Losing control : anxiety and executive performance

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Chapter 1

General introduction

It is common in life to not perform at the very top of our cognitive abilities. This phenomenon usually exacerbates when we are under high levels of stress and in people with psychiatric disorders. Attention to negative information is considered to play a crucial role in the development and maintenance of these disorders, especially anxiety-related disorders. This information can be either external, such as people ignoring us during a presentation or simply seeing a spider, and internal, such as worrisome thoughts about our performance. Attention to negative information is not necessarily bad as it is an evolutionary function to protect us from dangerous situations. However, it can be destructive when it occurs constantly or when we need to focus on an important task. There are many situations in our lives where we have to perform difficult cognitive tasks and we worry about our performance or other people's evaluation. Slightly elevated levels of anxiety/stress might augment performance whereas high levels might lead to adverse outcomes (Yerkes, 1908; Arnsten, 2011). Trait cognitive control, the ability to control attention and maintain a goal-relevant behaviour, is suggested to play a key role in the relationships between anxiety/stress, attention to negative information, and cognitive performance. Yet, the evidence is limited and further investigation is needed. In the current thesis, the relations between anxiety/stress, attention to emotional information, and cognitive performance will be investigated in a multidisciplinary approach, synthesizing clinical and cognitive factors and neurobiological underpinnings, while focusing on the role of trait cognitive control.

Anxiety

Anxiety is an emotion that can wax and wane in a matter of seconds, and some situations trigger anxiety in almost everyone. However, some people are anxious very often or almost continuously, and anxiety has become part of their identity or personality. These two aspects are labeled as state and trait anxiety, respectively. While trait anxiety is considered a fixed characteristic that reflects the individual differences in probability, frequency, and severity of anxious feeling, state anxiety can be seen as an episodic state of mood that is induced by a personally threatening situation (Spielberger, 1982; Derakshan et al., 2009). In the present thesis, the term stress will be used to refer to evoked increase in state anxiety. The distinction between trait and state anxiety is emphasized at this point as these two constructs are going to be used regularly in the rest of this thesis. Specifically, much of the research discussed in this thesis is on trait anxiety and it is often assumed that the relationship between trait anxiety, attentional processing of emotional information, and cognitive performance is the same for state anxiety. This is, however, an oversimplified assumption that is not supported by neurobiological evidence and needs to be further investigated. Specifics on the evidence related to trait anxiety/stress and executive performance are further discussed in a following section of this chapter.

Cognitive failure and attention to negative external or internal information (thoughts) are common characteristics of anxiety disorders. In achievement-oriented societies, evaluative situations appear as a vigorous class of stress-evoking stimuli, which may undermine individuals' performance in various settings, such as school or work. Cognitive performance anxiety, part of social anxiety disorder or general anxiety disorder (American Psychiatric Association, 2013), is characterized by biased internal cognitive schemata towards individuals' performance and others' evaluation. Cognitive performance anxiety is a common phenomenon that can lead to actual declined performance. For example, many students underperform in crucial exams due to high levels of anxiety, even though they are well-prepared (Powel, 2004). Public speaking, writing block, stage fright, and test anxiety are some of the most commonly investigated examples of performance anxiety. The prevalence of test anxiety ranges between 10% and 52%, and is higher for females (Beidel, Turner, and Trager, 1994; Mano, Gibler, Mano, & Beckmann, 2018; McDonald, 2001; Putwain, 2007; Putwain & Daly, 2014). In the last decades, the prevalence has increased, possibly indicating the societal pressure to adhere to high levels of performance. Performance anxiety is a serious problem that needs to be further investigated in relation to the cognitive underpinnings under acute stress and cognitive performance (see chapter 4).

