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Anxiety and Cognitive Performance: A Test of Attentional Control Theory

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Anxiety and Cognitive Performance: A Test of Attentional Control Theory

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Declaration of Originality

This thesis is submitted to Bond University in fulfilment of the requirements of the degree of Doctor of Philosophy. This thesis represents my own original work towards this research degree and contains no material which has been previously submitted for a degree or diploma at this University or any other institution, except where due acknowledgement is made. All of the raw data and analyses have been retained and are available upon request. I certify that I have made and retained a copy of this document.

Elizabeth J. Edwards
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Publications

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Abstract

Attentional Control Theory (ACT) predicts that trait anxiety and situational stress interact to impair performance on tasks that involve the phonological loop and central executive, specifically the updating, inhibition and shifting functions. The theory suggests that anxious individuals recruit additional resources (e.g., effort, motivation) to prevent shortfalls in performance effectiveness (accuracy), with deficits becoming evident in processing efficiency (the relationship between accuracy and time taken to perform the task). These assumptions however, have not been systematically tested.

Two series of experimental studies investigated the relationship between anxiety and cognitive performance and were premised on ACT. Series 1 included four studies (Study 1.1, Study 1.2, Study 1.3, & Study 1.4) that examined the relationship between trait anxiety (somatic and cognitive; operationalised using questionnaire scores), situational stress (somatic and cognitive; manipulated using threat of electric shock and ego threat instructions, respectively), mental effort (indexed using a self-report visual analogue scale) and performance on phonological (forward and backward word span), updating (reading span), inhibitory (Go-No-Go), and shifting (WCST) tasks. Series 2 included three studies (Study 2.1, Study 2.2, & Study 2.3) that investigated the associations between cognitive trait anxiety (measured using questionnaire scores), situational stress (manipulated using ego threat instructions), motivation (indexed using questionnaire scores) and performance on an updating (reading span), inhibitory (Go-No-Go), and shifting (WCST) tasks. The two attentional tasks (inhibition and shifting) in Series 2 contained both neutral and threat-related stimuli (Study 2.2 & Study 2.3). The quasi-experimental designs examined the separate and combined

contributions of trait anxiety and situational stress in predicting performance effectiveness (quality of performance) and processing efficiency (ratio of effectiveness to RT), and investigated the moderating effects of mental effort (Series 1) and motivation (Series 2). For each experiment, the data were interpreted using separate hierarchical moderated regression analyses that allowed for the examination of the unique and combined contributions of the factors after controlling for depression, which is known to co-vary with anxiety.

The data suggested that somatic trait anxiety, somatic stress and effort did not combine to predict performance effectiveness or efficiency on phonological, updating, inhibitory or shifting tasks. Somatic trait anxiety and somatic stress did however combine to predict phonological efficiency on the complex task (backward word span), such that higher somatic trait anxiety predicted greater backward span efficiency at low stress relative to high stress (Study 1.1.1). This relationship was not moderated by mental effort. The findings were consistent with the notion that anxiety-performance link manifests in cognitive rather than somatic anxiety.

For phonological performance, the data revealed that cognitive trait anxiety, cognitive situational stress and effort interacted to predict phonological efficiency (but not effectiveness) on both the simple (forward word span) and complex (backward word span) task. When under evaluative stress conditions (ego threat) only, higher trait anxiety predicted lower efficiency at lower effort (Study 1.1.2).

In terms of updating performance, cognitive trait anxiety, situational stress and effort did not predict updating effectiveness or efficiency (Study 1.2.1 & Study 2.1.1) on the reading span task. With the inclusion of motivation as a predictor however, the data revealed that cognitive trait anxiety and motivation combined to predict updating efficiency (but not effectiveness). At higher motivation, higher cognitive trait anxiety was related to better updating efficiency, whereas at lower motivation, higher cognitive trait anxiety was associated with poorer efficiency (Study 2.1.2).

With respect to inhibitory control, cognitive trait anxiety, cognitive stress and effort were inter-related with inhibitory effectiveness and efficiency. Irrespective of stress condition, higher trait anxiety was related with lower effectiveness at lower effort, yet higher trait anxiety was related to lower efficiency at higher effort (Study 1.3.2).

For shifting performance, the data showed that cognitive trait anxiety, situational stress and effort were inter-related with efficiency, but not effectiveness. At higher effort, higher trait anxiety was associated with poorer shifting efficiency independent of stress condition, whereas at lower effort, this relationship was highly significant and most pronounced for those in the ego threat group (Study 1.4).

In term of attentional biases in anxiety, the results demonstrated that situational stress and motivation combined to predict inhibitory efficiency (but not effectiveness) for threat-related relative to neutral words, such that higher motivation was related to poorer inhibitory efficiency for threat under high (ego threat), but not low (ego safe) situational stress (Study 2.2). Trait anxiety and situational stress combined to predict shifting effectiveness for threat words relative to neutral words, such that when under ego threat conditions, those lower in trait anxiety had better shifting effectiveness for threat versus neutral words, yet those higher in trait anxiety had poorer shifting effectiveness for threat.

Situational stress and motivation also combined to predict shifting effectiveness for threat-related relative to neutral words, such that lower trait anxiety was associated with better shifting effectiveness for threat at higher motivation. These patterns, however were not present in the data for shifting efficiency in the presence of threat (Study 2.3).

The overall patterns of results were interpreted with respect to ACT. Limitations of the current program of research are noted and directions for future work are suggested.

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CHAPTER 1: ANXIETY AND COGNITIVE PERFORMANCE

Overview and Theoretical Perspectives

Introduction

Anxiety is commonly recognised as a negative mood state and definitions are usually couched in terms of a combination of both cognitive and physical symptoms. Cognitive characteristics include worry, fear and apprehension, whereas physical symptoms include physical tension, shortness of breath, and elevated heart rate (see Clark & Watson, 1991). Further, anxiety can be separated into two theoretical dimensions: trait anxiety as an enduring, dispositional proneness or susceptibility to emotional arousal, and state anxiety as a current, situationally-based, aroused state, such as fear of impending threat or danger (Spielberger, Gorsuch, & Lushene, 1970; Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983). Empirical studies (e.g., Spielberger et al., 1970, 1983) have found significant positive correlations (.70 or greater) between trait and state anxiety with trait anxious individuals more likely to experience heightened levels of state anxiety.

There is evidence to suggest that higher anxiety is related to poorer performance on a range of cognitive tasks, such as reasoning (Leon & Revelle, 1985), memory (MacLeod & Donnellan, 1993), attention (Matthews & MacLeod, 1985), and planning and decision making (Nichols-Hoppe & Beach, 1990). More specifically, elevated levels of anxiety have been associated with performance deficits on simple tasks such as recall of word lists (Mueller, 1977), digit span (Firetto & Davey, 1971), and letter transformation (Eysenck, 1985). Anxiety has also been shown to have detrimental effects on more complex cognitive tasks, such as analogical reasoning (Tohill & Holyoak, 2000), reading span (Sorg &

Whitney, 1992), and the Wisconsin Card Sorting Test (WCST; Goodwin & Sher, 1992). Poor task performance has been linked to both high levels of trait anxiety (e.g., Ansari, Derakshan, & Richards, 2008; Derakshan & Eysenck, 1998) and elevated state anxiety (e.g., Derakshan, Smyth, & Eysenck, 2009; Eysenck, 1985) with several studies reporting performance deficits to be associated with the relationships between state and trait anxiety (e.g., Edwards, Burt, & Lipp, 2006; Edwards, Moore, Champion, & Edwards, 2015; Sorg & Whitney, 1992). Additionally, cognitive performance deficits have been linked to elevated cognitive anxiety or worry (e.g., Derakshan & Eysenck, 1998; MacLeod & Donnellan, 1993) and high levels of somatic anxiety (e.g., Hudetz, Hudetz, & Klayman, 2000; Meinhardt & Pekrun, 2003).

Performance deficits in anxiety are by no means universal or fully understood. Understanding the link between the complex biological and psychological characteristics of anxiety and cognition remains a challenge for clinical psychologists, medical professionals and researchers. The proposed program of research focuses on understanding the relationship between anxiety and cognitive performance, whilst undertaking a robust test of one of the most recent theoretical approaches in this area, namely attentional control theory (ACT; Derakshan & Eysenck, 2009; Eysenck & Derakshan, 2011; Eysenck, Derakshan, Santos, & Calvo, 2007).

Theoretical Perspectives

Since the proposal of the Yerkes-Dodson 'Law' (Yerkes & Dodson, 1908), the relationship between anxiety and cognitive performance has become an increasingly important topic of inquiry in cognitive psychology. In turn, numerous frameworks and models have emerged describing the possible mechanisms that might form the basis of the relationship between anxiety and cognitive processing (e.g., Derakshan & Eysenck, 2009; Eysenck, 1979; Eysenck & Calvo, 1992; Humphreys & Revelle, 1984; Sarason, 1984). The following section reviews the theoretical developments within this domain and concludes with an in-depth description of ACT (Derakshan & Eysenck, 2009, Eysenck et al., 2007; Eysenck & Derakshan, 2011), which forms the focus of the thesis.

Yerkes-Dodson Law (Yerkes & Dodson, 1908). Yerkes and Dodson (1908) proposed a curvilinear relationship (also known as an inverted U) between arousal and performance. The principle proposed that performance peaks at a moderate level of arousal, with poorer performance being noted at both low and high levels of arousal. Later work attributed the pattern to other relationships, such as the effects of anxiety and/or motivation on memory and/or processing efficiency (see Teigen, 1994 for a review). It seemed plausible that individuals lacking in motivation, or even a conservative amount of arousal to maintain focus on the task, would most likely experience performance deficits. Conversely, an individual expending too much energy or strain would also possibly suffer performance impairments. Despite offering a seemingly logical description of the relationship between arousal and task performance, critics argued that the Yerkes-Dodson principle failed to explain the internal processes that produced the curvilinear pattern (e.g., Eysenck, 1985; Landers, 1980). Furthermore, successors claimed the theory was too simplistic in that it did not allow for discrimination of task difficulty or other moderating factors that might influence the arousal-performance relationship (see Teigen). Consequently, over the next century several theories and models have been proposed to account for the effects of anxiety on task performance.

Anxiety, Learning and Memory Theory (Eysenck, 1979). One of the early theories that attempted to explain the mechanisms underlying the relationship between anxiety and cognitive performance was proposed by Eysenck (1979). He suggested that anxious individuals engage in task-irrelevant thoughts, which in turn consume some of the available cognitive capacity, resulting in decreases in performance. Eysenck proposed that highly anxious individuals attempt to compensate for the adverse effects of their task-irrelevant processing by expending additional effort on the task. He proposed that anxiety has differential effects on task performance (i.e., the quality of performance) relative to the efficiency in which the task is processed (i.e., accuracy relative to effort), and suggested that anxiety always impairs processing, but will not impair performance if there is sufficient effort expended. Eysenck's theoretical contributions towards understanding the relationship between anxiety and cognitive performance have continued over more than three decades (e.g., Derakshan & Eysenck, 2009; Eysenck & Calvo, 1992; Eysenck et al., 2007; Eysenck & Derakshan, 2011) and are discussed below.

Attentional Interference Theory (Sarason, 1984). Sarason's work described the relationship between test anxiety and cognitive performance within an attentional processing framework. According to attentional interference theory, threatening situations produce a stress reaction that includes two types of cognitions: task-relevant thinking (e.g., thoughts about solving the problem at hand) and task-irrelevant thinking (e.g., worry about abilities and difficulties). Attentional interference theory suggested that task-irrelevant cognitions (i.e., worrisome thoughts) impede attention to task-oriented information, thereby reducing the cognitive resources available to undertake the task. The theory suggested that performance deficits are likely when task-irrelevant thoughts outweigh thoughts related to attaining the goal of the task. Later theories, however, argued that Sarason may have overlooked the positive contribution of worry under certain conditions (Eysenck & Calvo, 1992). Eysenck and Calvo suggested that despite evidence for task-irrelevant thoughts consuming attentional resources (e.g., Sarason, Sarason, Keefe, Hayes, & Shearin, 1986), worry can potentially increase motivation, which may consequently have a compensatory effect on task performance (e.g., Eysenck, 1985).

Personality, Motivation and Performance Theory (Humphreys & Revelle, 1984). Personality, motivation, and performance theory viewed motivation as the critical factor determining cognitive performance via the availability and allocation of cognitive resources. Humphreys and Revelle suggested that motivation determines whether resources are allocated to one facet of performance over another (e.g., accuracy may be favoured over speed, or vice versa) and that motivation is linked to the level of mental effort invested in performing the task (i.e., increased motivation leads to increased effort, hence increased cognitive resources available to perform the task). Furthermore, Humphreys and Revelle proposed that the effects of anxiety on task performance vary according to the difficulty of the task, such that high anxiety can facilitate performance on simple tasks and hinder performance on complex tasks. Despite the theoretical merit in recognising anxiety as having a variable influence on cognitive performance, Eysenck and Calvo (1992) suggested that the model overestimated the negative influence of anxiety on performance. They further criticised this approach for viewing the individual as a passive reactor rather than having the flexibility to re-allocate resources as required.

Processing Efficiency Theory (Eysenck & Calvo, 1992). Processing efficiency theory sought to address the limitations in the work of Sarason (1984) and Humphreys and Revelle (1984) and proposed a model to account for performance deficits in anxious individuals (i.e., individuals high in trait anxiety) under high levels of situational stress. According to the theory, anxious individuals engage in task-irrelevant worrisome thoughts which have a two-fold implication for cognitive performance. Worry can reduce the resources available to perform the task, yet enhance performance by initiating recruitment of extra effort. The theory defined performance effectiveness (i.e., the quality of performance; typically operationalised as accuracy) and processing efficiency (i.e., the relationship between accuracy and the resources used to accomplish the task; typically operationalised as RT) and suggested that anxiety impairs processing efficiency more than performance effectiveness. The theory posits that anxious individuals may be capable of overcoming performance deficits by deploying extra effort, however the worry-costs consume processing resources which in turn manifests as lower efficiency.

Processing efficiency theory is premised on the tripartite model of working memory (see Baddeley & Hitch, 1974; Baddeley, 1986). Baddeley's model (1986) described the central executive as responsible for attentional control, processing and co-ordinating information; the phonological loop as accountable for rehearsal and short-term storage of verbal information; and the visuo-spatial sketchpad as a mechanism dedicated to the processing and transient storage of visual and spatial information. A fourth component, the episodic buffer, was later added to the model (see Baddeley, 2000; 2002), but not incorporated into later iterations of the theory. In adopting Baddeley's model, processing efficiency theory implicated the central executive and the phonological loop as the components affected by anxiety. The theory predicted that the inner-verbal nature of worry involves the phonological loop to a greater extent than the visuo-spatial sketchpad (see also Rapee, 1993), since at the time it was thought not to have a visual or spatial component. Despite gaining some empirical support (see Eysenck et al., 2007) the theory fell short of specifying the precise relationship between anxiety and executive functioning, particularly in light of increasing evidence that the central executive was not unitary, but rather a multi-component system responsible for discrete cognitive operations (see Miyake et al., 2000 for a review). Processing efficiency theory also made no assumptions related to the presence of distracting or threat-related stimuli, nor for situations when anxious individuals perform better than their non-anxious counterparts.

Attentional Control Theory (Eysenck et al., 2007). Drawing on the theoretical perspectives of its predecessors (Eysenck, 1979; Eysenck & Calvo, 1992), ACT provides a systematic account of the mechanisms underpinning the relationship between anxiety and cognitive performance and specifies the behavioural characteristics inherent in this relationship. ACT retained several key assumptions from processing efficiency theory, and generated some major theoretical developments to address its limitations. Though some predictions were initially speculative, many are now empirically supported, and others remain to be specifically tested (see Chapter 2 for a review of the empirical support for ACT).

ACT is premised on the idea there are two attentional systems, one involved in top-down, goal-driven processing and one associated with bottom-up, stimulus driven processing (see also Yantis, 1998). The main assumption of ACT is that anxiety heightens activation of the stimulus-driven system (i.e., preferential resource allocation to internal and external threat-related stimuli) and reduces the influence of the goal-driven system (i.e., involved in the ongoing performance of tasks), such that this imbalance between the two systems results in impaired attentional control. According to ACT, asymmetry in these systems should be most apparent when trait anxiety and/or situational stress are elevated. The theoretical framework of ACT provides numerous specific predictions that will be discussed below to provide the context for a comprehensive examination of the theory using existing empirical work (see Chapter 2) and new experimental data collected in the process of this program of research.

Assumptions of attentional control theory. The assumptions described here are a compilation of the theoretical literature thus far, inclusive of the authors' most recent reviews (e.g., Berggren & Derakshan, 2013; Derakshan & Eysenck, 2009; Eysenck & Derakshan, 2011).

Anxiety is determined interactively by trait anxiety and situational stress. ACT posits that trait anxiety has a multiplicative effect on the arousal of individuals in a stressful situation (i.e., an anxious state) and this combined degree of anxiety is associated with adverse performance on cognitive tasks.

