | x | x |
| | *Moderation: N vs. R vs. TB* | | | | | |
| | *mean latency* | - | x | x | + | x |
| | *latency SDs* | - | x | x | + | - |

*Note:* "+" denotes that the predicted effect was found whereas "x" denotes that it was not; "-" indicates that this was not tested.
N = Neuroticism; R = Reappraisal; TB = Threat bias.

In two (Word-Face Stroop, Chapter 3, and Stop signal, Chapter 5) out of four tasks I found that threatening targets interfere with performance, such that responses are selectively slowed in the presence of angry threat content, particularly when it is task-relevant. These findings provide good support for Pessoa's (2009) Dual-competition model, which asserts that highly arousing emotional content consumes common processing resources that are shared with cognitive control processes, thus interfering with task performance. Furthermore, at least in the case of the Stop signal reaction task performance impairment in the presence of threat material (SSRT, a measure of response inhibition) was greater in individuals with higher levels of trait neuroticism and reduced emotion regulation abilities (reappraisal). These latter findings could suggest that neuroticism is particularly linked to response inhibition (as opposed to distracter interference: Stroop/Flanker tasks), but only at low levels of trait reappraisal and might explain the inconsistent findings in the literature on neuroticism and cognitive control. This discrepancy in findings between these tasks might be explained by the fact that threat, being associated with fight and flight responses, might be more strongly linked to emotional motor responses. Such a motor component might, in turn, be more salient in the Stop signal task which involves motor inhibition (Verbruggen & Logan, 2008) and may provide an explanation for why emotional traits were found to interact with stop signal performance, but not with performance on the other tasks. As a more general conclusion arising from this finding, it would be useful for future studies to consider emotion regulation skills when examining the relationship between neuroticism and cognitive control.

In terms of the theoretical frameworks of this thesis, the findings are consistent with and extend the cognitive model of Mathews and Mackintosh (1997, 1998). According to this model, neuroticism (especially its anxiety facet) is associated with greater sensitivity of a threat evaluation system, which when activated leads to enhanced processing resources being diverted to threatening content. Blechert et al. (2012) have recently found that variation in emotion regulation is associated with reduced cortical processing at both early and late stages of selective attention, as indexed by ERPs. My findings suggest that individuals high in neuroticism with effective emotion regulation abilities are able to counter the enhanced output from the threat evaluation system, to prevent threat material from gaining increased access to cortical processing resources, such that threat material does not impair SSRT in high neurotic individuals with adequate emotion regulation. In view of Bishop's (2007) neural model of threat processing one could argue that high habitual use of reappraisal strengthens the input of prefrontal top-down regions on bottom-up regions such as the amygdala even when this region is hyper-responsive as is likely to be the case in high trait neuroticism. My findings extent Pessoa’s (2009) model by showing important modulatory influences of key personality traits and suggest that emotional appraisal is a key determinant of resource allocation to emotional material. Specifically, Pessoa (2009) stipulates that individual differences such as trait anxiety or reward sensitivity can have an effect on the common pool resources. My data suggest that his model could usefully be extended to encompass individual differences in neuroticism and, crucially, in that positive emotion regulation traits like reappraisal can exert a buffering role on the impact of such emotion-linked traits on cognitive resources. This idea is resonant with the model by Bishop (2007) in that voluntary control mechanisms (e.g. from prefrontal regions) are assumed to regulate reactivity from bottom-up regions (e.g. amygdala). It will be important to extend this work to neuroimaging applications to determine where in the brain (fMRI) and when (EEG/MEG) these personality traits have their influence on such resource allocations.

This result (i.e. the moderation effect) is also promising as reappraisal is a construct that is amenable to training or interventions (Beck et al., 1979; Schartau et al., 2009). However, not only could reappraisal be trained behaviourally, but by targeting the relevant brain mechanisms (e.g. the prefrontal circuit; Ochsner & Gross, 2007), using techniques such as TMS or deep brain stimulation (Mayberg et al., 2005), it might also be possible to improve someone's reappraisal skills. Future avenues in research could examine the underlying brain mechanisms of these tasks and traits (e.g. using fMRI) as well as their temporal signatures (EEG/MEG), followed by investigations concerned with the stimulation of specific brain regions.