Cognitive underpinnings of anxiety and executive function

Cognitive theories suggest that the stress-induced decline of cognitive performance is explained by increased attentional processing of threatening information resulting in limited resources for the task at hand. This attentional phenomenon is also known as attentional bias (AB) to threat. Specifically, the cognitive interference theory (Sarason, 1988) suggests that stress increases AB and resulting interference from negative information at the cost of available resources for the task at hand. In other words, anxious people are preoccupied with negative thoughts about their performance or others' evaluation and, as a result, they fail to focus on their task. The attentional control theory (Derakshan et al., 2009) further posits that the mechanism behind this phenomenon is attentional control, a key function of the central executive system of working memory (WM). Performance on most cognitive tasks relies on this central executive system that involves various higher-order functions such as planning and attentional control (Derakshan et al., 2009). Attentional control is a higher order function of the central executive WM, responsible for the ability to inhibit information, shift attention, and update information in WM (Miyake & Friedman, 2012). Attentional control is under the reciprocal influence of a bottom-up, stimulus-driven system (i.e., salience network) and a top-down, goal-directed system (i.e., executive network; for an overview, see Eysenck, Derakshan, Santos, & Calvo, 2007). The attentional control theory suggests that anxiety disrupts the balance between these two systems by enhancing the bottom-up

processing, manifested as AB to threat. As a result, the available resources for the task at hand are limited and people fail to perform at the level that would be otherwise typical of their proficiency.

Attentional bias

Increased processing of threatening information has evolutionary advantages in dangerous situations (e.g., LeDoux, 1995; Mogg & Bradley, 1998). However, when it occurs systematically and incongruent to objective levels of present and relevant threat, it can be disadvantageous. For instance, when preparing a report, it is important to notice an e-mail about an important deadline that expires the same day in order to react accordingly. On the other hand, it could be disadvantageous if a person is distracted by any irrelevant negative cues, such as negative words like “illness” or “death” that the person comes across in a text or negative thoughts about failing or receiving a negative evaluation. AB to threatening information occurs in response to visual and auditory stimuli, but also in response to physical or cognitive representations of stress such as palpitations or worries (Bar-Haim et al., 2007; Hirsch &Mathews, 2012). AB, especially to threatening information, has received ample attention as it is suggested to play a crucial role in the development and/or maintenance of anxiety disorders. Higher AB to threat has been found in non-clinically anxious individuals, but also in people with anxiety disorders (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007; Cisler & Koster, 2010; van Bockstaele et al., 2014). There has been an increased interest, among researchers and clinicians, to reduce anxious symptomatology by training individuals to direct their attention away from threat, thereby assuming a causal role for AB to threat in the pathogenesis or maintenance of anxiety disorders. The evidence for the efficacy of AB modification trainings, however, has been rather inconclusive showing that, often, there are no effects either on anxious mood or on AB itself (Mogg & Bradley, 2016, 2018). Besides, previous research has shown that attentional avoidance of threatening information, an alternative coping mechanism, is possibly an important factor in the development and maintenance of threat-related disorders, such as post-traumatic stress disorder, phobia, and obsessive compulsive disorder (e.g., Bardeen & Daniel, 2017; Brewin & Holmes, 2003; Mogg, Philippot, & Bradley, 2004; Schoorl et al., 2014).

A possible explanation for the inconsistent findings in relation to attentional bias towards or away from threat may be the role of perceived threat-level. Cognitive models have introduced threat-level as an important factor more than two decades ago, proposing distinct adaptive attentional responses to different levels of threat (Mogg & Bradley, 1998; Mathews & Mackintosh, 1998). Specifically, the cognitive-motivational analysis (Mogg & Bradley, 1998, 2016) suggests the advantages of two distinct mechanisms: on the one hand, *attending* high threats (HT) in order to respond to threatening environmental cues or sustain physical/emotional integrity, and, on the other hand, *avoiding* mild