Anxiety and effort. ACT suggests that anxious individuals engage in task-irrelevant thoughts, hence they actively respond to cognitive processing deficits by investing extra mental effort to prevent cognitive performance shortfalls (i.e., to avoid performance impairments). Specifically, anxious individuals protect against accuracy deficits by allocating additional resources to the task. The resourcing costs, however, manifest as additional time to complete the task.

Effectiveness and efficiency. ACT differentiates performance effectiveness, that is, the quality of cognitive performance, from processing efficiency, specifically the cognitive resources used to accomplish the task (see also processing efficiency theory).

Anxiety impairs efficiency more than effectiveness. ACT proposes that in some circumstances high-anxious individuals are able to demonstrate comparable effectiveness (i.e., accuracy) to their low-anxious counterparts by recruiting adequate effort, however the costs are borne in poorer efficiency. For example, highly anxious indivduals will take longer to perform the task (e.g., longer RTs).

Adverse effects of anxiety on performance are greater as task demands increase. ACT posits that when task demands increase, it becomes increasingly difficult to overcome anxiety-linked impairments. The theory predicts that impaired performance in anxiety is more apparent during complex rather than simple tasks since the former places greater demands on the storage and processing components of working memory, whereas the latter utilises short-term storage only.

Anxiety impairs the functioning of the central executive. According to ACT anxiety has adverse effects on attentional control, one of the main functions of the limited capacity central executive. In an investigation into individual differences of executive functions, Miyake and colleagues (2000) identified three separate control functions of the central executive: inhibition, shifting and updating. The inhibition function involves the inhibition of a dominant response, such that attentional control is utilised to prevent interference from task-irrelevant stimuli (see also Friedman & Miyake, 2004). The shifting function involves switching between tasks or mental sets, such that it is used to apportion attention in an optimal way to the stimulus or task that is the most important (see also Monsell, 2003), and the updating function involves monitoring, coding and revising information within working memory (see also Smith & Jonides, 1997). In accepting Miyake's work, ACT proposes that anxiety impairs the three main functions of the central executive such that the effect would be most noticeable on the inhibition and shifting functions, and to a lesser extent on updating.

Anxiety impairs the functioning of the phonological loop. In light of limited empirical support for the prediction that anxiety impairs phonological performance, revisions of ACT have excluded assumptions regarding this component (see Berggren & Derakshan, 2013; Eysenck & Derakshan, 2011). Processing efficiency theory (Eysenck & Calvo, 1992), however, suggested that anxiety has adverse effects on phonological performance (i.e., the rehearsal and storage of verbal information) and other work by Rapee (1993) reported that worry predominantly utilises the phonological function of working memory. Thus, for the purpose of completeness, the present program of research has investigated this assumption.

Anxiety impairs the updating function (under stressful conditions). Miyake and colleagues (2000) suggested that the updating function involves the monitoring and updating of information in working memory. Consistent with this definition, ACT predicts that the updating function is more aligned to working memory than attentional control. ACT suggests that highly anxious individuals (i.e., high-trait anxious) will display updating efficiency (and sometimes effectiveness) deficits under stressful conditions, when the demands of the central executive are heightened.

Anxiety impairs the inhibition function. Friedman and Miyake (2004) suggested that the inhibition function involves two interrelated processes: response inhibition (supressing a dominant response to a target stimulus) and resistance to distractor interference (resisting attention to a task-irrelevant stimulus). ACT posits that anxiety reduces inhibitory control, such that anxiety produces more incorrect dominant responses and decreases the ability to resist attending to task-irrelevant information. Accordingly, ACT suggests that anxiety-linked impairments are greater in the presence of threat- relative to neutral-stimuli.

Anxiety impairs the shifting function. Miyake and colleagues (2000) identified the shifting function as the process of switching back and forth between mental sets (either between tasks or between categories within a single task). In other work, Monsell (2003) described the shift from one mental set to another much like changing gears in a car, and demanding of a switch-cost (e.g., an increased RT on the switch trial) requiring the exertion of attentional control (e.g., Monsell & Driver, 2000). ACT suggests that elevated anxiety is associated with shift-cost efficiency, specifically poorer efficiency on trials in which switching is necessary.

Anxiety impairs attentional control in the presence of threat-related stimuli. ACT suggests that anxiety over-activates the stimulus-driven attentional system which in turn disrupts the balance between it and the goal driven system, resulting in impaired attentional control. Performance on tasks that rely mainly on the stimulus driven system is likely to be impaired in the presence of anxiety. In accord with others (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007 for a review), ACT accepts that highly-anxious individuals preferentially allocate attention to the source of threat. However ACT also posits that these individuals are slower to disengage from threat. Taken together, ACT therefore inherently predicts that anxiety facilitates performance on tasks that involve threat detection, and attenuates performance on tasks that involve attentional withdrawal from threat.

Anxiety and motivation. In a recent update to ACT, Eysenck and Derakshan (2011) proposed that motivation might be used as a compensatory strategy by high-anxious individuals during performance on cognitive tasks. ACT suggests that when the task is easy and/or the goals of the task are unclear, anxious individuals have a tendency to feel less motivated and use fewer attentional control resources, resulting in poorer performance. Conversely, when the task is more demanding and/or has clear goals, highly anxious individuals tend to engage more resources, resulting in better performance than their low-anxious counterparts.

Diagrammatic representation of ACT. Figure 1 shows a diagramatic representation of ACT. As can be seen in the figure, trait anxiety and situational stress comprise separate dimensions of cognitive and somatic anxiety, and combine interactively. Moving from left to right, the figure shows that mental effort and/or motivation moderate the relationship between anxiety and performance. The centre of the figure symbolizes the working memory model proposed by Baddeley (1986) and includes the systems accepted by ACT as most affected by anxiety. Finally, the right of the figure shows how performance effectiveness and processing effciency are dependent on cognitive load (or task complexity).

The present program of research provides a comprehensive test of the predictions of ACT in terms of the theoretical components represented in Figure 1. The program of research reported in the present thesis comprises (Series 1) a four-part investigation of the relationship between trait anxiety, situational stress,

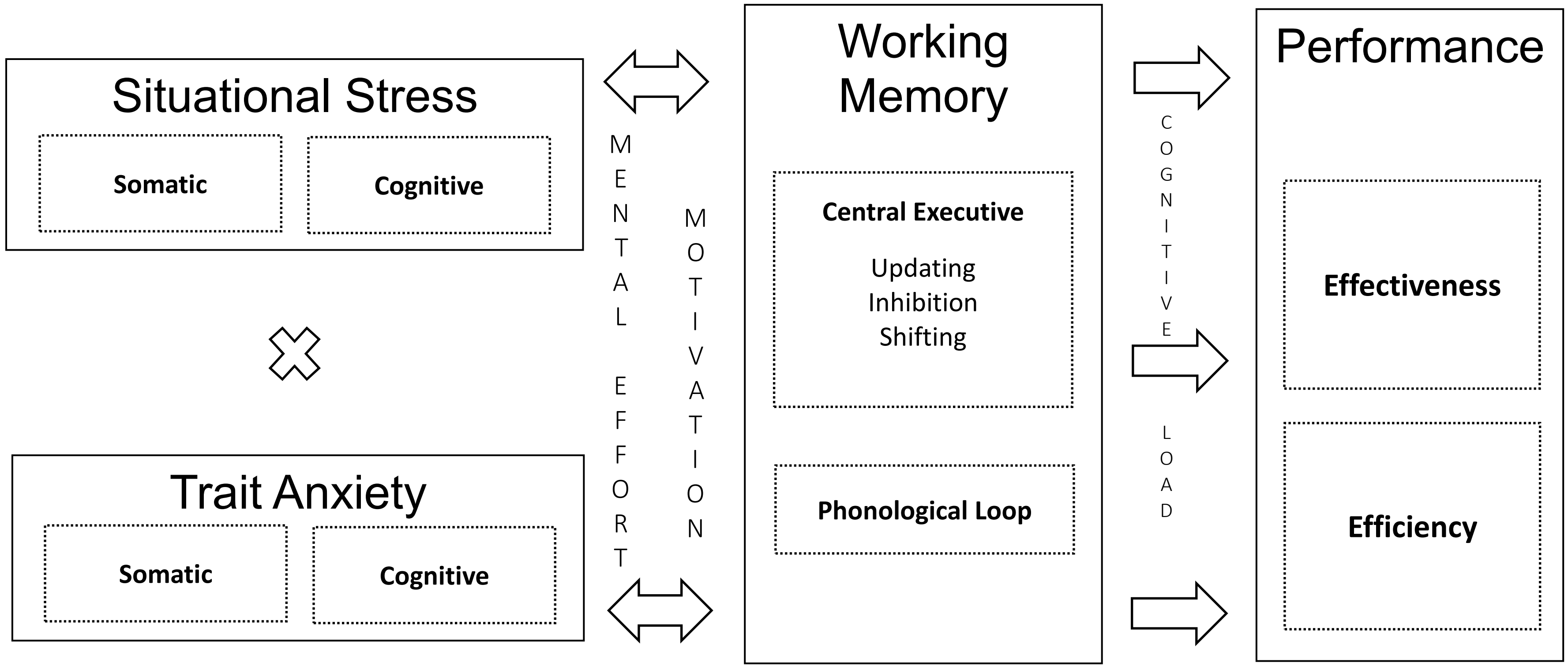

Figure 1. A diagrammatic representation of Attentional Control Theory (Eysenck, Derakshan, Santos, & Calvo, 2007)

effort and performance (effectiveness and efficiency) on tasks designed to tap phonological, updating, inhibition and shifting performance (see Studies 1.1, 1.2, 1.3, & 1.4), and (Series 2) a three-part investigation of the relationship between trait anxiety, situational stress and motivation on indicies of updating, inhibition and shifting (see Studies 2.1, Study 2.2, & Study 2.3).

Summary of Theoretical Perspectives

From a historical perspective there have been numerous influential theoretical accounts of the relationship between anxiety and cognitive performance. In sum, it is apparent that the models have several commonalities. First, the models share the view that effort and motivation are in some way connected to the relationship between anxiety and performance. Second, the theories recognise that task complexity (or cognitive load) contributes to performance variability. Third, the later theories acknowledge that attention to task-relevant and/or irrelevant thoughts/stimuli contributes to cognitive performance, although the direction of this relationship warrants further clarification. Finally, the models concur that anxiety can be trait-like or situationally-based and both contribute to the adverse effects on performance and processing outcomes.

Eysenck's theories (with others in 1979, 1992, & 2007) have evoloved over time, resulting in the most sophisticated set of assumptions in the area to date (see ACT; Eysenck et al., 2007). Despite both processing efficiency theory (Eysenck & Calvo, 1992) and ACT (Eysenck et al.) recognising that the pattern of cognitive performance in anxiety is unique to the specific components of the working model (e.g., phonological loop, central executive), ACT was the first theroretical perspective to specify the precise nature in which the functions of the central executive (i.e., updating, inhibition, and shifting) are affected by anxiety. Consequently, ACT (Eysenck et al., 2007) and later reviews (Derakshan & Eysenck, 2009; Eysenck & Derakshan, 2011) certainly merit the comprehensive investigation conducted here.

Chapter Summary

In Chapter 1, the concept that anxiety comprises trait-, situational-, somatic- and cognitive- characteristic was described. The idea that anxiety is associated with individual differences in cognitive performance was introduced, and the theoretical perspectives attempting to explain anxiety-linked performance deficits were discussed with particular emphasis on the assumptions of ACT. The foundations were laid for a comprehensive investigation of ACT. In Chapter 2, the empirical evidence for ACT is reviewed and relevant factors (trait anxiety, situational stress, effort, motivation, performance effectiveness and processing efficiency) are critically evaluated for their place in the model (the factors were diagrammatically represented in Figure 1).

CHAPTER 2: A CRITICAL REVIEW OF THE LITERATURE

Empirical Evidence for Attentional Control Theory

The focus of the present research is to systematically test the predictions of ACT (Eysenck et al., 2007). Chapter 1 outlined the development of some of the more influential theoretical perspectives on the relationship between anxiety and cognitive performance. The present chapter provides a critical review of the empirical support that has guided the development of ACT (see Eysenck & Derakshan, 2011 for a review). The evidence is reviewed with respect to the phonological loop and the three functions of the central executive proposed by Miyake et al. (2000) and accepted by ACT (updating, inhibition, and shifting). Each study is presented with the aim of critically reviewing its methodology, detailing the contribution of the findings with respect to ACT and suggesting the limitations and interpretational difficulties arising from the use of different tasks, measures, and procedures. The chapter includes a discussion of possible extraneous variables in the current literature and concludes with an overview of the structure and approach of the present thesis.

Anxiety and Phonological Performance

The phonological loop is thought to be responsible for storage and processing of verbal and acoustic information (see Baddeley, 1986). The digit and word span tasks are recognised measures of phonological processing within both laboratory (e.g., Markham & Darke, 1991) and clinical settings (e.g., Gerton et al., 2004). In a prototypical version of these tasks, the researcher reads aloud item sequences that vary in length, and the participant is required to recall a given sequence in the order in which the items were presented (forward span) or in the reverse order (backward span).

In an early study employing the span task, Walker and Spence (1964) investigated the relationship between situational stress and phonological processing using the forward digit span task. Although the results revealed equivalent span scores between their high and low stress groups, they did report that individuals in the high stress group who reported feeling ‘disturbed’ after the test recalled fewer digit span sequences than control participants. Similar results were found in replication studies (e.g., Firretto & Davey, 1971; Walker, Sannito, & Firetto, 1970). The major interpretational difficulty with this approach, however, was that the self-assignment procedure does not clarify the direction of the relationship between anxiety and phonological performance. That is, it was unclear whether anxiety affected phonological performance or whether poor performance caused participants to self-report feeling more *disturbed.* In other work, Darke (1988) examined the effects of test anxiety and situational stress on forward digit span accuracy. Results indicated that individuals in the high stress group recalled fewer digit sequences than their low stress counterparts, suggesting that higher stress is associated with lower phonological effectiveness (i.e., accuracy). Although this early work provided some promise for the idea that anxiety is associated with poorer phonological performance, reliable replications have not been reported (e.g., Ikeda, Iwanaga, & Seiwa, 1996; Sorg & Whitney, 1992; Walkenhorst & Crowe, 2009).

The inconsistent results using these paradigms might plausibly be explained by the use of accuracy (performance effectiveness) as the dependent measure. As predicted by ACT, anxiety will have little effect on accuracy under conditions in which participants are able to recruit extra resources; however, the effort cost will be evident in the additional time it takes to perform the task (i.e., lower processing efficiency). Support for this idea was reported by Ikeda et al. (1996) who found that high state anxious participants took longer to perform a verbal memory task than did those low in anxiety, despite both groups performing with equivalent accuracy. Although these data offer support for this key assumption of ACT, there are well-documented problems using RT alone as the dependent measure. For example, it is important that consideration be given to the relationship between accuracy and time in order to discount a speed-accuracy confound. More importantly, RT is only an appropriate measure of efficiency under conditions in which all participants perform with equal accuracy. When accuracy varies between participants, efficiency is better operationalised as the ratio of accuracy over RT (see Edwards, Edwards, & Lyvers, 2015, & Edwards, Moore et al., 2015, for further details).

It is also plausible that the forward span task utilises insufficient phonological resources to capture consistent anxiety-related performance deficits (i.e., it is a simple task). In accord with ACT, it is possible that anxious individuals are able to recruit additional effort to overcome performance shortfalls on this simple task, whereas the adverse effects of anxiety on performance increase as the task demands increase. Since the backward span task places greater demands on the phonological loop due to the additional processing required to reverse the items (i.e., a complex task; Engle, Tuholski, Laughlin, & Conway, 1999), administration of both forward and backward versions in the one study would allow a for robust test of the relationship between anxiety and phonological performance at low- and high- cognitive load.

The ability of ACT to explain the relationship between anxiety and the functioning of the phonological loop remains unclear. Although there is some evidence for an association between situational stress and performance effectiveness deficits using a span task (e.g., Darke, 1988), and impaired processing efficiency using a verbal memory task (e.g., Ikeda et al., 1996), further work is warranted. The methodological problems discussed here are addressed in the present work (see Study 1.1).

Anxiety and Updating Performance

Early work in understanding the executive functions suggested that the updating of information in working memory is part of the coordinating role of the central executive (Morris & Jones, 1990). This definition was later expanded to include the updating (i.e., overwriting old and no longer relevant) and monitoring (i.e., checking for new and more relevant) of information (see Miyake et al., 2000 for a review). It is now accepted that the function of updating actively monitors and manipulates information in working memory (Miyake et al.). Several paradigms have been used to investigate the relationship between anxiety and updating. Empirical work has typically deployed tasks that involve both updating and recall of information, such as the *n*-back task (e.g., Vytal, Cornwell, Arkin, & Grillon, 2012; Wong, Mahar, Titchener, & Freeman, 2013), the reading span task (e.g., Calvo, 1996; Sorg & Whitney, 1992) and other tasks (e.g., Calvo, Ramos, & Esteves, 1992).