Another clinically relevant aspect arises from recent evidence on depression. That is, research shows that depressed individuals exhibit a poor cognitive control capacity (Joormann & Siemer, 2011; Joormann, 2004). This suggests that the impact of negative material in a cognitive control task should be greater in depressed individuals, something that is also in accord with models of threat processing (Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998). An important extension of the work reported here could therefore be to test if reappraisal can still buffer the impact of negative appraisals when cognitive control skills are low, which would likely be paired with a stronger effect of the emotional material. This could be tested using populations that are known to have poor cognitive control skills, such as depressed individuals (Joormann & Siemer, 2011; Joormann, 2004), or by depleting the cognitive control resources (Freeman & Muraven, 2010; Sheppes & Meiran, 2008). Such experiments would be very useful as they could establish to what degree the adaptive effects of reappraisal found here apply to clinical levels where it would, without doubt, be of most benefit.

In contrast to the results from the Stroop and Stop signal paradigms, in both Flanker tasks I showed a speeding for happy targets. It is noteworthy that this finding was obtained with two different target types (words and faces). It is therefore unlikely due to stimulus specific features, although a useful extension of these studies would be to target other sensory modalities (e.g. using auditory material). Again, this finding could be consistent with Pessoa's (2009) Dual-competition model, which argues that low arousing emotional stimuli have enhanced early sensory representations and thereby improve behavioural performance when task-relevant. Indeed, prior neuroimaging evidence has shown enhanced early visual cortex activation for happy relative to neutral faces (Pessoa, 2009). This finding highlights the fact that even though Stroop, Flanker and Stop signal tasks may have some common underlying mechanism (Response-Distracter Inhibition; Friedman & Miyake, 2004), they each also possess unique features (Miyake et al., 2000; Miyake & Friedman, 2012), the latter of which might explain this result. Specifically, at least on a theoretical level, Stroop and Stop signal tasks involve prepotent processes, whereas the Flanker task is thought to mainly tap into distracter interference processes (MacLeod, 1991; Miyake et al., 2000).[33] In the context of the experiments reported in this thesis such a distinction might, however, be overly simplistic in that the Word-Face Stroop and Word-Face Flanker tasks were designed to be very similar, with the same targets and virtually identical distracter cues. In the traditional word Stroop task the distracter cue (word reading) is considered to be the prepotent cue. Even though there is some evidence suggesting that face cues fulfil the same (prepotent) function in the Word-Face Stroop paradigm (Beall & Herbert, 2008), by virtue of the fact that both Word-Face Stroop and Flanker tasks utilised face distracters, such a prepotent role for face distracter cues would then also need to apply to the Flanker task in this context. Nevertheless, it seems that one of the key differences between the Flanker versus the

[33] It should be noted that some researchers categorize the Stroop and Flanker tasks into one group (e.g. interference inhibition) and the Stop signal task into another (e.g. motor response inhibition) (Hart et al., 2013; Nigg, 2000; Wöstmann et al., 2013 - see General introduction for a more detailed discussion) based on their assumed predominant underlying processes of interference versus motor inhibition, respectively.

Stroop and Stop signal tasks is that (1) the distracter cue in the Flanker paradigms was spatially separated from the target and (2) the face cues were substantially smaller compared to those of the other paradigms. It is possible that these distinctions may have resulted in the targets being differentially processed, thereby leading to the current pattern of results.

A discussion of the findings of this thesis is, however, incomplete without a consideration of the potential limitations. Throughout this thesis, family-wise errors were consistently corrected using Bonferroni adjustment. This approach could, however, be considered too stringent, potentially leading to a failure to reject an incorrect null-hypothesis (Nakagawa, 2004). Some of the analyses (e.g. for the Face-Flanker task) were therefore also run using a less conservative approach (Sidak correction), but the pattern of results remained unchanged. Nevertheless, studies now suggest using alternative, statistically more powerful approaches, such as the false discovery rate or confidence intervals when multiple testing is involved (Benjamini, Drai, Elmer, Kafkafi, & Golani, 2001; Benjamini & Hochberg, 1995; Nakagawa, 2004) and it is likely that future studies will benefit from such approaches.