threats (MT) in order to pursue a goal-directed behavior. For instance, while preparing a report, it is adaptive to ignore negative thoughts about others' evaluation in order to proceed with the task at hand, whereas, it is adaptive to notice an important e-mail about a deadline that expires today in order to react accordingly and adjust one's performance. The concept of threat-level, however, has received surprisingly little attention (for notable exceptions, see Koster et al., 2005; Koster et al., 2006a,b; Mogg et al., 2000). The majority of research investigating the relation between anxiety and AB has used only one type of threatening stimuli per study, such as emotional words or facial expressions, which would be considered MT. As a result, the previously found positive relation between trait anxiety and AB to threat (e.g., for a review, see Bar-Haim et al., 2007; Cisler & Koster, 2010; Van Bockstaele et al., 2014) may be driven by MT stimuli. Another potentially important factor in AB to threat is the time-course of attentional processing. Koster et al. (2005) found increased attention towards HT in earlier stages of attention for the whole sample, while high anxious participants showed avoidance of MT and HT in later stages of attention. This anxious avoidance of threat would require increased top-down control in order to alleviate anxious feelings in response to the initial processing of threat (Mogg & Bradley, 2016). However, the empirical evidence in relation to threat-level and time-course of AB, which is discussed in detail in chapters 2 and 3, is limited and inconclusive.

As mentioned above, AB is considered a manifestation of bottom-up and top-down processes. While the salience network facilitates the bottom-up processing of salient information, the executive network endorses goal-directed behaviour and cognition (e.g., for a review, see Hermans et al., 2014). Accordingly, neurocognitive evidence shows that trait cognitive control plays a crucial role in AB (e.g., Bishop, Jenkins, & Lawrence, 2007; Peers & Lawrence, 2009; Putman, Arias-Garcia, Pantazi, & van Schie, 2012; Peers, Simons, & Lawrence, 2013). Previous studies have also shown an interactive role between cognitive control and trait anxiety on AB with both subjective and objective measurements (e.g., Bardeen & Orcutt, 2011; Bardeen, Tull, Daniel, Evenden, & Stevens, 2016; Derryberry & Reed, 2002; Schoorl, Putman, van der Werff, & van der Does, 2014). However, the evidence is mixed and inconclusive. While some studies show attentional avoidance of threat for individuals with higher trait anxiety and higher trait attentional control (e.g., Bardeen & Orcutt, 2011), other studies show avoidance of threat for individuals with higher trait anxiety and lower trait attentional control (e.g., Schoorl et al., 2014). Importantly, up until now, no study has investigated the role of trait cognitive control, and trait anxiety, in relation to threat-level, and the time-course of attentional processing, even though it is considered a crucial factor (Mogg & Bradley, 2016, 2018). This topic is discussed in detail in chapters 2 and 3.

Anxiety, attentional bias, and cognitive performance

The evidence supporting the interactive role between trait and state anxiety on executive performance and AB is limited. As previously mentioned, the majority of the findings supporting the assumptions of cognitive theories for the positive relationship between anxiety and AB, such as the attentional control theory (Derakshan et al., 2009), are based on trait anxiety. The negative relationship between trait anxiety and AB and cognitive performance is well-documented (e.g., for a review, see Moran, 2016; van Bockstaele et al., 2014; Cisler et al., 2011). There is, however, very limited and inconclusive evidence about state anxiety. Importantly, many of these studies only assessed state anxiety without using any stress-induction procedure, making it even more difficult to conclude whether the results are related to state anxiety or other temperamental factors. Previous evidence has shown positive, negative or no effect between state acute stress and executive performance (e.g., Jiang, Buchanan, Yao, Zhang, Wu, & Zhang, 2017; Coy, O'Brien, Tabaczynski, Northern & Carels, 2011; Lautenbach, Laborde, Putman, Angelidis, & Raab, 2016; Mandrick, Peysakhovich, Rémy, Lepron, & Causse, 2016; Oei, Everaerd, Elzinga, van Well, & Bermond, 2006), underlining the necessity of further investigating this phenomenon. Moreover, some cognitive theories do not distinguish between the role of trait and state anxiety on executive performance, whereas others propose that trait and state anxiety have unique and interacting effects on cognitive performance (Williams, Mathews, & MacLeod, 1996; Mogg & Bradley, 1998). To illustrate, negative cognitive schemas related to trait anxiety may be activated under circumstances that evoke stress (Williams et al., 1996). In line with this theory, a meta-analysis showed that individuals with higher trait anxiety who are in a state of anxiety (not induced acute stress) show higher AB to threat than individuals with lower trait anxiety (Bar-Haim et al., 2007). Most of the studies included in this meta-analysis, however, did not manipulate stress but rather assessed state anxiety, thereby neglecting the effects of acute stress on executive performance. Even though individual differences in trait anxiety are of major importance and relevance to stress-related cognitive failure, the evidence is very limited. There is only a single empirical study showing that trait anxiety moderates the effects of acute stress on attentional processing of emotional information (Egloff & Hock, 2001), while there is no study in relation to executive performance. This issue is further discussed in chapters 5 and 6.