The *n*-back task requires participants to monitor a series of numbers or letters presented in blocks of increasing difficulty (either *1*-back, *2*-back, *3*-back or *4*-back requirements), such that they are required to push a button or make a keystroke when presented with an item on the previous trial (*1*-back), after one intervening trial (*2*-back), after two intervening trials (*3*-back), or after three intervening trials (*4*-back). Studies using *n*-back performance to examine the relationship between anxiety and the updating function have shown mixed results. For example, Wong and colleagues (2013) found no relationship between trait anxiety and *n*-back effectiveness, but highly anxious individuals took longer to identify previously presented items (i.e., longer RTs), which was interpreted as having poorer efficiency relative to their low-anxious counterparts. In other work, Vytal et al. (2012) found anxiety related *n*-back effectiveness deficits, however no difference in RTs was evident between individuals in the high- and low- anxiety groups. Other studies, however, have found no relationship between anxiety and *n*-back effectiveness or efficiency (Fales et al., 2008; Walkenhorst & Crowe, 2009).

One explanation for the differences in *n*-back results rests with the different indices of anxiety used across studies. Wong et al. (2013) and Walkenhorst and Crowe (2009) examined self-reported trait anxiety, whereas Vyal et al. (2012) and Fales et al. (2008) manipulated situational stress using threat of electric shock and watching threat-related movies, respectively. For the differences in indices of anxiety to be responsible for variances in updating performance, however, studies that examined the same index of anxiety should have revealed conceptually the same pattern of results, which was not the case (i.e., Wong et al. vs. Walkenhorst & Crowe). In line with ACT, it is reasonable that both trait anxiety and situational stress play an interactive role in the relationship between anxiety and updating performance, and that empirical work to date using the *n*-back task has not examined both of these dimensions of anxiety in the one study.

Results of studies using the reading span task to examine the relationship between anxiety and updating performance have also reported equivocal results.

The reading span task requires participants to read aloud a series of sentences one at a time in close succession, and then recall the last word from each sentence (see Daneman & Carpenter, 1980). Following last-word recall participants (in some studies) perform a sentence processing check, such as a true/false question (e.g., Harris & Cumming, 2003) or a comprehension cloze test (e.g., Calvo et al., 1992; Calvo, 1996), as a control for a last-word recall versus sentence processing trade-off (see Masson & Miller, 1983). Typically data from participants who perform at a minimum level of comprehension on the processing check are included in the analyses (i.e., > 85% comprehension is recommended; see Conway et al., 2005).

Darke (1988) examined the interactive effects of test anxiety and situational stress (experimentally manipulated using an evaluative stressor) and found that high test-anxious individuals in the stressful condition had poorer reading span performance compared to those low in test anxiety. These data are consistent with the prediction that highly anxious individuals demonstrate poorer updating effectiveness under high-stress, however the findings should be interpreted with caution as reading span measures were not taken under low-stress conditions. ACT suggests that trait anxiety and situational stress combine to produce updating performance deficits such that a relationship is evident only under stressful conditions. In the absence of reading span performance data for a low-stress group, it is not possible to draw conclusions about the multiplicative relationship between anxiety and situational stress. In similar work, Calvo et al. (1992) found that individuals high in test anxiety recalled fewer last-words on the reading span task (i.e., poorer updating effectiveness) when under evaluative stress, and their design was able to clarify that in the absence of stress, performance did vary as a function of test anxiety. Sorg and Whitney (1992) employed the reading span task to examine the interactive effects of trait anxiety and situational stress (manipulated using a competitive situation). In accord with ACT, they found that high trait-anxious individuals under high situational stress recalled fewer last-words than those safe from stress, whereas low-anxious individuals' performance did not differ between stress groups. Despite Sorg and Whitney's findings affording empirical support for ACT, their study did not include a sentence processing check to rule out the possibility that participants were *storing* last-words at the expense of *processing* the sentences. Assessing both the storage and processing of information in working memory constitutes a more fine grained measure of updating performance. Studies that have included a processing check, however, have returned mixed results. For example, Harris and Cumming (2003) found no differences in last-word recall between high- and low-trait- or state- anxious individuals based on self-reported measures of anxiety, whereas Calvo and others (Study 2; 1992) found high test-anxious individuals recalled fewer last-words than those low in test-anxiety under evaluative stress conditions, but not in the absence of stress. Given the mixed findings to date, further work is warranted to clarify the relationship between anxiety and updating effectiveness using the reading span task. Moreover, in order to shed light on reading span efficiency, methodological procedures would need to include a measure of RT, which has not been done previously.

Together, the findings from the studies utilising the *n*-back and reading span tasks offer some insight into the association between anxiety and updating performance. For example, it seems plausible that situational stress plays some role in predicting updating performance, however it is possible that other factors such as mental effort or motivation may buffer the anxiety-stress relationship and that these factors have been overlooked in the literature to date. These issues are addressed in the current work (see Study 1.2 & 2.1, respectively).

Anxiety and Inhibitory Performance

Inhibition involves interrupting, delaying and/or suppressing a dominant response to task-irrelevant information (see e.g., Harnishfeger, 1995). Inhibitory control has been investigated in multiple event-related potential (e.g., Ansari & Derakshan, 2011; Bishop, 2009; Kamarajan et al., 2004) and behavioural studies (e.g., Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998; Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010), with experimental paradigms such as the emotional Stroop (e.g., Reinholdt-Dunne, Mogg, & Bradley, 2009; see Bar-Haim et al., 2007 for a review), variations of the Go-No-Go task (e.g., Gomez, Ratcliff, & Perea, 2007; Johnstone, Pleffer, Barry, Clarke, & Smith, 2005), and the antisaccade task (e.g., Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009; Garner, Ainsworth, Gould, Gardener, & Baldwin, 2009). When emotional stimuli have been employed, a common finding has been that anxiety is associated with a bias to preferentially process threat material (see e.g., Cisler & Koster, 2010, for a review). Although these data offer support for ACT, they do not permit an analysis of the separate contributions of internal (i.e., worrisome thoughts) and external (i.e., item content) threats on inhibitory processes, as both are present during task performance. An assessment of the contribution of internal distraction can be obtained by using tasks that employ only neutral stimuli, and accordingly only studies reporting the inclusion of neutral stimuli are reviewed here. A review of the inhibition literature that included threat-related stimuli is included in Chapter 5.

Garner and colleagues (2009) used an antisaccade task (with neutral stimuli) to examined the relationship between anxiety and inhibitory control. In the antisaccade task, participants are asked to inhibit the natural tendency to look towards an object in their periphery, compared to prosaccade performance when the individual is instructed to look towards the peripheral object. Garner et al.'s data revealed that high anxious participants made more eye movement errors on antisaccade trials than their low anxious counterparts. In similar work using the antisaccade task, Derakshan, Ansari et al. (2009; Experiment 1) found that high anxious participants took longer to respond on correct antisaccade trials than low anxious participants, albeit there was no difference between groups in terms of error rate. Conceptually, Derakshan, Ansari et al.'s findings were replicated by Ansari and Derakshan (2010). Taken together, the data from investigations using the antiscaccade task suggest that anxiety is associated with poorer inhibitory efficiency and effectiveness, although the latter effect seems to be less robust.

Righi, Mecacci, and Viggiano (2009) investigated the relationship between anxiety and inhibition using a Go-No-Go task which requires participants to respond to a non-target stimulus (Go trials) and to suppress a response to a target stimulus (NoGo trials). Their target stimulus was the digit 3, with Go trials requiring participants to push the space bar on the keyboard in response to any number other than 3. Contrary to ACT, they found no relationship between state or trait anxiety and inhibitory control (indexed as the number of correct Go trials or the number of NoGo errors), and no association between anxiety and inhibitory efficiency (operationalised as RTs on Go trials). Several explanations are feasible. ACT suggests that anxious individuals can recruit additional resources (e.g., effort) in order to overcome performance shortfalls, particularly on less demanding tasks. Therefore, it is possible that the task (i.e., inhibiting a simple response to a digit) did not place sufficient demands on inhibitory processes to reveal performance deficits. Alternatively, the measures of effectiveness and efficiency employed may not have been sufficiently sensitive to detect the effect of anxiety. Signal detection theory (Pastore & Scheirer, 1974) proposed that a measure of performance should take into account the ability to discriminate between non-target and target stimuli, namely stimulus sensitivity (*d';* see Stanislaw & Todorov, 1999 for a review). Thus, *d'* is calculated by subtracting the *z* score for NoGo trials from the *z* score for the Go trials. This parameter has been used in other studies as a valid and sensitive index of inhibitory efficiency (e.g., Pacheco-Unguetti et al., 2010; Wong et al., 2013).

Wong and colleagues (2013) employed the Go-No-Go task and tested the relationship between anxiety and effectiveness (indexed as stimuli sensitivity) and efficiency (RT). They reported no association between anxiety and inhibitory effectiveness (*d'*), however highly anxious individuals demonstrated poorer efficiency relative to low anxious participants. Their predictive model, however, was constrained by the absence of a measure of state anxiety. Congruent results were reported in similar work by Pacheco-Unguetti and colleagues (2010) who found that anxiety was unrelated to effectiveness (*d'*) on the Go-No-Go task, but anxious individuals performed with longer RTs (i.e., lower efficiency).

In combination, the data reported by Wong et al. (2013) and Pacheco-Unguetti et al. (2010) offer support for ACT, such that anxiety impairs efficiency more than effectiveness. A limitation of both approaches however was that the use of RT on correct Go trials as the index of efficiency does not control for the possibility that speed of response and accuracy were confounded. For example, an individual who responds with great speed on 100% of trials (i.e., Go trials and NoGo trials) would be highly efficient despite making 100% errors on NoGo trials. An appropriate measure of inhibitory efficiency should therefore consider the relationship between the participant's ability to discriminate between target-absent (correct responses on Go trials) and target-present stimuli (errors on NoGo trials), and the speed of response on correct trials (see e.g., Edwards, Edwards et al., 2015; Edwards, Moore et al., 2015).

Notwithstanding these limitations, the data from antisaccade and Go-No-Go paradigms using neutral stimuli suggest that anxiety is associated with impaired inhibitory efficiency, and to some extent poorer effectiveness. A systematic study addressing the measurement issues related to inhibitory effectiveness and efficiency would clarify the relationship between anxiety and inhibitory control in the presence of neutral stimuli (i.e., investigate the extent to which internally-generated threat acts as anxiety-inducing stimuli) and in the presence of threat-related stimuli (i.e., examine the extent to which externally-generated threat acts as anxiety-inducing stimuli). This work is conducted in Study 1.3 and Study 2.2 respectively.

Anxiety and Shifting Performance

Shifting performance is the process of switching back and forth between tasks or accommodating mental set changes in task requirements (Miyake et al., 2000). There is accumulating evidence to suggest that anxiety is associated with impaired shifting as assessed by the mixed pro- and anti-saccade task (e.g., Ansari et al., 2008), the Wisconsin Card Sorting Task (e.g., Caselli, Reiman, Hentz, Osbourne, & Alexander, 2004; Goodwin & Sher, 1992), and other task-switching paradigms (e.g., Derakshan, Smyth et al., 2009; Edwards, Moore, et al., 2015).

Ansari and colleagues (2008) explored the relationship between anxiety and task switching using a mixed anti- and pro-saccade paradigm. The task required participants to identify the direction of an arrow that was presented following random presentations of antisaccade trials (experimenter instructions to look away from a cue signal) and prosaccade trials (experimenter instructions to look towards a cue signal). It was suggested that shifting between antisaccade and prosaccade trials consumes attentional resources, thus they anticipated slower RTs on these trials relative to non-shift trials (i.e., prosaccade to prosaccade or antisaccade to antisaccade). In general, their results were consistent with ACT, such that high-anxious individuals made more errors and had slower RTs than low-anxious individuals on shift- compared to non-shift trials. The authors however noted that a limitation of their approach was that they did not separate the effects of trait anxiety and situational stress, as is necessary to demonstrate full support for ACT. Similar anxiety-related shifting deficits have been observed in other work (e.g., Derakshan, Smyth et al., 2009).

The Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Talley, Kay, & Curtiss, 1993) is a widely used executive function task that has been used to index shifting performance (see Miyake et al., 2000). The task requires participants to select one of four target cards that match a stimulus card in form, colour or number. Performance feedback is given following each trial, and after 10 consecutive correct matches the sort criterion is changed. Shifting effectiveness is typically operationalised as the number of perseverative errors (i.e., continued use of the same sorting criterion despite negative feedback). Caselli and colleagues (2004) employed the WCST to investigate the relationship between anxiety and shifting performance. In support of ACT, their results confirmed that self-reported trait anxiety was positively associated with the number of perseverative errors on the task, suggesting that anxiety impairs shifting effectiveness. Their procedure, however, was constrained by fact that RT data were not collected. In the absence of confirmation that the pattern of errors did not match the pattern of RT data, it is not possible to discount that those higher in anxiety made more perseverative errors simply because they were faster to respond (i.e., a speed vs. accuracy trade-off).

Similar work was undertaken by Goodwin and Sher (1992) using a computerised version of the WCST to examine shifting performance (effectiveness and efficiency). In accord with the predictions of ACT, they found that higher self-reported state anxiety was associated with more perseverative errors (index of shifting effectiveness) and longer total times to complete the task (index of shifting efficiency). Although conceptually these data demonstrate the relationship between anxiety and shifting effectiveness and efficiency, they too are somewhat constrained by procedural difficulties. First, the effect of trait anxiety was not investigated, and second, if these data were to be accepted as direct support for ACT then using the total time to complete all trials (inclusive of shift and no-shift trails) would seem imprecise. Failing to separate the RTs of shift trials from no-shift trials results in being unable to identify whether it is slower RTs on shifting trials or faster RTs on no-shift trials that influenced shifting efficiency.

Notwithstanding some procedural problems, there is growing evidence to suggest that individuals higher in anxiety are less effective and efficient at flexibly shifting mental sets than those lower in anxiety. Two methodological issues require attention to systematically test the assumptions of ACT on shifting tasks.

First, there is a concern with the use of RT as an index of processing efficiency (e.g., Caselli et al., 2004; Goodwin & Sher, 1992). As mentioned previously, to accommodate individual differences in performance effectiveness (accuracy), it is more appropriate to express processing efficiency as a ratio of accuracy to RT on respective trials (cf. Edwards, Edwards, et al., 2015; Edwards, Moore, et al., 2015). Second, some studies have examined trait anxiety (e.g., Ansari et al., 2008; Caselli et al., 2004) and others state anxiety (e.g., Derakshan Smyth et al., 2009; Goodwin & Sher, 1992). A full investigation of the effect of anxiety on shifting would require both trait anxiety and situational stress to be examined in a single study (e.g., Edwards, Moore, et al., 2015). These procedural challenges are addressed in this program of research (see Study 1.4 & 2.3).

Methodological Challenges

Despite accumulating evidence suggesting that anxiety is associated with performance deficits on tasks involving the phonological loop (e.g., Darke, 1988; Ikeda et al., 1996), and on the updating (e.g., Sorg & Whitney, 1992; Wong et al., 2013), inhibition (e.g., Derakshan, Ansari et al., 2009; Wong et al., 2013) and shifting (e.g., Ansari et al., 2008; Caselli et al., 2004; Goodwin & Sher, 1992) functions of the central executive, a number of studies have emerged that have failed to replicate these findings. For example, some studies have not observed a relationship between anxiety and phonological (e.g., Walkenhorst & Crowe, 2009), updating (e.g., Harris & Cumming, 2003), inhibitory (e.g., Righi et al., 2009), and shifting (e.g., Kofman, Meiran, Greenberg, Balas & Cohen, 2006) performance. In sum, empirical support for ACT rests on a plethora of studies utilizing a range of cognitive tasks and differing experimental designs and procedures.

Although the particular reasons for the discordant findings are uncertain, consideration of the following methodological issues may hold some clues as to possible explanations: (1) differences in dimensions of anxiety included across studies, that is, some studies have included trait anxiety or situational stress alone, whereas only a few studies have examined both the separate and combined contributions of trait anxiety and situational stress; (2) failure to delineate the separate effects of cognitive and somatic anxiety on performance, such that most studies have utilised a measure of anxiety that included a mix of both; (3) differences in induction procedures of situational stress, for example threat of electric shock, ego threat instructions, and watching threat-related videos; and (4) potential difficulties due to the measures of performance effectiveness and processing efficiency used across studies. These challenges will be discussed in detail below.

Dimensions of Anxiety

One challenge for researchers in the field of cognition and emotion concerns the various dimensions of anxiety employed across studies. Some studies included measures of trait anxiety (e.g., Ansari et al., 2008; Wong et al., 2013), others incorporated measured- or manipulated- situational stress (e.g., Eysenck, 1985; Ikeda et al., 1996), and some studies included both trait anxiety and situational stress in their predictive models (e.g., Sorg & Whitney, 1992; Vytal et al., 2012). One argument for the inclusion of both trait anxiety and situational stress as separate and combined predictors of performance relates to the original theoretical definitions reported by Spielberger and colleagues (1970; 1983). Spielberger et al. reported that individuals high in trait anxiety were more susceptible to elevated situational stress (state anxiety) by nature of their proneness to emotional arousal. Notwithstanding the value of Spielberger's argument, the strongest justification for inclusion of both trait anxiety and situational stress in the present context is to test the predictions of ACT. To recap briefly, ACT makes clear predictions with respect to the separate and combined contributions of trait anxiety and situational stress on cognitive performance. As such, a systematic examination of the predictions of ACT requires inclusion of both the separate and multiplicative relationships of the two anxiety dimensions (i.e., trait anxiety and situational stress). The work conducted for the present thesis addresses this concern.