Consideration should also be given to some of the stimulus features. Research suggests that physical properties of stimuli, such as luminance, contrast or spatial frequency (Delplanque, N'diaye, Scherer, & Grandjean, 2007) may affect performance to affective cues if not controlled for. The stimuli in this thesis were not matched on these properties and therefore it could be that any differences observed between the different emotions can, at least partly, be explained by differences in physical properties. Still, the results are mostly in accord with existing theoretical models (Bishop, 2007; Mathews et al., 1997; Mathews & Mackintosh, 1998; Pessoa, 2009) and exhibit a theoretically meaningful pattern, suggesting that physical properties may not have played a strong role, if any. However, this argument assumes that a specific stimulus type (e.g.

happy faces) was not strongly associated with a particular stimulus feature (e.g. high luminance), which, if the case, might account for some of the findings. Hence, it is essential that these findings are replicated in future studies, with the physical properties of the stimuli being controlled for. One way to disentangle this could be by using, for example, a fear conditioning procedure, such that the same physical stimulus (neutral) is paired with threat or safety, depending on the condition. In this way emotionally neutral and perceptually matched stimuli can become associated with different, potentially opposing, emotional states (e.g. threat or safety), as would be needed for the type of paradigm reported in this thesis. This approach has been used by Pessoa and colleagues (Pessoa et al., 2012).

The advantage of non-clinical samples, as used in this thesis, is that they are comparatively easy to recruit in larger numbers and that performance is not affected by concurrent medication, as is often the case in patient research. At the same time, this may also entail a certain problems. Specifically, it could be that insufficient variation in neuroticism or few participants with extreme scores, as is not uncommon in some healthy samples, may partly explain the lack of associations between individual difference variables and threat appraisal. During testing an attempt was made to address this potential shortcoming by adding 10 further participants with extreme scores on neuroticism to the samples of the Word-Face Stroop and Word-Face Flanker tasks. However, it is not unlikely that an increased variability or a greater proportion of participants with extreme scores would be needed to observe a link with neuroticism and threat appraisal in the Stroop and Flanker tasks. Indeed, as has been mentioned before, attentional bias to threat is particularly strong at high levels of anxiety (Mathews et al., 1997), but may not be seen at lower levels. So, even though these samples contained participants with extreme scores on the BFI-11, it should also be noted that high scores on this scale may not necessarily be equivalent to clinical levels respectively there may not have been a sufficiently large number of participants with extreme scores that would allow the detection of an attentional bias. In other words, the current findings cannot be generalized to clinical sample where quite possibly a link between neuroticism and attentional bias may have been observed. Nevertheless, the sample for the Stop signal task was recruited from the same population and here a moderation effect of reappraisal was found. Hence, small differences in variability of neuroticism between the tasks of this thesis aside, it is therefore likely that other factors have also contributed to the lack of an association between individual difference variables and threat appraisal for the Stroop and Flanker tasks.

For example, as has been discussed before, a limitation of all Stroop and Flanker experiments reported in this thesis is that the proportion of compatible trials may have been too low to develop a prepotent response, thereby potentially reducing the strength of the interference effects (Casey et al., 2000; Crump et al., 2006, 2008; Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; West & Baylis, 1998). This is particularly noteworthy as in none of these tasks an association or interaction with trait variables was found, whereas in the Stop signal task, where go trials were sufficiently frequent to become prepotent, neuroticism and reappraisal were found to interact in predicting threat appraisal. This point is further supported by the finding that expectancy of threat-related distracters (frequent vs. infrequent threat distracter blocks) has been linked to decreased activation of lateral prefrontal regions in people with enhanced state anxiety (Bishop, Duncan, Brett, & Lawrence, 2004), suggesting that the frequency of a particular distracter type does affect links to measures of personality. Other differences between the paradigms aside, this explanation may account for the lack of associations between individual difference variables and threat appraisal in Chapters 2-4 and should be more closely examined in future work.