Moreover, trait cognitive control is considered to play a key role on the effects of stress on AB and executive performance (e.g., Derakshan et al., 2009). As mentioned above, the attentional control theory suggests that stress impairs cognitive performance by enhancing the bottom-up processes against top-down, goal-directed control. However, up until now, there are no studies showing that these effects depend on individual differences in trait cognitive control. Only Putman et al. (2014) reported that individuals with higher trait attentional control showed lower stress-induced decline of self-report state attentional control. Finally, as mentioned above, trait anxiety and trait cognitive control

interact with each other in their relation to cognition. Although it is also suggested that the effect of stress on cognition depends on individual differences in trait anxiety and trait cognitive control, there is no single study investigating the unique and interacting role of both trait cognitive control and trait anxiety on the effect of acute stress on cognitive performance and AB to threat. This subject is discussed in detail in chapters 5 and 6.

Furthermore, the effect of acute stress on cognitive performance through selective attention has not been investigated sufficiently since most of the studies focused on the effects of stress on either AB or cognitive performance but not both. There is only one study focusing on the effects of acute stress on threat-interference and cognitive performance (Coy et al., 2011), yet threat-interference was subjectively assessed (see below for the importance of using objective and subjective measurements). This issue is extensively discussed in chapters 5 and 6.

Neurobiological underpinnings of anxiety and executive function

The bottom-up processing of salient information is mediated by amygdala and anterior cingulate cortex (Bishop, 2008; Hermans et al., 2014), whereas the top-down cognitive control of such information is mediated by (dorso lateral) prefrontal cortex ((dl)PFC; Bishop, 2008; Fani et al., 2012; Gregoriou et al., 2014). Anxiety is suggested to disrupt the balance between these systems by increasing processing of salient/threatening information, while decreasing top-down (dl)PFC-mediated cognitive control (Bishop, 2008; Fani et al., 2012; Gregoriou et al., 2014; Hermans et al., 2014). In addition, anxiety also has a direct effect on (dl)PFC-mediated cognitive control (Arnsten & Rubia, 2012; Burgess et al., 2011; Rossi et al., 2009). This, however, has not been taken sufficiently into account by the cognitive theories. Neurobiological evidence show that stress-induced release of catecholamines (i.e., nor-adrenaline and dopamine) in the PFC can have direct negative effects on performance (Qin et al., 2009; for a review see, Hermans et al., 2014). This direct effect of stress on top-down control allows for salient information to interfere with cognitive performance. As a result, besides the indirect effect of anxiety on cognitive performance through AB to threat, there is also a direct effect of stress on executive performance through PFC-mediated cognitive control.

Glucocorticoid system

Cortisol is traditionally described as the “stress hormone”. The fast effects of cortisol are known for their negative effects on cognition. However, the slow effects of cortisol can be advantageous, such as for emotional processing. Although there is extensive research on the effect of hydrocortisone (i.e., synthetic cortisol) on attentional processing of emotional information, up until now, no study has investigated whether the slow effects of cortisol can prevent the negative effects of psychological stress on emotional processing.