Somatic Versus Cognitive Anxiety

The well-accepted distinction between trait and situationally based anxiety further reflects a combination of both somatic symptoms (e.g., physical tension, shortness of breath, and elevated heart rate) and cognitive characteristics (e.g., worry, fear, and apprehension; see Clark & Watson, 1991), each of which may interact in unique ways to affect cognitive performance. Ree, MacLeod, French, and Locke (2000; see also Ree, French, MacLeod, & Locke, 2008) reported that cognitive and somatic components of anxiety can be recognised at both trait- and state- anxiety level, and developed the State-Trait Anxiety Inventory for Cognitive and Somatic Anxiety (STICSA) as an index of these four dimensions (i.e., Somatic-State, Somatic-Trait, Cognitive-State and Cognitive-Trait). Many studies (and most reported in this chapter), however, employed the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983) to capture just two facets, trait and state anxiety, thereby neglecting consideration of the cognitive-somatic dimension. Studies examining the effect of worry on cognitive performance have provided support for the link between cognitive anxiety and cognitive performance (e.g., Eysenck, 1992; Hayes, Hirsch, & Mathews, 2008; Walkenhorst, & Crowe, 2009), and other work has evidenced the adverse effects of somatic anxiety on cognitive performance (e.g., Hudetz et al., 2000; Meinhardt & Pekrun, 2003). Furthermore, a study by Edwards et al. (2006) demonstrated that somatic stress (threat of electric shock) and trait anxiety combined to predict biases in attentional control (using the Stroop task) not seen in low anxious participants.

Given the multidimensional nature of anxiety, further work is needed to specify how cognitive and somatic trait anxiety, in combination with cognitive and somatic stress, is associated with cognitive control. In order to predict precisely how anxious individuals perform under stress it is necessary to investigate separately the performance of highly cognitive-trait anxious individuals under cognitive situational stress, and likewise to examine performance of those high in somatic-trait anxiety under somatic situational stress. The dimensions of cognitive and somatic trait anxiety were operationalized using questionnaire scores (Ree et al., 2008). The distinction of somatic and cognitive anxiety on cognitive performance is investigated in the first series of studies in this thesis (see Series 1).

Induction of Situational Stress

A review of the literature revealed that despite several studies using self-reported pre-existing measures of state anxiety (e.g., Derakshan, Smyth et al., 2009; Harris & Cumming, 2003), the use of a stress induction procedure can maximise the focal relationship between the situational stress variable and the criterion. There are numerous methods of manipulating situational stress in the literature. For example, some studies have required participants to watch threat-related videos (e.g., Fales et al., 2008), play competitive video games (e.g., Sorg & Whitney, 1992), or perform a modified cold pressor task (e.g., place their hand in ice water while told they are being videotaped for analyses of their facial expression; Banks, Tartar, & Welhaf, 2014). Although manipulation checks have demonstrated the efficacy of these methods in elevating situational stress, it is possible that these procedures would elevate both physical and psychosocial stress. Other studies, however, have used induction methods that more clearly align with either somatic or cognitive anxiety. For example, some studies have used CO_2 inhalation (e.g., Garner, Attwood, Balwin, James, & Munafo, 2011) and threat of electric shock (e.g., Edwards et al., 2006, Vytal et al., 2012) to induce somatic situational stress, whereas others have used ego-threat instructions (e.g., Calvo et al., 1992; Calvo, Eysenck, Ramos, & Jiménez, 1994; Darke, 1988; Derakshan & Eysenck, 1998) and pressured speeded subtraction (e.g.,Tohill & Holyoak, 2000) as manipulations of cognitive anxiety. Threat of shock is a well-established paradigm to induce situational stress (see Grillon, Baas, Lissek, Smith, & Milstein, 2004) that involves participants wearing an electrode (on their non-dominant forearm) capable of emitting unpleasant shocks whilst they engage in cognitive tasks. Studies have demonstrated the threat of shock to be a short-term immediate stressor (e.g., Miller & Patrick, 2000) capable of elevating situational somatic anxiety.

Ego threat instructions involve informing participants that their performance on a task is predictive of their level of intelligence, that their performance is being compared to others who have completed the tasks, and their performance is somewhat slower and less accurate than others. This type of evaluative procedure has been shown to elicit elevated levels of cognitive situational stress (e.g., threat to self-esteem and increased worrisome thoughts; see Hodges, 1968 for a review). The present study examined both somatic and cognitive anxiety and to this end, the threat of electric shock was selected as the somatic stressor, and ego-threat instruction was selected as the cognitive stressor.

Measures of Performance

ACT posits that cognitive performance can be measured in two ways, performance effectiveness and processing efficiency. At present, however, empirical investigations have been inconsistent in the measurement of indices of effectiveness and efficiency.

Performance effectiveness. Performance effectiveness (or the quality of performance) has typically been operationalised as accuracy on a task. It seems reasonable therefore that the number of correctly recalled items or correct trials has been used almost exclusively as an index of span performance or phonological effectiveness (e.g., Darke, 1988; Walker & Spence, 1964). Effectiveness measures on updating tasks across studies are less cohesive. Both the *n*-back and reading span tasks require participants to respond to increasingly difficult trials to test their ability to monitor and update larger sections of information in working memory, therefore determining an appropriate measure of the quality of updating performance presents a greater challenge to researchers.

Only scoring on the reading span task is reviewed here, as this was the task employed in the current work (see Study 1.4 & 2.1). Various scoring techniques are possible for the reading span task (see Conway et al., 2005 for a review). Some studies have used the traditional, quasi-absolute or span scoring technique (see Daneman & Carpenter, 1980) such that a span score was assigned based on the threshold of accuracy or the last item size recalled correctly after the individual's performance reached the termination criterion. Conway et al. (2005), however, suggest that absolute span scoring is less than ideal for studies of individual differences, citing that the use of item size at threshold alone (i.e., the point of task termination) and discarding performance indicators on all subsequent trials limits the sensitivity of the measure (see also Oberauer & Süß, 2000). Other work used a unit scoring technique which comprised the total number of correctly recalled last words or trials (e.g., Sorg & Whitney, 1992), and some studies have deployed a weighted (or load) scoring technique which awards a higher weight to items with a higher load, that is, trials of a greater sentence set length earn higher scores (e.g., Darke, 1988; Kensinger & Corkin, 2003). A review of Conway et al.'s (2005) extensive work on scoring the reading span task suggests that there are marginal internal consistency differences between unit- and weighted- scoring and recommends that scoring choices should be justified by theory. On the basis of this argument the weighted scoring procedure provides the most suitable, sensitive index of updating effectiveness, and aligns more closely with the definition from ACT, that is, the quality of the updating performance.

Measures of inhibitory effectiveness have been guided by task parameters and operationalised in several ways. For example, on the antisaccade task, effectiveness has been indexed by the number of antisaccade errors (e.g., Garner et al., 2009), and on the Go-No-Go task, inhibitory effectiveness has been operationalised as either the number of NoGo errors (e.g., Righi et al., 2009), or by using the stimulus sensitivity index (*d'*; e.g., Pacheoco-Unguetti et al., 2010; Wong et al., 2013). The latter approach is favoured as it affords the opportunity to capture individual differences in discriminative ability between non-target and target stimuli. Further, *d'* indexes the quality of inhibitory performance required for a robust test of ACT.

Studies examining the relationship between anxiety and shifting have operationalised shifting effectiveness as the number (or percentage) of perseverative errors on the WCST (e.g., Caselli et al., 2004; Goodwin & Sher, 1992). However, a perseverative error is demonstrative of an inability to shift. Consequently, shifting effectiveness is better operationalised as the percentage of responses that were not perseverative errors. Thus the effectiveness measure used here was calculated by deducting the percentage of perseverative errors from 100% (see Study 1.4 for further details).

Processing efficiency. ACT describes processing efficiency as the relationship between accuracy and the resources used to accomplish the task. In previous research, efficiency has typically been operationalised as the time taken to perform the task (e.g., RTs). Recent studies, however, have suggested that due to individual differences in accuracy, it is imperative to include a measure of accuracy in the equation for efficiency to avoid confounding problems with the potential for a speed versus accuracy trade-off (e.g., Edwards, Edwards, et al., 2015; Edwards, Moore, et al., 2015). More specifically, if RT alone was the index of processing efficiency then those participants who perform with great speed at the expense of numerous errors would be scored highly efficiently despite their high error rates. As defined by ACT, individuals who operate with great accuracy and speed should be those attributed with greater processing efficiency. Efficiency, therefore, is more appropriately operationalised as accuracy divided by RT (cf. Edwards, Edwards, et al., 2015; Edwards, Moore, et al., 2015).

Possible Extraneous Variables

Notwithstanding the accumulation of a considerable body of evidence from studies that have reported data indicating that anxiety is implicated as a predictor of impaired processing efficiency and sometimes performance effectiveness, many studies have not taken into consideration other person variables that may vary with anxiety and task performance. For example, individual differences in invested mental effort and depression have both been shown to co-vary with anxiety and with cognitive performance. Each is discussed in turn below.

Mental Effort

According to ACT, highly anxious individuals recruit additional resources in the form of invested mental effort to prevent performance shortfalls on cognitive tasks (Eysenck et al., 2007). Although the origins of this assumption were somewhat speculative (see Eysenck & Calvo, 1992), there is now growing empirical support for this prediction in studies that have found that higher mental effort buffers the anxiety-performance relationship on motor (e.g., Smith, Bellamy, Collins, & Newell, 2001) and cognitive (e.g., Edwards, Edwards et al., 2015; Hadwin, Brogan, & Stevenson, 2005) tasks. While the data from these recent studies afford support for the prediction that individual differences in effort might moderate performance outcomes, further investigations are required to determine the role of this factor in phonological, updating, inhibitory and shifting performance. One of the aims of the present thesis was to examine the role of effort in a predictive model premised on ACT. Mental effort was measured using a visual analogue scale (Zijlstra, 1993).

Depression

Comorbid depression is a complicating factor for studies investigating the relationship between anxiety and cognitive performance, given that positive correlations between these variables range between .40 and .70 (e.g., Bradley, Mogg, Millar, & White, 1995: Clark & Watson, 1991). The majority of studies, however, fall short of implementing an appropriate control for the relationship between depression and cognition. Depression has been found to affect performance on tasks which involve the working memory system (e.g., Baker & Channon, 1995; Channon, Baker, & Robertson, 1993). Specifically, there is evidence to suggest that depression is associated with impairments in executive function, specifically updating performance (e.g., Harvey et al., 2004), inhibitory performance (see Koster, De Lissnyder, Derakshan, & De Raedt, 2011) and shifting performance (e.g., Reinholdt-Dunne et al., 2012). There is however limited evidence to suggest that depression is associated with phonological performance (e.g., Gass & Russell,1986).

In light of the high levels of comorbidity between anxiety and depression, it is important to address the possibility that any anxiety-linked performance impairments could be reflective of the effects of depression. Furthermore, given the possibility of depression confounding individual performance it would seem important to conduct two protective procedures: First, to screen participants on a measure of depression and exclude those who fall above criterion levels (this was also a requirement of the university ethics committee); and second, to measure depression and control for it in the predictive modelling, that is, treat the depression scores of participating individuals as a covariate in statistical analyses. In the present work, depression was controlled in such a way that the effect of anxiety and situational stress on cognitive performance could be examined after controlling for variance in the criterion predicted by depression.

Structure of the Thesis

This chapter reviewed a number of key studies in the existing anxiety-cognition literature. By contrasting this work in terms of the assumptions of ACT, it is clear that support for ACT is based on numerous studies that have used different meaures and/or manipulations of anxiety and/or stress, and employed a range of tasks to assess the functions of working memory. Very few studies have examined the specific predictions of ACT, with many studies selecting individual components or factors in a piecemeal approach, and as such many of the predictions of ACT remain untested.

In review, the methodological challenges for future studies attempting to understand cognitive performance in anxious individuals are (1) include the separate and combined associations of trait anxiety and situational stress, (2) allow for the delineation of the separate relationships of cognitive and somatic anxiety, (3) include satisfactory manipulations of situational stress (somatic and cognitive), (4) include tasks and indices of effectiveness and efficiency that align with the definitions of ACT, (5) include a control for depression, and (6) examine possible factors that might moderate the anxiety-performance relationship (e.g., mental effort, motivation). A study addressing these issues would provide a robust and systematic test of ACT, and this is the approach taken in the current thesis.

Data Analytic Approach

The data were analysed using the Statistical Package for the Social Sciences (SPSS Version 20). Interactions in regression were followed up using the Interactions in Multiple Linear Regression with SPSS and Excel software (IRSE;

Meier, 2008). The multiplicative interaction terms used in the regression analyses were formed using mean-centred scores. To control for inflation of family-wise errors, follow up tests for mean differences in ANOVA were carried out using Bonferroni correction. All tests were considered reliable at $\alpha = .05$.

Chapter Summary

In Chapter 2, the evidence for cognitive performance deficits in anxiety was examined and critically appraised. Specifically, the literature was evaluated in terms of the assumptions of ACT and led to the identification of a number of procedural matters requiring attention that led to difficulties with interpretation of the existing empirical data. The chapter concluded with a description of the structure of the present thesis and a statement of the objective of the current series of experimental studies. In Chapter 3, the general methodology for the first 4-part experimental series of studies is described.

CHAPTER 3 – EXPERIMENTAL SERIES 1: GENERAL METHOD

Participants

Undergraduate psychology students were recruited from the Bond University Psychology Participation Pool using online and notice-board announcements. Only those who reported English as their native language, who had normal or corrected to normal vision, and who had normal colour vision, were invited to undertake preliminary screening. On the basis of meeting these criteria, 158 undergraduate psychology students (aged between 18 and 55 years, *M* = 23.91, *SD* = 7.96) participated in the studies reported in this series; of these 35 were male and 123 were female. Testing for each participant was conducted individually, in a single session which took approximately 2 hours each. In return for participation, students received research credit towards an introductory psychology course. All were provided a handout describing features of anxiety and depression and contact details of the university's counselling service.

Upon arrival at the laboratory, participants provided written informed consent (see Appendix A) and then completed the psychometric measures (discussed later in this chapter). At the request of the University human research ethics committee, individuals who scored in the extremely severe range (above 28) on the DASS- Depression scale were excluded. On this basis, 5 participants were thanked, released and replaced. Those who met the criteria for retention then completed the experimental tasks.

Based on their order of arrival at the laboratory, participants were systematically assigned to either low- situational stress (ego safe/shock safe) or one of two high-situational stress conditions (ego threat and shock threat), such that every third participant was allocated to the low-stress condition (allocations followed the pattern safe, ego threat, shock threat conditions and so on). Individuals in the low situational stress group acted as control participants for the ego and shock threat groups (approximately *N* = 90 per study). Bond University Human Research Ethics Committee (BUHREC) approval was obtained prior to commencement of data collection.

The data from a number of participants were excluded from the final analyses. The details of these exclusions are provided in the corresponding empirical sections that follow, and the details of each final, full sample are reported separately for each study.

Situational Stress Induction

Somatic Stress Induction

In the shock threat condition, an electrode was attached to the participant's non-dominant forearm, and the shock intensity level was individually determined using a shock workup procedure. Starting from a baseline of 0-volts the intensity of the 500 ms electric stimulus was increased in 10 volt increments until the participant reported the intensity to be *uncomfortable but not painful*. In the current sample, participants set the stimulus intensity from 20 to 90 V (M = 52 V, SD = 16.18) and they were informed that the intensity of any further shocks would be the same as the maximum voltage reached in this workup phase.

Cognitive Stress Induction

The ego threat condition comprised instructions emphasising evaluative stress, such that participants were told their performance was related to their intelligence, that it was being evaluated against others who had volunteered for the study and following the practice trials they were told their performance was somewhat slower and less accurate than others. The false performance feedback was restated during breaks throughout the tasks. By comparison, those in the low stress condition were told their participation was greatly appreciated and that most people find the task quite interesting and they were only provided with instructions that related to their understanding of the task.

Facilities and Equipment

All data were collected in a sound-attenuated laboratory in the Cognitive Psychology Laboratories of the School of Psychology at Bond University.

Experimental Hardware

All stimuli were presented on an ASUS PR031Pseries DUO Core laptop computer running at 7200 MHz connected to a 17-inch monitor. Participants wore a Logitech ClearChat Comfort USB Headset microphone which was connected to the laptop and captured their vocal responses.

Experimental Software

Visual Basic 6.0 software controlled the presentation of stimuli for tasks. The software also recorded RT latencies (ms) and errors.

Electric Stimulus

Participants who performed under the threat of electric shock (i.e., in the somatic situational stress condition) wore an electrode on their forearm which was attached to a Grass SD9 stimulator (0-90V) that delivered the electric stimulus (200 ms) through a 35mm diameter concentric stainless steel electrode. Electrode-skin contact was made through a sponge soaked in saline.