It should also be mentioned that although the measures of neuroticism and reappraisal used here exhibit high reliability and validity (Gross & John, 2003; Rammstedt & John, 2007), they may nevertheless be prone to demand effects or other self-report biases. One way to, at least partly, address this in future research could be to experimentally induce state anxiety in participants, which has also been linked to attentional bias (see e.g. Macleod & Mathews, 1988). Further avenues would include using neurobiological markers of these trait measures, such as genetics (Aleksandrova et al., 2012; Canli et al., 2009; Canli & Lesch, 2007; Canli, 2008; Murakami et al., 2009; Sen et al., 2004; van Rijn et al., 2006), neurotransmitter concentration (Boy et al., 2011), facial muscle activation (Urry, 2009) or pupil diameter (Johnstone, Van Reekum, Urry, Kalin, & Davidson, 2007). Moreover, instead of trait reappraisal, as measured by a questionnaire, reappraisal ability could also have been recorded in an experimental task (McRae et al., 2012; Troy, Shallcross, Davis, & Mauss, 2012; Troy et al., 2010). Finally, there have been suggestions that interview, behavioural observation, diary, or peer report methods could usefully supplement any self-report based measures of personality (Caspi, Roberts, & Shiner, 2005; Funder, 2001).

Another key issue is the nature (i.e. severity) of the threat. This could be tailored to individual concerns (e.g. via autobiographical memories; Schartau et al., 2009), or threats could be rendered more severe/ realistic by manipulating the realism of faces (e.g. via dynamic multi-modal stimuli; De Silva, Miyasato, & Nakatsu, 1997), the threat value or the self relevance (N’Diaye, Sander, & Vuilleumier, 2009). Moreover, studies could create scenarios of social threat (e.g. fear of public speaking; Pertaub, Slater, & Barker, 2001) or utilise film sequences

(Dunn, Billotti, Murphy, & Dalgleish, 2009), music (Blood, Zatorre, Bermudez, & Evans, 1999; Trost, Ethofer, Zentner, & Vuilleumier, 2012) or virtual reality environments (Pertaub et al., 2001), amongst others, to further investigate the link between personality and threat processing.

The experiments in this thesis provide an essential step in further elucidating the construct of neuroticism and its impact on behaviour. As Lahey (2009) has convincingly argued, neuroticism is a personality trait with potentially vast implications for the public health sector. This is, as the author emphasises, because it has been linked to numerous physical as well as mental disorders. However, compared to other disorders of emotion, the significance of neuroticism for public health is frequently under-appreciated (Lahey, 2009). Further research focussing on the identification of the factors that may aid in alleviating the behavioural consequences of high levels on this trait is therefore urgently needed. The evidence from Chapter 5 suggests that reappraisal may be one such factor. Currently there are no known treatments that can effectively reduce levels of neuroticism (Lahey, 2009). Even though the data from this thesis do not allow conclusions as to whether trait neuroticism can be reduced, they do suggest that, in at least some circumstances, its impact on behaviour can be buffered by adequate emotion regulation skills. It seems plausible to assume that such a buffering effect may already aid in or contribute to coping with certain disorders of public health, which might have positive effects for people's well being as well as costs associated with the public health sector. However, this would ultimately have to be tested more rigorously in dedicated future experiments.

Another important contribution of this thesis is that novel behavioural paradigms (e.g. affective Flanker and Stop signal tasks) or improved versions compared to previous studies (Word-Face Stroop task) were tested (see Chapter 1 for further details). Except for the Face Flanker task, all paradigms have demonstrated an effect of emotion on the underlying cognitive control mechanism (distracter interference and response inhibition), attesting to their usefulness for future research. Moreover, this work has further elucidated the role of various emotion-linked trait measures in a series of affective cognitive control paradigms. This has not been reported before in such scope and provides a useful addition to the literature.

To conclude, by examining the mechanisms that subserve interactions between personality, emotion and cognitive control, my findings provide new insights for understanding the mechanisms of cognitive deficits that are frequently observed in mood disorders, conditions that are thought to represent extreme variants of normal range personality traits, like neuroticism.