Acute physiological and psychological stress affects the central nervous system through the activation of mineralocorticoid and glucocorticoid receptors by the glucocorticoid hormone (e.g., de Kloet, Joëls, & Holsboer 2005). Neurobiological evidence supports the notion that these fast non-genomic effects are related to up-regulation of the salience network, that involves the amygdala and hippocampus, and down regulation of the executive network, that includes the prefrontal cortex (PFC; Hermans et al., 2011; Menon, 2011; Corbetta, Patel, & Shulman, 2008; Hermans et al., 2014). For example, evidence shows that higher stress-induced cortisol levels are related to increased processing of emotional information (e.g., Oei, Tollenaar, Spinhoven, & Elzinga, 2009), but this may be confounded by the anxious processes that caused the cortisol response in the first place. Contrariwise, at least an hour after stress-induced release of the glucocorticoid hormone, corticosteroids activate PFC function through a slow genomic process that reverses the fast effects on amygdala and hippocampus (Maggio & Segal, 2009; Soravia et al., 2006; Yuen et al., 2009). These slow effects have been related to up-regulation of the executive network and enhanced WM performance (Yuen et al., 2009; Henckens et al., 2011). In line with this notion, accumulating evidence supports that slow effects of hydrocortisone reduce automatic attentional processing of emotional information. Previous studies have shown that hydrocortisone, at least an hour after administration, reduces automatic attentional processing of both negative and positive emotional information (Oei, Tollenaar, Elzinga, & Spinhoven, 2009; Putman, Hermans, van Honk, 2010a; Putman et al., 2007b; Putman et al., 2011; for a review see, Putman & Roelofs, 2011). However, there is no evidence showing whether the slow effects of corticosteroids reduce AB to emotional information under acute stress. Moreover, it is known that catecholamines influence effects of cortisol on memory processes, including processes in the hippocampus which is involved in WM (e.g., Barsegyan et al., 2010; McReynolds et al., 2010; Roozendaal, Quirarte, & Mc Gaugh, 2002, Roozendaal, McEwen, & Chattarji, 2009). Thus, it should not be assumed that the effects on executive control are not also influenced by such co-activity. In chapter 7, the effect of hydrocortisone on attentional processing of emotional information under acute psychosocial stress is investigated, an hour after administration, in order to observe whether the slow effects of cortisol prevent the effects of stress on attentional processing.

Frontal EEG theta/beta ratio

Electroencephalographic (EEG) neural oscillations of low and high frequency bands have been often investigated in relation to psychological constructs. The relations between fast wave and slow wave oscillations are suggested to reflect the balance between cortical and subcortical brain systems (Knyazev 2007). Spontaneous (resting-state) frontal EEG theta/beta ratio (TBR) is suggested to be an electrophysiological marker for trait executive control, including attentional control. Specifically, spontaneous TBR is suggested to reflect PFC-mediated

regulation over emotional bottom-up tendencies (Knyazev et al., 2007), such as described in the attentional control theory. Beta oscillations are generated in cortical areas and are found to reflect motoric and executive cognitive control, such as cognitive (attentional) inhibition and cognitive effort (e.g., Engel & Fries, 2010; Huster, Enriquez-Geppert, Lavallee, Falkenstein, & Hermann, 2013). On the other hand, theta activity is suggested to be of anterior cingulate cortical origin and other more subcortical areas, such as the hippocampus (Mitchell, McNaughton, Flanagan, & Kirk, 2008).