Cognitive Tasks

Four tasks were employed in the present series of experimental studies: word span task (forward and backward), reading span task, Go-No-Go task, and the WCST. Each task was employed to capture the functions of the working memory system as specified by ACT. The word span task was used as an index of phonological functioning, the reading span task as an index of updating, the Go-No-Go task as an index of inhibition, and the WCST as an index of shifting. A Latin square design was used to present tasks in a counter-balanced order. Four task sequences were administered, based on the participant's order of arrival at the laboratory. Each sequence contained a different first, second, third and fourth task. Sequence A consisted of word span, then reading span, then WCST, and finally Go-No-Go; Sequence B consisted of reading span, then WCST, then Go-No-Go, and finally word span; Sequence C consisted of WCST, then Go-No-Go, then word span, and finally reading span; Sequence D consisted of Go-No-Go, then word span, then reading span, and finally WCST.

Word Span Task (Forward and Backward)

The word span task is a recognised measure of phonological processing (e.g., Darke, 1988, Sorg & Whitney, 1992). Using forward and backward word span paradigms, participants were presented with words in lowercase, 40 point Arial font. Nine single-syllable words served as the stimuli (*doors, hook, step, desk, chair, wall, bath, keys, rack*). The words were matched with the digits 1 – 9 and substituted for the digits forward- and digits backward- task from the Wechsler Adult Intelligence Scale – 3rd ed. (Wechsler, 1997) to provide the sequences for the forward and backward word span trials, respectively (see Appendix B). A *ready* cue was presented for 1 sec to signal the start of each trial, after which the screen was blanked for 2 sec. The stimulus words were then presented individually for 1 sec each, at 1 sec intervals, until a *recall* cue signalled the end of the trial at which time participants were instructed to recall the words as quickly and accurately as possible, in the order they were presented (forward-word span), or in the reverse order (backward- word span). Following two practice trials (each of two and three words, respectively), the first scored trial consisted of a sequence of two words. Trials continued with sequences increasing in length by one word each time, and participants were given two attempts at each sequence length. Testing was terminated if both trials of the same length were recalled incorrectly. Accuracy and RT data were collected by the computer using a headset microphone. RTs on each trial were recorded upon the participant's last vocal response, such that if a response required a three-word answer the RT was measured from the onset of the *recall* cue to the final vocal response of the third word. The forward and backward word span tasks were administered separately with total scores for each task based on the number of sequences recalled correctly (i.e., number of correct trials). The maximum possible scores for the forward and backward word span tasks were 16 and 14, respectively.

Reading Span Task

Twenty-five unrelated sentences were adopted from Daneman and Carpenter's (1980) reading span task, and a further five sentences from Masson and Miller's (1983) study were used as practice trials. Appendix C contains a list of the sentences used here. Each sentence contained 11 to 17 words (M = 13.8; Mdn = 14), each ended in a different word, and they were arranged in 2, 3, 4, 5 and 6 sentence set lengths. The sentences were presented one at a time, on the computer screen, typeset in 20 point Arial font. Participants were required to read the sentence aloud as soon as it appeared on the screen. At completion of each sentence, the next sentence appeared and so on. A *recall* cue signalled the end of the trial at which time they were instructed to recall the last-word of each sentence in the set, as quickly and accurately as possible (in the order they were presented).

Immediately following the last-word recall task, an associated true/false question was presented as an assessment of sentence comprehension (or processing for understanding). The true/false question related to one sentence from the set and was presented in a fixed order to all participants. Participants were asked to put equal emphasis on accurately recalling the last-words and answering true/false questions correctly. The sentences and questions were presented using Visual Basic software; however, to allow for individual differences in reading time, presentation of the sentences was operated manually by the experimenter. Following two practice trials (each of two and three sentences, respectively), the first experimental trial consisted of a sequence of two sentences. Trials continued with sets increasing in length by one sentence each time, and participants were given five attempts at each sentence set-length, except on the six-sentence set-length which was limited to three attempts. Testing was terminated if three out of five trials of the same sentence set-length were recalled incorrectly. Accuracy and RT data were collected by the computer using a headset microphone. RTs of each last-word sequence were recorded upon the participant's last vocal response; e.g., if a response required a four-word answer the RT was measured from the onset of the *recall* cue to the final vocal response to the fourth word. Before beginning the task, participants were reminded to answer as quickly and accurately as possible. Scoring was conducted using a weighted scoring technique, such that correctly recalled sequences of last-words on greater sentence set-lengths were awarded higher scores (see Conway et al., 2005 for a review). Specifically, correct last-word sequence scores were as follows: two-sentences set = 4, three-sentence set = 9, four-sentence set = 16, five-sentence set = 25, and six-sentence set = 36. Scores were summed and total weighted reading span scores ranged from 4 to 378.

Go-No-Go Task

The Go-No-Go task is well-established as a measure of inhibitory control (see Miyake et al., 2000). Participants were shown a series of words on a computer screen for 300ms each, with a 900ms inter-stimulus interval. They were instructed to respond to any word that did not contain the letter ‘a’ (i.e., initiate a response to target-absent trials), and these were classified as Go trials. If the word did contain the letter ‘a’, participants were told to withhold their response (i.e., inhibit a response to target-present trials), and these were classified as NoGo trials. A response involved pushing the space bar of the keyboard with their dominant hand. Each block contained an equal number of target-absent and target-present stimuli, and the number of correct and incorrect Go and NoGo responses and respective RTs were collected by the computer. Following two practice blocks, there were 16 test blocks. Each block contained 16 neutral words (*suite, blanket, wall, doors, desk, fence, taps, beds, hook, bath, iron, cups, eaves, sugar, stair, chair*). Words were presented in lowercase, 40 point Arial font, and were presented in a fixed randomised order (see Appendix D). Blocks were separated by a 20s rest break. Blocks commenced with a fixation cue, such that the word *ready* was presented for the final 4s of the rest break to warn the participant that the next block was about to commence. Participants were asked to place their hand on the space bar when they saw the *ready* signal. Prior to commencing the task, they were reminded to place equal emphasis on being accurate and responding as fast as possible. Possible scores for correct Go and incorrect NoGo responses ranged from 0 to 128, for each.

Wisconsin Card Sorting Task (WCST)

The WCST is a widely used neuropsychological test that has shown to assess the shifting function of the central executive (see Miyake et al., 2000). On each trial, a single stimulus card was presented on the monitor and participants were instructed to match the card to one of four fixed target cards (labelled A, B, C, & D) by verbalising the letter corresponding to the target. Card matches could be made using three categories: form, colour or number. Participants were required to demonstrate cognitive flexibility by shifting to the new category. To allow for item valence to be investigated in Experimental Series 2, and for ease of comparison with the current study, the original test (see Heaton et al., 1993) was modified to incorporate words rather than shapes as stimuli (further details are provided in Chapter 5). As such, for all cards the triangle was replaced with the word *carpet*, the star with the word *garage*, the cross with the word *sheets*, and the circle with the word *coffee*. Form, colour, number distributions followed the original test, and category changes occurred after 10 consecutive correct matches in a predetermined fixed order.

The target and stimulus cards were displayed in 65 mm x 65 mm dimensions, and the words were presented in dimensions approximately 1 cm high (exemplar cards are provided in Appendix E). Given that some stimulus cards matched the targets on more than one category it was not possible for participants to predict category changes on every 10th trial. Participants were instructed to respond as quickly and accurately as possible. Responses were recorded using a headset microphone and RTs on each trial were recorded by the computer upon the participant’s first vocal response. The experimenter manually recorded the match responses and provided verbal feedback (i.e., right or wrong) following each trial. The task was completed after all 128 stimulus cards were presented. The WCST score of interest was the relationship between the percentage of perseverative errors (i.e., errors made when the participant continued to unsuccessfully use a matching category after being told their selections were incorrect) and the mean RTs on these trials. Further scoring details are provided in the method section of Study 1.4.

Psychometric Measures

This section describes the measures, their psychometric properties and scoring procedures. For each measure, a section is dedicated to describing reliability and validity indices and selected examples are provided.

Depression Anxiety Stress Scale (DASS-21; Lovibond & Lovibond, 1995)

The DASS is a 21 item self-report measure designed to assess depression, anxiety and stress using a 7-item subscale for each. Only scores from the Depression subscale were included in the analyses. The Anxiety and Stress subscales of the DASS were not appropriate indices of trait anxiety or situational stress because respondents report on these symptoms over the past week.

Scoring. Participants indicate the degree to which statements such as *I felt downhearted and blue,* and *I felt I wasn't worth much as a person*, applied to them in the previous week. Responses are made using a 4-point Likert scale where 0 = *Did not apply to me at all*, 1 = *Applied to me to some degree, or some of the time*, 2 = *Applied to me to a considerable degree, or a good part of the time* and 3 = *Applied to me very much, or most of the time.* There are no reverse scored items. Scores are summed and multiplied by two, creating a score range of 0-42 with higher scores reflecting higher symptoms of depression. Only participants who scored in the minimal to mild depression ranges (i.e., 0-27) were invited to participate in the study. The DASS is included as Appendix F.

Reliability and validity. Prior to employing the DASS-21 Depression scale as an index of depression, its reliability and validity was established. A review of the literature confirmed the instrument has good internal reliability. Reliability analyses conducted by the authors and others (e.g., Brown, Chorpita, Korotitsch, & Barlow, 1997; Crawford & Henry, 2003; Henry & Crawford, 2005) have been favourable, $\alpha = .81$, $\alpha = .96$, $\alpha = .93$, and $\alpha = .82$, respectively. In a student sample, the authors reported that scores on the Depression subscale were significantly and positively correlated with scores on the Beck Depression Inventory ($r = .74$; Beck, Ward, & Mendelsohn, 1961), and in a non-clinical sample Henry and Crawford (2005) reported that scores on the Depression scale were significantly positively correlated with the Negative-Affect dimension ($r = .59$), and negatively correlated with the Positive-Affect dimension ($r = -.48$) of the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). These data suggest the DASS-Depression scale was appropriate for assessing depression in student samples.

State and Trait Inventory for Cognitive and Somatic Anxiety (STICSA; Ree et al., 2000)

The STICSA is a self-report measure of somatic (11 items) and cognitive (10 items) anxiety, designed to capture the state and trait dimensions of each. Items 1-21 provide an index of how participants feel *right now, at this very moment* (State scale), whereas items 22-43 index how participants feel *in general* (Trait scale). Scores from the Cognitive and Somatic subscales of State and Trait anxiety were calculated and analysed separately giving a measure of the four anxiety dimensions: State-Somatic, State-Cognitive, Trait-Somatic, and Trait-Cognitive.

Scoring. Individuals were required to respond to statements such as *My heart beats fast* and *My muscles are tense* (Somatic subscale) and *I think that others won't approve of me* and *I keep busy to avoid uncomfortable thoughts* (Cognitive subscale). For each item, subjects were asked to provide responses to statements ranging from 1 = *Not at all* to 4 = *Very much so* (State scale) and 1 = *Almost never* to 4 = *Almost always* (Trait scale). No items are reversed scored. Scores on each dimension are summed with higher scores reflecting higher levels of anxiety. Possible total scores ranged from 11-44 (State-Somatic), 10- 40 (State-Cognitive), 11-44 (Trait-Somatic), and 10-40 (Trait-Cognitive). The STICSA is included as Appendix G.

Reliability and validity. The cognitive scales have demonstrated good internal consistency estimates, STICSA Trait-Cognitive ($\alpha = .87$) and STICSA State-Cognitive ($\alpha = .88$) (Gros, Antony, Simms, & McCabe, 2007). Analyses of convergent and discriminant validity suggest the STICSA provides a more specific assessment of anxiety than the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983); see Gros et al. (2007) for a review. These data suggest the STICSA was appropriate for assessing the Somatic and Cognitive dimensions of State and Trait anxiety, as required here.

Rating Scale of Mental Effort (RSME; Zijlstra, 1993)

The RSME is a uni-dimensional, visual analogue scale, regarded as a self-reported estimation of mental costs associated with task execution, that is, the amount of mental effort required to execute a task.

Scoring. Participants were asked to mark a point on a 150 mm vertical axis scale that reflected the amount of mental effort in task performance. Nine anchor points are marked along the scale from 2 mm to 112 mm to indicate ratings from *not at all effortful* to *tremendously effortful,* with effort operationalised as the distance in mm to this mark. The RSME is included as Appendix H.

Reliability and validity. Scores on the RSME have been shown to be sensitive to changes in task load, psychophysiological state of the person and time-on-task (e.g., Veltman & Gaillard, 1996; Zijlstra, 1993). The RSME has demonstrated adequate psychometric properties. For example, reliability is good in workplace (r = .78) and laboratory (r = .88) settings (see Zijlstra), and the RSME undergone extensive validation in a range of settings (see also Wilson, 2008 for a review). Taken together, this work suggests that RSME was an expedient and appropriate index of mental effort for the current program of research.

Stress Rating Questionnaire (SRQ)

The SRQ is a brief, five-item, self-report measure developed to evaluate changes in situational stress. This questionnaire was used as the experimental approach demanded multiple assessments of situational stress throughout each testing session and the SRQ was quick to administer and complete.

Scoring. Participants rated their current stress levels on five bipolar dimensions: *Calm to Nervous, Fearless to Fearful, Relaxed to Anxious, Unconcerned to Worried,* and *Comfortable to Tense* on a seven-point scale. For example, 1 = *Very calm,* 2 = *Quite calm,* 3 = *Slightly calm,* 4 = *Neither Calm/nor nervous,* 5 = *Slightly nervous,* 6 = *Quite nervous,* 7 = *Very nervous*. Composite scores are calculated by summing responses on each dimension to produce scores ranging between 5 and 35. Higher scores are representative of higher reported situational stress. The SRQ is included as Appendix I.

Reliability and validity. Given that the measure was developed for the purpose of this program of research, there were no data available on the reliability and validity of the SRQ. The SRQ, however, is an expanded version of the three-item Arousal Rating Questionnaire (ARQ; Nervousness, Fearfulness, and Anxiousness) used by Edwards et al. (2006). The ARQ has been shown to positively correlate with the State-Anxiety scale of the STAI (Spielberger et al., 1983) such that Nervousness $r = .47$, Fearfulness $r = .49$, and Anxiousness, $r = .40$, and to be sensitive to changes in state anxiety produced by situational stressors (see Edwards et al., 2006 for details).

Experimental Series 1

The series of experiments reported in the following chapter extend theoretical and empirical work on the inter-relationships between anxiety, situational stress, and effort on cognitive performance (i.e., phonological, updating, inhibitory and shifting functions). In each study, trait anxiety was operationalised using the somatic and cognitive trait anxiety scales from the STICSA (Ree et al., 2000) and situational stress was manipulated using a somatic stressor (threat of electric shock) and a cognitive stressor (ego threat instructions). For each task, the somatic and cognitive anxiety data were analysed and reported as separate experiments. Mental effort was measured using a visual analogue scale (RSME). The current work employed the forward and backward word span tasks as indices of simple and complex phonological performance (respectively; see Study 1.1), the reading span task as the measure of updating (see Study 1.2), the

Go-No-Go task as the measure of inhibition (see Study 1.3), and the WCST as the index of shifting performance (see Study 1.4). Performance effectiveness was operationalised as the quality of performance and processing efficiency was indexed by the ratio of accuracy to RT. Scores on the DASS-Depression subscale (Lovibond & Lovibond, 1995) were used as a control variable.

Procedure

Participants were tested individually on all tasks and measures in a sound-attenuated laboratory, and the procedure took approximately 120 minutes for each. After providing informed consent, they completed the STICSA, DASS, and the SRQ (i.e., SRQ at baseline). In accordance with a request from the university's ethics committee, individuals who scored above 28 (extremely severe) on the DASS Depression Scale were excluded from participation; 5 participants were released on the basis of this criterion. Participants were systematically assigned to either the low situational stress (shock safe/ego safe) or one of two high situational stress conditions (shock threat and ego threat) based on their order of arrival at the laboratory, such that every third participant was allocated to the safe condition. Following the stress manipulation, participants completed the SRQ a second time (i.e., SRQ at post-manipulation), and they were reminded to work as quickly and accurately as possible on the tasks. Based on their order of arrival at the laboratory, participants completed the four tasks in a counter-balanced order. After each task, participants were asked to complete the RSME, after which the stress induction procedure was readministered, followed by the SRQ (i.e., SRQ at post-manipulation). This procedure continued with each task until all tasks were completed. Upon completion of all of the four tasks participants completed the RSME, were thanked, debriefed and released.

CHAPTER 4 – EXPERIMENTAL SERIES 1

Study 1.1: Anxiety and Phonological Performance

Study 1.1 examined the relationship between trait anxiety, situational stress, effort and phonological performance using forward (i.e., simple task) and backward (i.e., complex task) word span. Study 1.1.1 tested whether somatic trait anxiety and a somatic stressor (i.e., shock threat) combined to predict phonological effectiveness and efficiency, and Study 1.1.2 investigated whether the relationship between cognitive trait anxiety and a cognitive stressor (i.e., ego threat) were related to phonological effectiveness and efficiency. The modelling also tested whether effort further moderated these relationships.