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## Appendix

### 1. *Word lists and ratings*

| *Word type* | *Word* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* |
|---|---|---|---|---|---|---|---|---|---|---|
| *Angry-related* | anger | 5.00 | 48.00 | 9.06 | 4.00 | 2.00 | 604.24 | 1.00 | 603.58 | 0.96 |
| | angry | 5.00 | 45.00 | 9.51 | 0.00 | 2.00 | 559.97 | 0.97 | 624.89 | 1.00 |
| | disturb | 7.00 | 10.00 | 7.24 | 0.00 | 2.00 | 627.76 | 1.00 | 660.14 | 1.00 |
| | enraged | 7.00 | 1.00 | 6.32 | 2.00 | 2.00 | 737.41 | 0.94 | 762.96 | 1.00 |
| | frustrated | 10.00 | 10.00 | 8.47 | 1.00 | 3.00 | 688.07 | 0.94 | 634.92 | 0.96 |
| | irritate | 8.00 | - | 6.46 | 1.00 | 3.00 | 758.13 | 0.97 | 738.39 | 0.82 |
| | mad | 3.00 | 39.00 | 9.79 | 29.00 | 1.00 | 584.94 | 0.97 | 563.86 | 1.00 |
| | noisy | 5.00 | 6.00 | 7.92 | 1.00 | 2.00 | 554.09 | 0.97 | 589.42 | 0.96 |
| Mean | | 6.25 | 22.71 | 8.10 | 4.75 | 2.13 | 639.33 | 0.97 | 647.27 | 0.96 |
| SD | | 2.19 | 20.31 | 1.34 | 9.88 | 0.64 | 79.28 | 0.02 | 70.43 | 0.06 |
| *Happy-related* | merry | 5.00 | 8.00 | 7.54 | 10.00 | 2.00 | 759.18 | 0.97 | 663.41 | 0.96 |
| | cheer | 5.00 | 8.00 | 7.55 | 3.00 | 1.00 | 603.47 | 1.00 | 627.82 | 0.96 |
| | elated | 6.00 | 3.00 | 5.51 | 4.00 | 3.00 | 718.74 | 1.00 | 635.80 | 0.96 |
| | success | 7.00 | 93.00 | 10.52 | 0.00 | 2.00 | 591.50 | 0.97 | 712.74 | 1.00 |
| | happy | 5.00 | 98.00 | 11.17 | 6.00 | 2.00 | 536.27 | 1.00 | 555.93 | 1.00 |
| | joke | 4.00 | 22.00 | 9.92 | 10.00 | 1.00 | 578.22 | 0.94 | 539.11 | 1.00 |
| | laughter | 8.00 | 22.00 | 8.54 | 1.00 | 2.00 | 572.82 | 1.00 | 602.41 | 1.00 |
| | joy | 3.00 | 40.00 | 9.37 | 13.00 | 1.00 | 516.91 | 1.00 | 588.48 | 1.00 |
| Mean | | 5.38 | 36.75 | 8.77 | 5.88 | 1.75 | 609.64 | 0.99 | 615.71 | 0.99 |
| SD | | 1.60 | 38.09 | 1.86 | 4.70 | 0.71 | 85.32 | 0.02 | 56.82 | 0.02 |
| *Neutral* | lamp | 4.00 | 18.00 | 8.80 | 12.00 | 1.00 | 587.85 | 1.00 | 556.48 | 1.00 |
| | month | 5.00 | 130.00 | 11.24 | 2.00 | 1.00 | 602.82 | 1.00 | 607.48 | 0.96 |
| | circle | 6.00 | 60.00 | 9.90 | 0.00 | 2.00 | 634.13 | 0.94 | 635.14 | 0.97 |
| | vehicle | 7.00 | 35.00 | 9.53 | 1.00 | 3.00 | 650.31 | 1.00 | 627.22 | 0.96 |
| | cabinet | 7.00 | 17.00 | 8.77 | 0.00 | 3.00 | 684.91 | 0.97 | 625.65 | 1.00 |
| | fabric | 6.00 | 15.00 | 8.68 | 0.00 | 2.00 | 618.24 | 0.97 | 622.71 | 1.00 |
| | garment | 7.00 | 6.00 | 6.98 | 0.00 | 2.00 | 697.09 | 1.00 | 589.32 | 0.96 |
| | hat | 3.00 | 56.00 | 9.37 | 26.00 | 1.00 | 577.06 | 1.00 | 632.93 | 1.00 |
| Mean | | 5.63 | 42.13 | 9.16 | 5.13 | 1.88 | 631.55 | 0.99 | 612.12 | 0.98 |
| SD | | 1.51 | 40.60 | 1.21 | 9.37 | 0.83 | 43.72 | 0.02 | 27.05 | 0.02 |