TBR, the measure of interest in this thesis, is the ratio of theta power divided by beta power. The relative predominance of theta band power over beta band power has been consistently found in patients with attentional dysregulation such as attention deficit/hyperactivity disorder (ADHD; for a review, see Arns et al., 2013). Accordingly, psychostimulants-administration, a common treatment for ADHD symptoms that enhances PFC network integrity (Arnsten, 2006), has been found to reduce TBR (Clarke et al., 2002; Clarke et al., 2007; Loo et al. 2016). In addition to the interest in TBR in relation to psychopathology with mainly attentional deficits, lower TBR has been associated with greater cognitive control also in healthy individuals. Lower TBR has been previously linked to higher self-report attentional control (Putman et al., 2010b, Putman et al., 2014). Moreover, WM training and theta transcranial current stimulation, a method that has been found to enhance WM capacity (Jausovc et al., 2014), are linked to lower TBR (Sari et al., 2015; Wischnewski et al., 2016). Moreover, lower TBR has been related to greater top-down control over motivated decision-making (Massar et al., 2014; Massar, Rossi, Schutter, & Kenemans, 2012), flexible contingency-learning during motivated decision-making (Schutte, Kenemans, & Schutter, 2017) and attentional orienting (Morillas-Romero, Tortella-Feliu, Bornas, & Putman, 2015b).

The last decade, accumulating evidence suggests that TBR might reflect PFC-mediated cognitive control over, specifically, emotional information. TBR has been associated with greater inhibition of fearful stimuli in a go/no-go paradigm (Putman et al., 2010b) and enhanced spontaneous emotional regulation of threatening pictures (Tortella-Feliu et al., 2014). Moreover, lower TBR has been found to predict resilience against the negative effects of acute stress on self-report state attentional control (Putman et al., 2014). Specifically, individuals with lower TBR, supposedly higher trait cognitive control, showed lower decline of state attentional control due to acute stress. As mentioned above, trait cognitive control is suggested to moderate stress-induced effects on interference from emotional stimuli, a phenomenon resulting from reduced top-down control and enhanced bottom-up processing. However, there is no evidence yet investigating TBR in relation to threat-selective attention or the effects of acute stress on the attentional processing of emotional information, as it is performed in this thesis. TBR will be used as an objective marker of executive control over emotional information in chapters 3, 4, 6, and 7.

Objective and subjective measures

An important methodological issue raised in this thesis is the use of subjective and objective measurements to assess trait cognitive control and threat-interference during performance. Trait attentional control is typically assessed with the Attentional Control Scale (ACS; Derryberry & Reed, 2002) while threat-interference during performance is assessed with the Cognitive Interference Questionnaire (CIQ; Sarason, Sarason, Keefe, Hayes, & Shearin, 1986). The validity of these measures is questionable, a common concern for many self-report measures. ACS is designed to assess individuals' ability to focus or shift their attention during daily life. However, it is arguable whether it assesses their actual capacity or perceived control. Trait cognitive control, subjectively-assessed with the ACS, has been related to AB, also in interaction with trait anxiety, (Bardeen & Orcutt, 2011; Bishop et al., 2007; Derryberry & Reed, 2002; Putman et al., 2012; Peers & Lawrence, 2009; Schoorl et al., 2014). Relevant evidence with objectively measurements is, however, very limited and only with computerized cognitive tasks (Bardeen & Daniel, 2017; Hou et al., 2014; Reinholdt-Dunne et al., 2009). Therefore, in the present thesis, trait cognitive control will be assessed with the ACS but also with spontaneous frontal TBR in most chapters.

Moreover, CIQ is used to assess interference from negative thoughts during cognitive performance. This scale is typically used in the field of stress and cognitive performance. CIQ consists of items such as "*I thought of how poorly I was doing*". Individuals are asked to indicate how often these thoughts occurred during a task with higher scores indicating higher cognitive interference. It is, however, an assumption that these thoughts interfere with performance. Assuming that the occurrence of thoughts is the same as cognitive interference can be erroneous as it takes for granted that more negative thoughts are negatively related to performance. After all, the emotional and cognitive components of stress are highly positively interrelated, while it is well-known that the relationship between stress/arousal and performance is not linear. While high levels of stress impair performance, moderate levels of stress can be advantageous. Consequently, it should not be expected that the relationship between negative thoughts and executive performance is negatively linear. Therefore, in the present thesis, threat-interference during cognitive performance will be assessed with both CIQ and task-based objective measures (see chapter 6).