Hypotheses

After controlling for depression, the predictions were derived from ACT (Eysenck et al., 2007) and the existing literature with respect to performance effectiveness and processing efficiency. ACT suggests that anxious individuals allocate additional resources, such as effort, to improve their accuracy. As such it was predicted that there would be no relationship between trait anxiety and stress on performance effectiveness on either the simple (forward word span) or complex (backward word span) tasks. ACT suggests, however, that the additional effort required to preserve accuracy comes at the cost of lower efficiency. It was therefore expected that the processing efficiency data would reveal three-way (trait anxiety x situational stress x mental effort) interactions on both the simple and complex tasks such that higher trait anxiety would be associated with lower efficiency but that this relationship would buffered by mental effort. It was predicted that these relationships would emerge as a function of both somatic and cognitive anxiety.

Measurement of Phonological Performance

Phonological effectiveness. Performance effectiveness was operationalized as the number of correct trials for both the forward- and backward- word span tasks.

Phonological efficiency. Processing efficiency was operationalised in accordance with ACT (i.e., the relationship between accuracy and RT) as the relationship between the number of correct trials and the total RT for those trials (see also Edwards, Edwards, et al., 2015; Edwards, Moore, et al., 2015). Phonological efficiency was calculated using the following equation:

$$\textit{Phonological Efficiency} = \left[\frac{\textit{Number of Correct Trials}}{\textit{Total RT on Correct Trials}} \right]$$

Study 1.1.1 Somatic Anxiety and Phonological Performance

Participants

Ninety undergraduate psychology students participated. They were aged between 18 and 55 years (*M* = 24.68 years, *SD* = 8.51) and 64 were female. There was no significant difference in sex and age between the shock safe and shock threat groups, $t(88) < 1$.

Validity of SRQ as an Index of Situational Stress

To confirm the efficacy of the SRQ as a measure of situational stress in somatic anxiety in the sample, a bivariate correlation was conducted between composite SRQ scores at baseline and scores on the STICSA State Somatic scale. There was a significant positive relationship between the measures, $r(90) = .37$, $p < .001$, confirming the SRQ as an appropriate index of situational stress.

Manipulation Check

To confirm the threat of electric shock induced somatic situational stress in the sample, a 2 x 2 repeated measures ANOVA with Time (baseline vs. post-manipulation) and Group (shock threat vs. shock safe) as the factors was conducted using composite SRQ scores. There was no significant main effect of Group, $F(1, 88) = 1.02$, $MSE = 45.59$, $p = .315$, however the main effect of Time, $F(1, 88) = 89.31$, $MSE = 13.51$, $p < .001$, $\eta^2 = .50$, and the Time x Group interaction, $F(1, 88) = 7.83$, $p = .006$, $\eta^2 = .08$, reached significance. Follow up *t*-tests revealed that at baseline, there was no difference in composite SRQ scores reported by individuals in the shock threat ($M = 11.89$, $SD = 5.06$) and shock safe ($M = 12.22$, $SD = 3.98$) conditions, $t\ (1, 88) < 1$, however following the stress manipulation those in the shock threat group ($M = 18.60$, $SD = 6.43$) showed significantly higher SRQ scores than their shock safe counterparts ($M = 15.86$, $SD = 5.67$), $t(1, 88) = 2.14$, $p = .035$. These results suggest that the threat of electric shock was an effective means of manipulating situational stress.

Results

Data Diagnostics and Assumption Checking

Prior to the main analyses, the predictor and criterion variables were screened for outliers and normality. RTs < 200 ms were considered anticipatory and removed, and RTs ± 3*SD* from each participant's mean score were removed (< 1% of trials). Univariate outliers were considered significant with *z*-scores > 3.50. Using this criterion, 1 outlier was detected for processing efficiency on the backward span task (*z*-score = 4.50) and after computation of Mahalanobis Distance and Cook's D the same case was identified as an extreme multivariate outlier with $p < .001$; consequently the case was removed. Assumptions of normality, linearity and homoscedasticity were satisfactory, and tests for skewness and kurtosis were acceptable with consideration to the sample (non-clinical, undergraduate students) and the nature of the task employed. The final data set reported for forward and backward word span contained N = 90 and N = 89 participants, respectively.

Descriptive Statistics

Table 1 shows the relevant means and standard deviations, inter-correlations among the predictors, and zero-order correlations between the predictors and criterion variables for the forward and backward word span tasks. As shown, there was a significant positive relationship between somatic trait anxiety and depression, such that higher somatic trait anxiety was associated with higher depression. There was a significant positive correlation between somatic trait anxiety and mental effort on both the forward and backward tasks, which in accord with ACT indicated that those who reported higher somatic trait anxiety also reported investing greater effort on the word span tasks. Furthermore, there were significant positive correlations between mental effort and performance effectiveness (but not processing efficiency) on both the forward and backward tasks, such that greater invested mental effort was related to greater effectiveness.

Main Analyses

To determine whether somatic trait anxiety, situational stress, mental effort and their interactions predicted performance effectiveness and processing efficiency on the forward and backward word span tasks, separate moderated multiple regression analyses were conducted for each task. Predictor variables were mean centred prior to calculating the interaction terms. The covariate (depression) was entered at Step 1, the component main effects (somatic trait anxiety, situational stress and mental effort) were entered at Step 2, the two-way interaction terms (somatic trait anxiety x situational stress, somatic trait anxiety x mental effort, and situational stress x mental effort) were entered at Step 3, and the three-way interaction term for all three predictors (somatic trait anxiety x situational stress x mental effort) was entered at Step 4.

Table 1.

Means, Standard Deviations, Zero-order and Inter-correlations of Depression, Somatic Trait Anxiety, Mental Effort, Phonological Effectiveness and Phonological Efficiency for Forward Word Span (FWS) and Backward Word Span (BWS) Tasks.

	M	*SD*	Depression	Somatic Trait Anxiety	Mental Effort
Depression	6.14	6.13			
Somatic Trait Anxiety	15.18	3.81	.30**		
Mental Effort on FWS	80.32	28.85	.31	.19*	
FWS Effectiveness	6.11	1.43	-.01	.13	.18*
FWS Efficiency	.65	.22	-.05	-.06	-.06
Mental Effort on BWS	85.67	26.84	-.04	.19*	
BWS Effectiveness	4.11	1.50	-.00	.03	.20*
BWS Efficiency	.73	.40	.07	.20*	-.10

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

Phonological Effectiveness in Somatic Anxiety

Forward word span effectiveness. Table 2 shows the unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step of the model. At Step 1, depression accounted for < 1% of the variance in phonological effectiveness, $R = .01$, $F < 1$. At Step 2, with the inclusion of the main effects, the model accounted for 8% of the variance in effectiveness, however the increase in R^2 was not significant, $R = .28$, $\Delta R^2 = .08$, ΔF (3, 85) = 2.39, $p = .075$, and the model was not significant, F (4, 89) = 1.79, $p = .138$. At Step 3, with the addition of the two-way interaction terms, the model accounted for 8% of the variance in the criterion, $R = .29$, however $\Delta R^2 = .00$ was not significant, $\Delta F < 1$, and the model was not significant, F (7, 89) = 1.05, $p = .404$. With the inclusion of the three-way interaction term at Step 4, the full model accounted for 10% of the variance in forward span effectiveness, yet there was no significant increase in R^2, $R = .31$, $\Delta R^2 = .02$, ΔF (1, 81) = 1.44, $p = .234$, and the full model was not significant, F (8, 89) = 1.10, $p = .371$. These results indicate that forward span effectiveness was independent of somatic trait anxiety, situational stress and mental effort.

Backward word span effectiveness. The unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step are shown in Table 3. Depression accounted for < 1% of the variance in effectiveness at Step 1, $R < .01$, $F < 1$. At Step 2, the model accounted for 3% of the variance, however the addition of the main effects failed to increase R^2, $R = .18$, $\Delta R^2 = .03$, $\Delta F < 1$, and the model was not significant, $F < 1$. At Step 3, with the inclusion of the two-way interaction terms the model accounted for 12% of the variance in effectiveness, and the increase in R^2 tended towards significance, $R = .34$, $\Delta R^2 = .09$, $\Delta F = 2.59$, $p = .058$, however the model failed to reach significance, F (7, 88) = 1.55, $p = .162$. With the three-way interaction term included at Step 4, the full model accounted for 12% of variance in backward span effectiveness, however the increment in explainable variance, $R = .34$, $\Delta R^2 = .00$, $\Delta F < 1$, and the

Table 2.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Phonological Effectiveness in Forward Word Span

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	6.13	.22		5.70	6.56
	Depression	-.00	.03	-.01	-.05	.05
Step 2	(Constant)	6.12	.22		5.69	6.56
	Depression	-.00	.03	-.01	-.05	.05
	Somatic Trait Anxiety	.05	.04	.13	-.04	.13
	Situational Stress	-.27	.16	-.19	-.57	.04
	Mental Effort	.01	.01	.18	-.00	.02
Step 3	(Constant)	6.10	.23		5.64	6.56
	Depression	-.00	.03	-.00	-.06	.05
	Somatic Trait Anxiety	.04	.05	.11	-.05	.13
	Situational Stress	-.27	.16	-.19	-.58	.05
	Mental Effort	.01	.01	.18	-.00	.02
	Somatic Trait Anxiety X Situational Stress	.02	.04	.05	-.07	.11
	Situational Stress X Mental Effort	.00	.00	.03	-.00	.00
	Somatic Trait Anxiety X Mental Effort	-.00	.01	-.03	-.02	.01
Step 4	(Constant)	6.11	.23		5.66	6.57
	Depression	-.01	.03	-.02	-.06	.05
	Somatic Trait Anxiety	.06	.05	.15	-.04	.15
	Situational Stress	-.23	.16	-.16	-.55	.08
	Mental Effort	.02	.01	.26	.00	.03
	Somatic Trait Anxiety X Situational Stress	.02	.04	.06	-.06	.11
	Situational Stress X Mental Effort	.00	.00	.14	-.00	.01
	Somatic Trait Anxiety X Mental Effort	-.01	.01	-.09	-.02	.01
	Somatic Trait Anxiety X Situational Stress X Mental Effort	-.00	.00	-.19	-.01	.00

$p < .05$*

Table 3.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Phonological Effectiveness in Backward Word Span

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	4.11	.23		3.67	4.56
	Depression	.00	.03	-.00	-.05	.05
Step 2	(Constant)	4.10	.23		3.64	4.57
	Depression	.00	.03	.01	-.06	.05
	Somatic Trait Anxiety	-.00	.05	-.01	-.09	.09
	Situational Stress	.02	.17	.01	-.31	.35
	Mental Effort	.01	.01	.20	-.00	.02
Step 3	(Constant)	3.94	.24		3.47	4.41
	Depression	.02	.03	.07	-.04	.07
	Somatic Trait Anxiety	-.04	.05	-.10	-.13	.07
	Situational Stress	-.01	.16	-.01	-.33	.31
	Mental Effort	.01	.01	.17	-.00	.02
	Somatic Trait Anxiety X Situational Stress	.04	.04	.10	-.05	.12
	Situational Stress X Mental Effort	.01	.01	.09	-.01	.02
	Somatic Trait Anxiety X Mental Effort	.00	.00	.22	.00	.01
Step 4	(Constant)	3.94	.24		3.47	4.41
	Depression	.02	.03	.07	-.04	.07
	Somatic Trait Anxiety	-.04	.05	-.10	-.13	.05
	Situational Stress	-.02	.17	-.01	-.35	.32
	Mental Effort	.01	.01	.16	-.01	.02
	Somatic Trait Anxiety X Situational Stress	.04	.04	.09	-.05	.13
	Situational Stress X Mental Effort	.00	.00	.21	-.00	.00
	Somatic Trait Anxiety X Mental Effort	.00	.00	.21	-.00	.01
	Somatic Trait Anxiety X Situational Stress X Mental Effort	.00	.00	.02	-.00	.00

$p < .05$*

full model, F (8, 88) = 1.34, p = .235, were not significant. These results suggest that backward span effectiveness did not vary as a function of somatic trait anxiety, situational stress and mental effort.

Phonological Efficiency in Somatic Anxiety

Forward word span efficiency. Table 4 shows the unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step of the model. At Step 1, depression accounted for < 1% of the variance in processing efficiency, R = .05, F < 1. With the addition of the component main effects at Step 2, the model accounted for 1% of variance in efficiency, however the increase in R^2 was not significant, R = .11, ΔR^2 = .01, ΔF < 1, and the model, F < 1, was not significant. At Step 3, with the inclusion of the two-way interaction terms, the model accounted for < 4% of the variance in the criterion, however, R = .19, and ΔR^2 = .02 were not significant, ΔF < 1, and the model was not significant, F < 1. At Step 4, the addition of the three-way interaction term resulted in the model accounting for 4% of the variance in forward span efficiency, however, R = .20, ΔR^2 < .01 was not significant, ΔF < 1, and the model, F < 1, was not significant. These data suggest that processing efficiency on forward word span did not vary as a function of somatic trait anxiety, situational stress and mental effort.

Backward word span efficiency. Table 5 shows the unstandardised coefficients, beta weights and 95% confidence intervals for all variables in the model. At Step 1, depression accounted for < 1% of the variance in the criterion, R = .02, F < 1. At Step 2, with inclusion of the main effects, the model accounted for 14% of variance in efficiency, and the increase in R^2 was significant, R = .37, ΔR^2 = .14, ΔF (3, 84) = 4.47, p = .006, and the model reached significance, F (4,

Table 4.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Phonological Efficiency in Forward Word Span

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	.66	.03		.59	.73
	Depression	-.00	.00	-.05	-.01	.01
Step 2	(Constant)	.65	.04		.58	.72
	Depression	.00	.00	-.01	-.01	.01
	Somatic Trait Anxiety	-.00	.03	-.08	-.07	.03
	Situational Stress	-.02	.03	-.08	-.07	.03
	Mental Effort	.00	.00	-.04	-.00	.00
Step 3	(Constant)	.65	.04		.58	.72
	Depression	.00	.00	.01	-.01	.01
	Somatic Trait Anxiety	-.00	.01	-.06	-.02	.01
	Situational Stress	-.02	.03	-.09	-.07	.03
	Mental Effort	.00	.00	-.02	-.00	.00
	Somatic Trait Anxiety X Situational Stress	-.01	.00	-.12	-.02	.01
	Situational Stress X Mental Effort	-.00	.00	-.10	-.00	.00
	Somatic Trait Anxiety X Mental Effort	.00	.00	.14	.00	.00
Step 4	(Constant)	.65	.04		.58	.72
	Depression	.00	.00	-.00	-.01	.10
	Somatic Trait Anxiety	-.00	.01	-.04	-.02	.01
	Situational Stress	-.02	.03	-.08	-.07	.03
	Mental Effort	.00	.00	.02	-.00	.00
	Somatic Trait Anxiety X Situational Stress	-.01	.01	-.11	-.02	.01
	Situational Stress X Mental Effort	-.00	.00	-.12	-.00	.00
	Somatic Trait Anxiety X Mental Effort	.00	.00	.19	.00	.00
	Somatic Trait Anxiety X Situational Stress X Mental Effort	.00	.00	-.10	-.00	.00

$p < .05$*

Table 5.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Phonological Efficiency in Backward Word Span

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	70	.06		.58	.82
	Depression	.01	.01	.07	-.01	.02
Step 2	(Constant)	.71	.06		.59	.84
	Depression	.00	.01	.04	-.01	.02
	Somatic Trait Anxiety	.03	.01	.25*	.00	.05
	Situational Stress	-.07	.04	-.17	-.16	.02
	Mental Effort	-.00	.00	-.16	-.01	.00
Step 3	(Constant)	.75	.06		.63	.87
	Depression	-.00	.01	-.03	-.02	.01
	Somatic Trait Anxiety	.03	.01	.32	.01	.06
	Situational Stress	-.06	.04	-.16	-.15	.02
	Mental Effort	-.00	.00	-.09	-.00	.00
	Somatic Trait Anxiety X Situational Stress	-.02	.01	-.21*	-.04	.00
	Situational Stress X Mental Effort	-.00	.00	-.23	-.01	.00
	Somatic Trait Anxiety X Mental Effort	.00	.00	-.06	-.00	.00
Step 4	(Constant)	.75	.06		.63	.87
	Depression	-.00	.01	-.03	-.02	.01
	Somatic Trait Anxiety	.03	.01	.32	.01	.06
	Situational Stress	-.07	.04	-.16	-.15	.02
	Mental Effort	-.00	.00	-.10	-.01	.00
	Somatic Trait Anxiety X Situational Stress	-.02	.01	-.21	-.05	.00
	Situational Stress X Mental Effort	-.00	.00	-.22	-.01	.00
	Somatic Trait Anxiety X Mental Effort	.00	.00	-.08	-.00	.00
	Somatic Trait Anxiety X Situational Stress X Mental Effort	.00	.00	.24	-.00	-.05

$p < .05$*

88) = 3.36, p = .013. The results revealed a significant main effect of somatic trait anxiety, however this effect was further qualified by a two-way situational stress x somatic trait anxiety interaction at Step 3. The inclusion of the two-way interaction terms brought about a significant change in R^2 and the model accounted for 28% of the variance in backward span efficiency, R = .53, ΔR^2 = .15, furthermore the increment was significant, ΔF (3, 81) = 5.52, p = .002, and the model also reached significance, F (7, 88) = 4.60, p < .001. The only two-way interaction to reach significance was somatic trait anxiety x situational stress (unique variance 9%), t = 3.26, p = .002. The pattern of this interaction is described below. At Step 4, the inclusion of the three-way interaction term did not increase explainable variance, R = .53, ΔR^2 = .00, ΔF < 1. The full model accounted for 29% of the variance in backward efficiency, which was significant, F (8, 88) = 3.99, p = .001.