**Table 1.** Angry-related, happy-related and neutral words with ratings on (*source*: Balota et al., 2007): 1. word length, 2. Kučera and Francis (1967) frequency norms, 3. log-transformed Hyperspace Analogue to Language (HAL) frequency norms (Lund & Burgess, 1996), 4. orthographic neighbourhood (Coltheart et al., 1977), 5. number of syllables, 6. mean lexical decision latency, 7. accuracy (lexical decision task), 8. mean naming latency and 9. accuracy (naming task).

| Word type | Word | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Female-related* | Amy | 3.00 | 15.00 | 9.00 | 4.00 | 2.00 | 615.62 | 0.97 | 596.56 | 1.00 |
| | Alice | 5.00 | 14.00 | 8.65 | 3.00 | 2.00 | 646.64 | 0.97 | 623.07 | 1.00 |
| | Sarah | 5.00 | 26.00 | 8.95 | 2.00 | 2.00 | 595.18 | 0.97 | 642.15 | 1.00 |
| | Lucy | 4.00 | 45.00 | 8.15 | 2.00 | 2.00 | 656.13 | 1.00 | 641.37 | 1.00 |
| | Lauren | 6.00 | 10.00 | 7.44 | 1.00 | 2.00 | 653.13 | 0.97 | 614.41 | 1.00 |
| | Charlotte | 9.00 | 13.00 | 8.63 | 0.00 | 2.00 | 699.97 | 0.97 | 739.80 | 0.96 |
| | Molly | 5.00 | 5.00 | 7.50 | 8.00 | 2.00 | 636.62 | 0.97 | 637.48 | 1.00 |
| | Anna | 4.00 | 7.00 | 8.37 | 3.00 | 2.00 | 680.55 | 1.00 | 607.67 | 1.00 |
| Mean | | 5.13 | 16.88 | 8.33 | 2.88 | 2.00 | 647.98 | 0.98 | 637.81 | 1.00 |
| SD | | 1.81 | 13.02 | 0.60 | 2.42 | 0.00 | 33.43 | 0.01 | 44.42 | 0.01 |
| *Male-related* | Oliver | 6.00 | 7.00 | 8.85 | 3.00 | 3.00 | 650.06 | 1.00 | 592.79 | 1.00 |
| | Jacob | 5.00 | 1.00 | 8.47 | 0.00 | 2.00 | 612.15 | 1.00 | 618.61 | 1.00 |
| | Leon | 4.00 | 5.00 | 8.41 | 8.00 | 2.00 | 645.50 | 0.97 | 663.96 | 1.00 |
| | Brandon | 7.00 | 8.00 | 8.42 | 2.00 | 2.00 | 755.16 | 1.00 | 650.74 | 1.00 |
| | Jake | 4.00 | 6.00 | 8.75 | 15.00 | 1.00 | 642.97 | 1.00 | 606.43 | 1.00 |
| | Nathan | 6.00 | 5.00 | 8.74 | 1.00 | 2.00 | 681.23 | 0.94 | 666.89 | 1.00 |
| | Adam | 4.00 | 44.00 | 9.89 | 1.00 | 2.00 | 602.12 | 0.94 | 635.31 | 0.96 |
| | John | 4.00 | 362.00 | 12.11 | 5.00 | 1.00 | 605.94 | 0.97 | 575.15 | 0.96 |
| Mean | | 5.00 | 54.75 | 9.20 | 4.38 | 1.88 | 649.39 | 0.98 | 626.24 | 0.99 |
| SD | | 1.20 | 124.90 | 1.27 | 5.01 | 0.64 | 50.38 | 0.03 | 33.67 | 0.02 |

**Table 2.** Female-related and male-related words with ratings on (*source*: Balota et al., 2007): 1. word length, 2. Kučera and Francis (1967) frequency norms, 3. log-transformed Hyperspace Analogue to Language (HAL) frequency norms (Lund & Burgess, 1996), 4. orthographic neighbourhood (Coltheart et al., 1977), 5. number of syllables, 6. mean lexical decision latency, 7. accuracy (lexical decision task), 8. mean naming latency and 9. accuracy (naming task).