Aims and Outline

The aim of this thesis is to provide further insights in the cognitive and neurobiological underpinnings of relations between anxiety and executive performance by focusing on attentional processing of emotional information and the role of trait cognitive control. This may contribute in a better understanding

of anxiety-related disorders and the effects of stress on performance, and might further support the target and development of new treatments. Although trait cognitive control is considered to play a key role in these relationships, the evidence is limited and inconclusive. Therefore, it is of main interest to investigate the role of trait cognitive control with subjective but also with objective measurements, as the evidence is even more limited for the latter. Moreover, threat-level is suggested to modulate AB in relation to trait anxiety, but the evidence is limited. In this thesis, we aim to investigate, for the first time whether cognitive control, also in interaction with trait anxiety, is related to spatial threat-level dependent interference by negative stimuli (chapters 3 and 4). At the same time, the role of trait cognitive control, but also trait anxiety, will be assessed in relation to early and late stages of attention as the time-course of attention is considered to be an important factor. Again, however, the evidence is limited in relation to trait cognitive control. Furthermore, for the first time, we test in a single experimental design whether acute cognitive performance anxiety affects objectively-assessed threat-interference and cognitive performance and whether individuals with higher trait test anxiety are more vulnerable to these effects. Moreover, we test the effects of stress on threat-interference and WM performance, and whether these effects are modulated by cognitive control as well as trait anxiety in these effects, using objective and subjective measurements for the first time (chapter 6). Finally, hydrocortisone administration is suggested to increase top-down control resulting in reduced interference from emotional information. Therefore we will test, for the first time, whether hydrocortisone administration prevents the effects of stress on emotional interference in highly anxious females, and whether this effect is moderated by trait cognitive control and trait anxiety (chapter 7). Considering TBR as a marker for executive cognitive control, we first attempt to replicate the relationship with TBR and self-report attentional control, and test, for the first time, its test-retest reliability (chapter 2). This is of importance as TBR is going to be used in the following studies of the current thesis as a trait measure for cognitive control.

In chapter 2, we investigate the test-retest reliability of frontal EEG TBR. Moreover, we attempt to investigate the relationship between self-report attentional control and TBR cross-sectionally and with one-week interval.

In chapter 3, we test the relationship between frontal TBR, as a marker for cognitive control, and threat-level dependent spatial AB. Moreover, we test whether this relationship is moderated by trait anxiety. Finally we investigate whether this relationship differs between earlier and later stages of attention (200 ms vs 500 ms).

In chapter 4, we investigate the same hypotheses as in chapter 3 and compare different stages of attention (80 ms vs 200 ms). Moreover, we test these hypotheses also using a self-report measure of attentional control. This allows

assessment of convergent validity of TBR as a marker of executive control in these processes.

In chapter 5, we test the effects of performance-like stress on WM performance and objective threat-interference during WM performance, and whether these effects are modulated by trait anxiety. In order to investigate this, we developed a stress-procedure, aiming to induce performance-like stress, and a new emotional WM task in order to assess threat-interference during WM performance. Consequently, we also test the validity of this stress-procedure.

In chapter 6, we test the effects of stress on objective and subjective measures of threat-interference, and on different measure of WM performance. Moreover, we test whether these effects are moderated by trait cognitive control and trait anxiety.

In chapter 7, we investigate whether hydrocortisone-administration, which is known to increase executive cognitive control, prevents the effects of stress on interference by emotional stimuli (negative and erotic) in healthy highly anxious individuals under acute stress. Moreover we test whether these effects are modulated by trait cognitive control and trait anxiety.

Finally, in chapter 8, the main findings of these studies are integrated and discussed. Moreover, limitations and implications of the current studies, and future directions are presented.