Interactions in Multiple Linear Regression with SPSS and Excel (IRSE; Meier, 2008) software was used to decompose the pattern of the two-way interaction between somatic trait anxiety and situational stress. Specifically, a test of simple slopes was conducted at high and low values of somatic trait anxiety (calculated at ± 1 *SD* from the mean) at each level of situational stress (shock threat vs. shock safe). The pattern of the interaction is shown in Figure 2. As can be seen in the figure, higher somatic trait anxiety was not related to backward efficiency when under the threat of shock , β = .00, t < 1, however in the shock safe condition, higher somatic trait anxiety was a positive predictor of backward efficiency, β = .10, t = 3.4, p = .001, such that those who reported higher somatic trait anxiety demonstrated higher backward span efficiency.

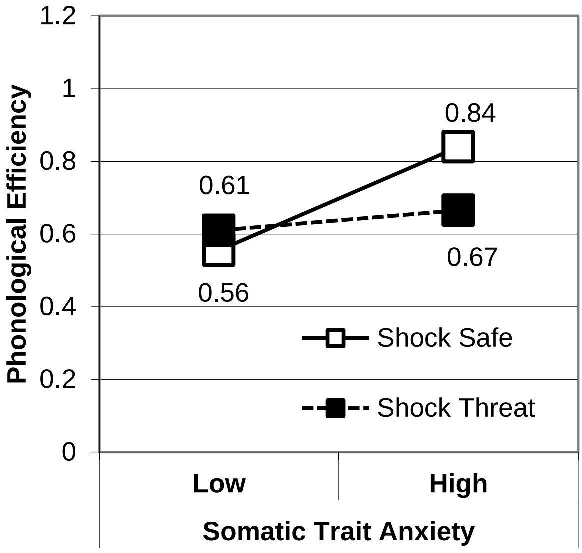

Figure 2. Relationship between somatic trait anxiety, somatic situational stress, and phonological efficiency using backward word span as a complex task.

Study 1.1.2 Cognitive Anxiety and Phonological Performance

Participants

Participants comprised 90 undergraduate university students (18 male, 72 female; mean age = 24.06 years, *SD* = 8.31). Participants were randomly assigned to either the ego safe or ego threat condition based on their arrival at the laboratory. Sex was proportionately represented within the ego safe and ego threat groups and the groups did not differ with respect to age, $t(88) = 1.30$, $p = .122$.

Validity of SRQ as an Index of Situational Stress

A bivariate correlation analysis was conducted between composite SRQ scores at baseline and scores on the STICSA State Cognitive scale to qualify the SRQ as an appropriate measure of cognitive situational stress. Results revealed a significant positive relationship, $r(90) = .35$, $p < .001$, thus the SRQ was deemed a satisfactory measure of situational stress in the sample.

Manipulation check

To confirm the effectiveness of the ego threat instructions as means of elevating situational stress, a 2 x 2 repeated measures ANOVA using SRQ composite scores was conducted with Time (baseline vs. post-manipulation) and Group (ego safe vs. ego threat) as the factors. There was no main effect of Group, $F(1, 89) = 1.21$, $p = .275$, however the main effect of Time, $F(1, 89) = 27.59$, $MSE = 18.00$, $p < .001$, $\eta^2 = .24$, and the Time x Group interaction, $F(1, 89) = 4.59$, $p = .035$, $\eta^2 = .05$, reached significance. Follow up *t*-tests revealed there was no difference in composite SRQ scores reported at baseline between the ego safe ($M = 14.18$, $SD = 5.67$) and ego threat groups ($M = 14.04$, $SD = 5.99$, $t < 1$). Following the stress induction manipulation, however, those in the ego threat condition ($M = 18.72$, $SD = 6.63$) showed significantly higher SRQ scores than those in the ego safe group ($M = 16.14$, $SD = 5.95$), $t(1, 88) = 1.98$, $p = .050$. The data therefore confirmed the efficacy of the ego threat instructions as an effective situational stress induction procedure.

Results

Data Diagnostics and Assumption Checking

Response times < 200 ms were removed and RTs ± 3*SD* from each participant's mean score were removed (< 1% of trials). Prior to the main analyses, the predictor and criterion variables were screened for outliers and normality. As in Study 1.1.1, univariate outliers were considered significant with *z*-scores > 3.50. Using this criterion, two outliers were identified for processing efficiency on the backward span task. Analyses were performed with the univariate outliers included and removed and there was no change in the pattern of results, so the cases were retained. Mahalanobis Distance and Cook's D were computed to detect the presence of multivariate outliers, however none were detected with $p < .001$. Assumptions of normality, linearity and homoscedasticity were satisfactory and tests for skewness and kurtosis were acceptable with consideration to the sample (non-clinical, undergraduate students) and the task. The full data set is reported for both forward and backward span ($N = 90$ for both data sets).

Descriptive Statistics

Means, standard deviations, and inter-correlations of the predictors and zero-order correlations between the predictors and criterion variables for the forward and backward word span data are shown in Table 6. As shown, there was a significant positive relationship between cognitive trait anxiety and depression, such that those who reported higher cognitive trait anxiety also reported higher depression. There was a significant positive correlation between cognitive trait anxiety and mental effort on both the forward and backward tasks, which supports ACT’s assumption that anxious individuals invest more effort. Furthermore, there were significant positive correlations between mental effort and both performance effectiveness and processing efficiency on both the forward and backward tasks, with individuals who invested greater mental effort performing with greater effectiveness and efficiency on both the simple and complex tasks.

Main Analyses

Separate moderated multiple regression analyses were conducted to determine whether cognitive trait anxiety, situational stress, mental effort and their interactions predicted performance effectiveness and processing efficiency on the forward and backward word span tasks. For each test, the covariate (depression) was entered at Step 1, the component main effects (cognitive trait anxiety, situational stress and mental effort) were entered at Step 2, the two-way interaction terms (cognitive trait anxiety x situational stress, cognitive trait anxiety x mental effort, and situational stress x mental effort) were entered at Step 3, and the interaction term for all three predictors (cognitive trait anxiety x situational stress x mental effort) was entered at Step 4. Predictor variables were mean centred prior to calculating the interaction terms.

Table 6.

Means, Standard Deviations, Zero-order and Inter-correlations of Depression, Cognitive Trait Anxiety, Mental Effort, Phonological Effectiveness and Phonological Efficiency for Forward Word Span (FWS) and Backward Word Span (BWS) Tasks.

	M	*SD*	Depression	Cognitive Trait Anxiety	Mental Effort
Depression	6.81	6.43			
Cognitive Trait Anxiety	18.40	5.19	.61***		
Mental Effort on FWS	81.27	30.12	.13	.19*	
FWS Effectiveness	5.98	1.46	-.10	.15	.22*
FWS Efficiency	.64	.20	.10	.00	-.18*
Mental Effort on BWS	66.11	30.12	.06	.25**	
BWS Effectiveness	3.96	1.42	-.03	.05	.29**
BWS Efficiency	.69	.42	.12	-.10	-.19*

NOTE: $p < .001$***; $p < .01$**; $p < .05$*

Phonological Effectiveness in Cognitive Anxiety

Forward word span effectiveness. The unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step are shown in Table 7. At Step 1, depression accounted for < 1% of the variance in performance effectiveness, $R = .10$, $F < 1$. At Step 2, the addition of the main effects brought about a significant increase in R^2, R = .35, ΔR^2 = .11, ΔF (3, 85) = 3.58, p = .017, and the model accounted for 12% of the variance in effectiveness, which was significant, F (4, 89) = 2.91, p = .026. In terms of unique contribution, depression (unique variance = 5%) significantly and negatively predicted effectiveness, such that higher depression was associated with lower effectiveness, t = 2.62, p = .025. Cognitive trait anxiety (unique variance = 5%) was a significant and positive predictor of effectiveness, such that higher anxiety was associated with higher effectiveness, t = 2.27, p = .026, and there was a marginal trend for effort (unique variance = 4%) to be positively related to the criterion, such that higher effort tended to be associated with higher effectiveness, t = 1.97, p = .052. The main effect of situational stress was not significant, t < 1. With the inclusion of the two-way interaction terms at Step 3, the model accounted for 13% of the variance in forward effectiveness, R = .36, however the increment was not significant, ΔR^2 = .01, ΔF (3, 82) < 1, and the model was not significant, F (7, 89) = 1.71, p = .117. At Step 4, with the inclusion of the three-way interaction term, the full model accounted for 13% of the variance in the criterion, but the unique contribution of the three-way interaction term was not significant, R = .37, ΔR^2 = .01, ΔF < 1, and the full model did not reach significance, F (8, 89) = 1.57, p = .149.

Backward word span effectiveness. Table 8 shows the unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step. At Step 1, depression accounted for < 1% of the variance in performance effectiveness, R = .03, F < 1. At Step 2, the addition of the main effects produced a significant increase in R^2, R = .32, ΔR^2 = .10, ΔF (3, 85) = 3.14, p = .029, and the model accounted for 10% of the variance which was significant, F (4, 89) =2.37, p = .046. Mental effort (unique variance = 4%) significantly and positively

Table 7.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Phonological Effectiveness in Forward Word Span

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	6.13	.23		5.68	6.57
	Depression	-.02	.02	-.10	-.07	.03
Step 2	(Constant)	6.44	.25		5.94	6.93
	Depression	-.07	.03	-.30*	-.13	-.01
	Cognitive Trait Anxiety	.08	.04	.30*	.01	.16
	Situational Stress	-.06	.15	-.04	-.36	.24
	Mental Effort	.01	.01	.20	.00	.02
Step 3	(Constant)	6.46	.26		5.94	6.98
	Depression	-.07	.03	-.30	-.13	-.01
	Cognitive Trait Anxiety	.09	.04	.30	.01	.16
	Situational Stress	-.07	.15	-.05	-.38	.23
	Mental Effort	.01	.01	.21	.00	.02
	Cognitive Trait Anxiety X Situational Stress	.02	.03	.07	-.04	.08
	Situational Stress X Mental Effort	-.00	.01	-.02	-.01	.01
	Cognitive Trait Anxiety X Mental Effort	-.00	.00	-.06	-.00	.00
Step 4	(Constant)	6.44	.26		5.92	6.97
	Depression	-.07	.03	-.31	-.13	-.01
	Cognitive Trait Anxiety	.09	.04	.31	.01	.17
	Situational Stress	-.05	.16	-.03	-.36	.27
	Mental Effort	.01	.01	.23	.00	.02
	Cognitive Trait Anxiety X Situational Stress	.03	.03	.09	-.04	.09
	Situational Stress X Mental Effort	-.00	.01	-.02	-.01	.01
	Cognitive Trait Anxiety X Mental Effort	.00	.00	-.04	-.00	.00
	Cognitive Trait Anxiety X Situational Stress X Mental Effort	-.00	.00	-.09	-.00	.00

p < .05*

Table 8.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Phonological Effectiveness in Backward Word Span

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	3.99	.22		3.56	4.43
	Depression	-.01	.02	-.03	-.05	.04
Step 2	(Constant)	3.99	.25		3.50	4.48
	Depression	-.00	.03	-.02	-.06	.05
	Cognitive Trait Anxiety	-.00	.04	-.00	-.08	.07
	Situational Stress	-.17	.15	-.12	-.47	.12
	Mental Effort	.01	.01	.29*	.00	.02
Step 3	(Constant)	3.92	.27		3.39	4.45
	Depression	.01	.03	.02	-.06	.07
	Cognitive Trait Anxiety	-.01	.04	-.03	-.09	.07
	Situational Stress	-.18	.15	-.12	-.47	.12
	Mental Effort	.01	.01	.29	.00	.02
	Cognitive Trait Anxiety X Situational Stress	.01	.03	.03	-.05	.07
	Situational Stress X Mental Effort	.01	.01	.12	-.01	.02
	Cognitive Trait Anxiety X Mental Effort	.00	.00	.03	-.00	.00
Step 4	(Constant)	3.92	.27		3.38	4.46
	Depression	.01	.03	.02	-.06	.06
	Cognitive Trait Anxiety	-.01	.04	-.03	-.09	.07
	Situational Stress	-.18	.16	-.13	-.50	.13
	Mental Effort	.01	.01	.28	.00	.02
	Cognitive Trait Anxiety X Situational Stress	.01	.03	.02	-.06	.07
	Situational Stress X Mental Effort	.01	.01	.11	-.01	.01
	Cognitive Trait Anxiety X Mental Effort	.00	.00	.02	-.00	.00
	Cognitive Trait Anxiety X Situational Stress X Mental Effort	.00	.00	.02	-.00	.00

$p < .05$*

predicted backward effectiveness, such that higher effort was associated with higher effectiveness, $t = 2.66$, $p = .009$, yet the main effects of situational stress and cognitive trait anxiety were not significant, $t = 1.16$, $p = .250$, and $t < 1$, respectively. With the inclusion of the two-way interaction terms at Step 3, the model accounted for 11% of the variance in backward effectiveness, however the increase in R^2, $R = .34$, $\Delta R^2 = .01$, $\Delta F < 1$, was not significant, and the model was not significant, F (7, 89) = 1.50, $p = .178$. At Step 4, with the three-way interaction term included, the increase in explainable variance on backward span effectiveness was not significant, $R = .34$, $\Delta R^2 = .00$, $\Delta F < 1$, and the full model was not significant, F (8, 89) = 1.30, $p = .254$.

Phonological Efficiency in Cognitive Anxiety

Forward word span efficiency. The unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step are shown in Table 9. At Step 1, depression accounted for approximately 1% of the variance in forward efficiency, $R = .10$, $F < 1$. At Step 2, with inclusion of the component main effects, the model accounted for 5% of variance in the criterion, however the increase in R^2 was not significant, $R = .23$, $\Delta R^2 = .04$, ΔF (3, 85) = 1.24, $p = .301$, and the model failed to reach significance, F (4, 89) = 1.15, $p = .340$. At Step 3, with the inclusion of the two-way interaction terms, the model accounted for 17% of the variance in forward span efficiency, $R = .41$, and $\Delta R^2 = .12$ was significant, ΔF (3, 82) = 3.87, $p = .012$; the overall model was also significant, F (7, 89) = 2.38, $p = .029$. The two-way interactions cognitive trait anxiety x situational stress and cognitive trait anxiety x mental effort reached significance, and were further qualified by the three-way interaction at Step 4. With the three-way interaction term added at Step 4, there was a significant increase in R^2,

Table 9.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Phonological Efficiency in Forward Word Span

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	.62	.03		.56	.68
	Depression	.00	.00	.10	-.00	.01
Step 2	(Constant)	.60	.04		.53	.67
	Depression	.01	.00	.17	-.00	.01
	Cognitive Trait Anxiety	-.00	.01	-.06	-.01	.01
	Situational Stress	-.01	.02	-.06	-.06	.03
	Mental Effort	-.00	.00	-.18	-.00	.00
Step 3	(Constant)	.59	.04		.52	.66
	Depression	.01	.00	.19	-.00	.01
	Cognitive Trait Anxiety	-.00	.01	-.09	-.01	.01
	Situational Stress	-.01	.02	-.03	-.05	.04
	Mental Effort	-.00	.00	-.23	-.00	.00
	Cognitive Trait Anxiety X Situational Stress	-.01	.00	-.29*	-.02	-.00
	Situational Stress X Mental Effort	.00	.00	.06	-.00	.00
	Cognitive Trait Anxiety X Mental Effort	.00	.00	.23*	.00	.00
Step 4	(Constant)	.60	.04		.53	.67
	Depression	.01	.00	.20	-.00	.02
	Cognitive Trait Anxiety	-.00	.01	-.10	-.01	.01
	Situational Stress	-.02	.02	-.07	-.06	.03
	Mental Effort	-.00	.00	-.27	-.00	.00
	Cognitive Trait Anxiety X Situational Stress	-.01	.00	-.34	-.02	-.01
	Situational Stress X Mental Effort	.00	.00	.06	-.00	.00
	Cognitive Trait Anxiety X Mental Effort	.00	.00	.19	.00	.00
	Cognitive Trait Anxiety X Situational Stress X Mental Effort	.00	.00	.21*	.00	.00

$p < .05$*

$\Delta R^2 = .03$, ΔF (1, 81) = 3.56, $p = .047$, and the full model accounted for 20% of the variance in the criterion, $R = .45$, which was significant, F (8, 89) = 2.58, $p = .015$. These results suggest that processing efficiency on forward word span varied as a function of cognitive trait anxiety, situational stress and mental effort.