| *Word type* | *Word* | *1* | *2* | *3* | *4* | *5* |
|---|---|---|---|---|---|---|
| *Angry-related* | anger | 17.00 | 2.34 | 1.32 | 7.63 | 1.91 |
| | angry | 18.00 | 2.85 | 1.70 | 7.17 | 2.07 |
| | disturb | 727.00 | 3.66 | 2.00 | 5.80 | 2.39 |
| | enraged | 149.00 | 2.46 | 1.65 | 7.97 | 2.17 |
| | frustrated | 177.00 | 2.48 | 1.64 | 5.61 | 2.76 |
| | irritate | 235.00 | 3.11 | 1.67 | 5.76 | 2.15 |
| | mad | 856.00 | 2.44 | 1.72 | 6.76 | 2.26 |
| | noisy | 904.00 | 5.02 | 2.02 | 6.38 | 1.78 |
| Mean | | - | 3.05 | 1.72 | 6.64 | 2.19 |
| SD | | - | 0.91 | 0.22 | 0.90 | 0.30 |
| *Happy-related* | merry | 872.00 | 7.90 | 1.49 | 5.90 | 2.42 |
| | cheer | 69.00 | 8.10 | 1.17 | 6.12 | 2.45 |
| | elated | 138.00 | 7.45 | 1.77 | 6.21 | 2.30 |
| | success | 417.00 | 8.29 | 0.93 | 6.11 | 2.65 |
| | happy | 200.00 | 8.21 | 1.82 | 6.49 | 2.77 |
| | joke | 826.00 | 8.10 | 1.36 | 6.74 | 1.84 |
| | laughter | 251.00 | 8.45 | 1.08 | 6.75 | 2.50 |
| | joy | 240.00 | 8.60 | 0.71 | 7.22 | 2.13 |
| Mean | | - | 8.14 | 1.29 | 6.44 | 2.38 |
| SD | | - | 0.35 | 0.39 | 0.44 | 0.29 |
| *Neutral* | lamp | 838.00 | 5.41 | 1.00 | 3.80 | 2.12 |
| | month | 283.00 | 5.15 | 1.09 | 4.03 | 1.77 |
| | circle | 687.00 | 5.67 | 1.26 | 3.86 | 2.13 |
| | vehicle | 473.00 | 6.27 | 2.34 | 4.63 | 2.81 |
| | cabinet | 675.00 | 5.05 | 0.31 | 3.43 | 1.85 |
| | fabric | 742.00 | 5.30 | 1.20 | 4.14 | 1.98 |
| | garment | 762.00 | 6.07 | 1.61 | 4.49 | 2.50 |
| | hat | 783.00 | 5.46 | 1.36 | 4.10 | 2.00 |
| Mean | | - | 5.55 | 1.27 | 4.06 | 2.15 |
| SD | | - | 0.43 | 0.57 | 0.38 | 0.35 |

**Table 3.** 1. ANEW word number, 2. valence (mean), 3. valence (SD), 4. arousal (mean), 5. arousal (SD) for angry-related, happy-related and neutral words (*source*: Bradley & Lang, 1999).

| *Word type* | *Word* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Angry-related* | anger | 1.07 | 0.25 | 4.40 | 1.16 | 2.50 | 1.36 | 2.23 | 1.33 | 1.97 | 1.38 |
| | angry | 1.03 | 0.19 | 4.48 | 0.95 | 2.45 | 1.27 | 2.55 | 1.24 | 2.14 | 1.36 |
| | disturb | 1.04 | 0.19 | 2.89 | 1.10 | 1.61 | 0.92 | 1.75 | 1.17 | 1.68 | 1.02 |
| | enraged | 1.07 | 0.36 | 4.03 | 1.28 | 2.10 | 1.08 | 2.60 | 1.36 | 1.67 | 1.01 |
| | frustrated | 1.00 | 0.01 | 3.75 | 1.17 | 2.00 | 1.12 | 1.75 | 1.11 | 1.82 | 1.28 |
| | irritate | 1.23 | 0.50 | 3.52 | 0.96 | 1.52 | 0.72 | 1.52 | 0.72 | 1.55 | 0.93 |
| | mad | 1.14 | 0.45 | 3.79 | 1.17 | 2.18 | 1.19 | 2.24 | 1.20 | 1.89 | 1.26 |
| | noisy | 1.29 | 0.71 | 2.89 | 0.88 | 1.36 | 0.78 | 1.32 | 0.77 | 1.32 | 0.67 |
| Mean | | 1.11 | 0.33 | 3.72 | 1.08 | 1.97 | 1.06 | 2.00 | 1.11 | 1.76 | 1.11 |
| SD | | 0.10 | 0.22 | 0.60 | 0.14 | 0.43 | 0.23 | 0.48 | 0.24 | 0.26 | 0.25 |
| *Happy-related* | merry | 4.07 | 1.13 | 1.07 | 0.26 | 1.17 | 0.47 | 1.14 | 0.74 | 1.10 | 0.31 |
| | cheer | 4.14 | 1.16 | 1.07 | 0.37 | 1.07 | 0.37 | 1.21 | 0.68 | 1.24 | 0.79 |
| | elated | 3.90 | 1.22 | 1.25 | 0.78 | 1.16 | 0.44 | 1.12 | 0.41 | 1.05 | 0.19 |
| | success | 3.94 | 1.18 | 1.26 | 0.58 | 1.42 | 0.96 | 1.84 | 1.21 | 1.16 | 0.45 |
| | happy | 4.48 | 1.00 | 1.10 | 0.40 | 1.32 | 0.83 | 1.16 | 0.45 | 1.10 | 0.30 |
| | joke | 3.94 | 1.00 | 1.48 | 0.85 | 1.16 | 0.45 | 1.16 | 0.45 | 1.58 | 0.89 |
| | laughter | 4.35 | 0.98 | 1.10 | 0.30 | 1.16 | 0.45 | 1.06 | 0.25 | 1.06 | 0.25 |
| | joy | 4.23 | 1.12 | 1.10 | 0.40 | 1.26 | 0.68 | 1.16 | 0.52 | 1.19 | 0.79 |
| Mean | | 4.13 | 1.10 | 1.18 | 0.49 | 1.22 | 0.58 | 1.23 | 0.59 | 1.19 | 0.50 |
| SD | | 0.21 | 0.09 | 0.14 | 0.22 | 0.11 | 0.22 | 0.25 | 0.29 | 0.17 | 0.28 |
| *Neutral* | lamp | 1.61 | 0.96 | 1.11 | 0.42 | 1.11 | 0.42 | 1.18 | 0.55 | 1.11 | 0.42 |
| | month | 1.49 | 0.92 | 1.04 | 0.19 | 1.00 | 0.00 | 1.07 | 0.38 | 1.04 | 0.19 |
| | circle | 1.76 | 1.12 | 1.03 | 0.19 | 1.03 | 0.19 | 1.17 | 0.60 | 1.03 | 0.19 |
| | vehicle | 2.70 | 1.42 | 1.70 | 0.99 | 1.57 | 1.04 | 2.00 | 1.14 | 1.30 | 0.88 |
| | cabinet | 1.47 | 0.82 | 1.10 | 0.31 | 1.07 | 0.25 | 1.13 | 0.43 | 1.27 | 0.83 |
| | fabric | 1.62 | 0.90 | 1.31 | 0.85 | 1.21 | 0.82 | 1.21 | 0.77 | 1.34 | 0.90 |
| | garment | 1.97 | 1.30 | 1.33 | 0.66 | 1.17 | 0.53 | 1.13 | 0.43 | 1.17 | 0.46 |
| | hat | 2.40 | 1.43 | 1.17 | 0.46 | 1.20 | 0.55 | 1.10 | 0.40 | 1.27 | 0.83 |
| Mean | | 1.88 | 1.11 | 1.22 | 0.51 | 1.17 | 0.48 | 1.25 | 0.59 | 1.19 | 0.59 |
| SD | | 0.45 | 0.25 | 0.22 | 0.30 | 0.18 | 0.34 | 0.31 | 0.26 | 0.12 | 0.31 |

**Table 4.** Ratings for angry-related, happy-related and neutral words on: 1. happy (mean), 2. happy (SD), 3. angry (mean), 4. angry (SD), 5. sad (mean), 6. sad (SD), 7. fear (mean), 8. fear (SD), 9. disgust (mean), 10. disgust (SD) (*source*: Stevenson et al., 2007).