To decompose the three-way interaction, tests of simple slopes at high and low values on the cognitive trait anxiety and mental effort scales (calculated at ± 1 *SD* from the mean score on each) were conducted at each level of situational stress. The data were analysed using IRSE software (IRSE; Meier, 2008) and the pattern of the interaction is shown in Figure 3.

As can been seen in the right panel, at higher mental effort (+ 1 SD), cognitive trait anxiety was not associated with efficiency in either the ego safe, $\beta < .01$, $t < 1$, or ego threat conditions, $\beta < .01$, $t < 1$. As the left panel shows, at lower mental effort (- 1 SD), the relationship between cognitive trait anxiety and efficiency varied as a function of situational stress. Under ego threat, cognitive trait anxiety was significantly and negatively associated with efficiency, $\beta = -.15$, $t = 3.34$, $p = .001$, such that those who reported higher cognitive trait anxiety performed with lower processing efficiency. In the ego safe condition, a similar trend emerged, however the slope was not significant, $\beta = -.05$, $t = 1.43$, $p = .158$.

Backward word span efficiency. The unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step are shown in Table 10. At Step 1, depression accounted for 1% of the variance in the criterion, $R = .12$, F (1,89) = 1.24, $p = .268$. At Step 2, with the main effects included, the model accounted for 9% of variance in backward span efficiency, however the

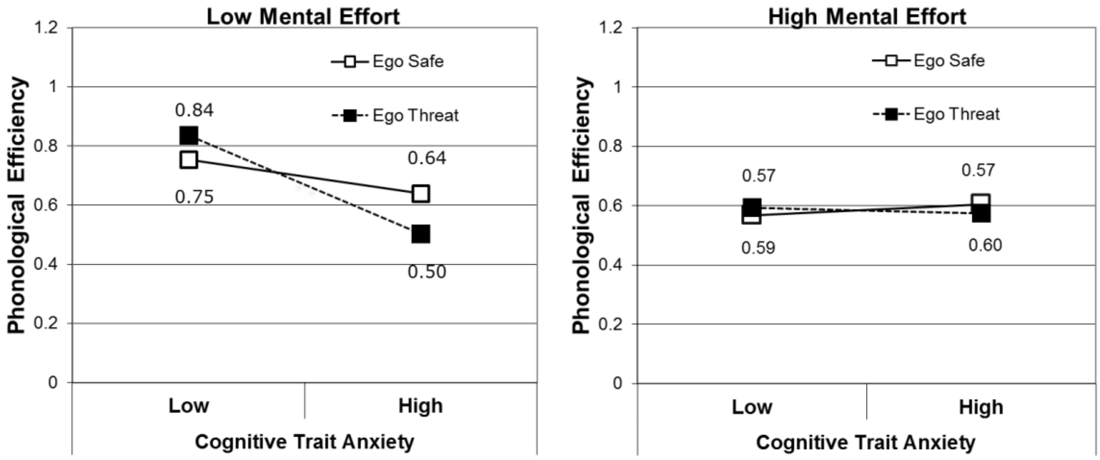

Figure 3. Relationship between cognitive trait anxiety, situational stress, mental effort, and phonological efficiency in forward word span.

increase in R^2 was not significant, R = .29, ΔR^2 = .07, ΔF (3, 85) = 2.24, p = .089, and the model was not significant, F (4, 89) = 2.00, p = .101. At Step 3, with the inclusion of the two-way interaction terms, the model accounted for 10% of the variance in efficiency, R = .32, ΔR^2 = .01, however the increment was not significant, ΔF < 1, and the overall model was also non-significant, F (7, 89) = 1.30, p = .261. At Step 4, the addition of the three-way interaction term brought about a significant increase in R^2, R = .41, ΔR^2 = .07, ΔF (1, 81) = 6.74, p = .011, and the full model accounted for 17% of the variance in efficiency, which was significant, F (8, 89) = 2.09, p = .048. These results suggest that processing efficiency on backward word span varied as a function of the combined contributions of cognitive trait anxiety, situational stress and mental effort.

To understand the pattern of the interaction, simple slopes tests at high and low values on the cognitive trait anxiety and mental effort scales (± 1 *SD* from the mean on each) at each level of situational stress were conducted using IRSE

Table 10.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Phonological Efficiency in Backward Word Span

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	.64	.07		.51	.77
	Depression	.01	.01	.12	-.01	.02
Step 2	(Constant)	.57	.07		.43	.72
	Depression	.02	.01	.28	.00	.04
	Cognitive Trait Anxiety	-.02	.01	-.23	-.04	.00
	Situational Stress	-.02	.04	-.06	-.11	.06
	Mental Effort	-.00	.00	-.15	-.01	.00
Step 3	(Constant)	.57	.08		.42	.73
	Depression	.02	.01	.25	-.00	.04
	Cognitive Trait Anxiety	-.02	.01	-.24	-.04	.00
	Situational Stress	-.02	.05	-.05	-.11	.07
	Mental Effort	-.00	.00	-.15	-.01	.00
	Cognitive Trait Anxiety X Situational Stress	-.00	.01	-.02	-.02	.02
	Situational Stress X Mental Effort	-.00	.00	-.11	-.01	.00
	Cognitive Trait Anxiety X Mental Effort	.00	.00	.05	-.00	.00
Step 4	(Constant)	.60	.08		.45	.76
	Depression	.02	.01	.25	-.00	.03
	Cognitive Trait Anxiety	-.02	.01	-.20	-.04	.01
	Situational Stress	-.06	.05	-.14	-.15	.03
	Mental Effort	-.00	.00	-.19	-.01	.00
	Cognitive Trait Anxiety X Situational Stress	-.01	.01	-.09	-.03	.01
	Situational Stress X Mental Effort	-.00	.00	-.09	-.00	.00
	Cognitive Trait Anxiety X Mental Effort	.00	.00	-.04	-.00	.00
	Cognitive Trait Anxiety X Situational Stress X Mental Effort	.00	.00	.29*	.00	.00

p < .05*

software (see Figure 2). As can be seen in the right panel, at higher mental effort, cognitive trait anxiety was not associated with efficiency in either the ego safe, β = .02, *t* < 1, or ego threat conditions, β = -.05, *t* = 1.30, *p* = .198. The left panel, however, shows that at lower mental effort, the relationship between cognitive trait anxiety and efficiency varied as a function of situational stress. Under ego threat, cognitive trait anxiety was significantly and negatively associated with efficiency, β = -.12, *t* = 2.75, *p* = .007, such that those who reported higher cognitive trait anxiety performed with lower processing efficiency. In the ego safe condition, a similar trend emerged, however the slope was not significant, β = -.05, *t* <1.

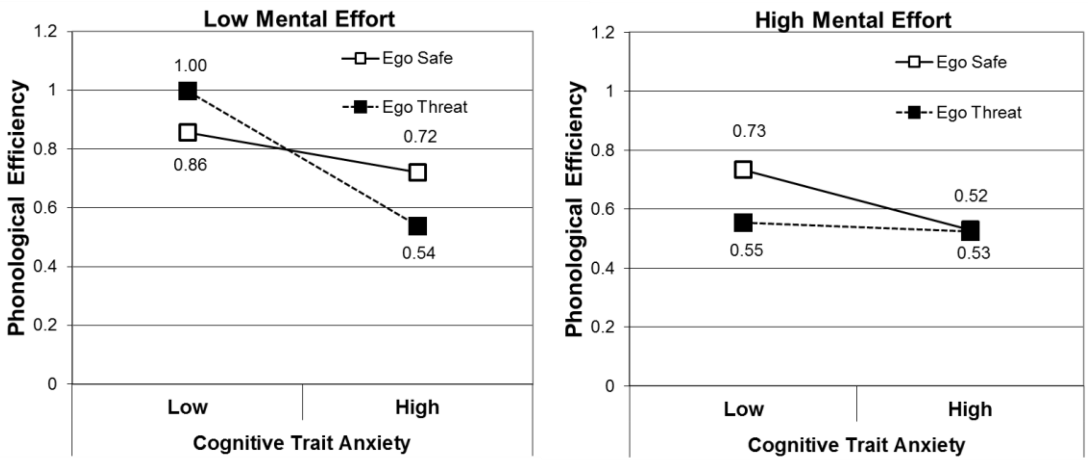

Figure 4. Relationship between cognitive trait anxiety, situational stress, mental effort, and phonological efficiency in backward word span.

Discussion of Anxiety and Phonological Performance

Study 1.1 examined whether trait anxiety, situational stress, mental effort, and their interactions were associated with phonological effectiveness and efficiency, and whether these relationships were further moderated by cognitive load. Somatic and cognitive trait anxiety were operationalised using the respective subscales of the STICSA (Ree et al., 2000), whereas somatic stress was manipulated through the threat of electric shock, and cognitive stress through ego threat instructions. The relationships between somatic anxiety and performance and between cognitive anxiety and performance were tested in separate experiments. In each study, the forward and backward word-span tasks reflected the low and high complexity conditions (respectively), and effort was measured using a visual analogue scale. Following ACT, it was predicted that performance effectiveness would be independent of both cognitive and somatic trait anxiety and situational stress in both the high and low phonological load conditions. For efficiency, however, significant three-way interactions were predicted, such that higher trait anxiety would be associated with lower efficiency in the stressful conditions (i.e., shock threat and ego threat) only, and that this relationship would be evident at lower, but not higher effort. This pattern was predicted as a function of both somatic and cognitive anxiety. The data found partial support for these predictions.

Study 1.1.1 investigated whether somatic anxiety, situational stress and effort were associated with effectiveness and efficiency on simple (forward) and complex (backward) phonological processing tasks. The data suggested that performance effectiveness was not associated with the unique main effects or interactive relationships between trait anxiety, stress, and mental effort, on either the forward or backward tasks. In terms of efficiency, on the simple (forward span) task the data indicated that performance was independent of somatic trait anxiety, somatic situational stress and mental effort, however on the complex (backward span) task, a two-way interaction between trait anxiety and situational stress emerged. The pattern of the interaction was such that that under high somatic stress, somatic trait anxiety was not predictive of efficiency, whereas at low stress, higher somatic trait anxiety predicted greater backward span efficiency. This relationship was not moderated by mental effort.

Study 1.1.2 examined whether cognitive anxiety, stress and effort were associated with phonological processing, and the hypotheses were fully supported. Specifically, phonological effectiveness did not vary as a function of the unique main or interactive effects of cognitive trait anxiety, cognitive situational stress and mental effort on either the simple (forward span) or complex (backward span) task. The efficiency data, however, yielded significant three-way interactions for both the forward and backward tasks. For both tasks, higher cognitive trait anxiety was associated with lower efficiency under high cognitive stress, and at lower mental effort. At higher mental effort, cognitive trait anxiety and cognitive situational stress were not associated with efficiency.

In accordance with the predictions of ACT, **t**he present data indicated that trait anxiety (somatic and cognitive), situational stress (somatic and cognitive) and mental effort were not related to phonological effectiveness on either simple (forward span) or complex (backward span) tasks. Although these results are inconsistent with previous studies that have reported anxiety to be associated with poorer phonological effectiveness (e.g., Darke, 1988; Walker & Spence, 1964), they are in accord with other work that reported null results (e.g., Sorg & Whitney, 1992; Walkenhorst & Crowe, 2009). The exact reason for the inconsistent results between studies is unclear. Both Study 1.1.1 and Study 1.1.2 employed measures of trait anxiety and situational stress that have been shown to illuminate the relationship between anxiety and performance on executive tasks in other work (e.g., Edwards, Edwards et al., 2015). Furthermore, as predicted by ACT, in both studies simple correlation tests revealed that greater mental effort was associated with better effectiveness, and those higher in trait anxiety invested greater mental effort. The data did not, however, reveal either unique or moderated links between anxiety and phonological effectiveness. The inconsistent results across studies might therefore be best explained by the differential measures of anxiety and stress employed, and/or subtle variations in mental effort across investigations. On the basis of the available data, it seems the relationship between anxiety and phonological effectiveness is, at best, tenuous.

The data suggested that somatic trait anxiety and somatic stress combine to predict phonological efficiency, such that higher anxiety was associated with higher efficiency at low but not high situational stress, and that this effect was restricted to tasks employing greater cognitive load (backward span). These data indicate that higher somatic trait anxiety might promote phonological efficiency on complex tasks, but only under conditions of low situational stress. The fact that the facilitative relationship between higher somatic trait anxiety and phonological efficiency was not evident under higher stress is suggestive of the idea that the relationship between somatic anxiety and stress on performance is additive, and that higher levels of both disrupt the efficiency with which phonological material is processed. These data are therefore somewhat consistent with theoretical views predicting a curvilinear relationship between performance and anxiety/arousal (cf. Yerkes & Dodson, 1908); performance efficiency is facilitated at moderate (high somatic anxiety + low stress) but not at higher levels of arousal (higher somatic anxiety + high stress). The results also suggest that the facilitative relationship between anxiety and performance is more likely to be manifest on moderately complex (backward span) rather than simple (forward span) tasks.

The data indicated that somatic anxiety and cognitive anxiety are differentially related to phonological efficiency, such that cognitive trait anxiety, cognitive situational stress and mental effort combined interactively to predict phonological efficiency on both the simple and the complex tasks. The relationship between cognitive trait anxiety and efficiency manifested under higher situational stress (ego threat) and at lower effort. Notwithstanding the different indices of processing efficiency, the data were conceptually comparable to those reported by Ikeda et al. (1996) who found that anxious individuals had longer RTs on a phonological task relative to those in the low anxious group. The present results further endorse the suggestion that anxiety and effort combine to produce an efficiency cost on phonological processing. The finding of a comparable pattern of results for both the simple and complex tasks suggests that for phonological efficiency the moderating effects of effort in the anxiety-efficiency relationship are somewhat robust, albeit restricted to those who report lower effort in higher stress situations. In sum, the relationship between cognitive anxiety, stress, effort and the phonological loop are evident irrespective of task complexity, yet, as predicted by ACT, are specific to efficiency rather than effectiveness.

It is important to consider the divergent patterns of data that emerged between the somatic and cognitive anxiety experiments. Under some conditions (low stress + complex task) higher somatic anxiety promoted phonological efficiency, whereas higher cognitive anxiety was associated with attenuated efficiency (high stress + lower effort) irrespective of task complexity. The exact reason for the differential patterns of results between studies is puzzling. Perhaps the simplest explanation might be made on the basis of the relationship between the resources required to complete the tasks, and how each type of anxiety might manifest within the cognitivedomain. It seems entirely plausible that somatic anxiety (e.g., elevated heart rate, shortness of breath, physical tension) may consume fewer cognitive resources than cognitive anxiety (e.g., worrisome thoughts, fear and apprehension), and that the additional mental resources available in somatic anxiety may promote phonological efficiency, at least under the conditions specified above. However when cognitive resources are further expended, as in the case of higher cognitive anxiety, the effects of high stress and lower effort become additive, and lower phonological efficiency. This explanation is however speculative, and requires empirical confirmation.

Study 1.1 provided a sound methodological inquiry into the relationship between anxiety and phonological performance, yet several limitations need mention. In the case of cognitive anxiety, it was noted that there were no differences in the patterns of data between the simple and complex tasks. One explanation for this result might be that the relationship between cognitive anxiety and phonological efficiency does not vary in accordance with task complexity. Alternatively, the manipulation of forward versus backward word span, as indices of simple versus complex phonological processing (respectively), may not have been sufficiently sensitive to reveal processing differences related to task complexity. For example, forward word span may not be simple enough, and/or backward span may not be complex enough, to operationalise appropriate differences in task complexity. It is important to note however that differences in performance between the tasks were observed as a function of somatic anxiety, and so the high and low task complexity manipulation employed here was likely fit for purpose.

The data revealed that effort played an important role in moderating the link between cognitive trait anxiety and situational stress on phonological efficiency, however we did not investigate whether other factors related to effort and anxiety might also explain this relationship. For example, recent work has shown motivation to be related to effort and anxiety (e.g., Hayes, MacLeod, &

Hammond, 2009), worry to be related to verbal processing and anxiety (e.g., Walkenhorst & Crowe, 2009), and working memory capacity to be related to both anxiety and cognitive processing (e.g., Edwards, Moore et al., 2015; Johnson & Gronlund, 2009). Furthermore, ACT references individual differences in cognitive processing of emotional stimuli specifically with regard to inhibitory processes. The present study however employed neutral words only, and therefore it is not known whether threat and neutral words are differentially processed in the phonological loop.

Together, these data provide empirical support for ACT and bring to light some of the mechanisms sustaining the relationship between anxiety and phonological functioning. The data are important for ACT, because they are the first to confirm that cognitive trait anxiety and situational stress interact to impair phonological efficiency to a great extent than effectiveness, and that mental effort plays an important role in moderating this relationship.

Study 1.2: Anxiety and Updating Performance

Study 1.2 investigated the relationship between trait anxiety, situational stress, mental effort and updating using the reading span task. Again, somatic anxiety was examined in Study 1.2.1 (somatic trait anxiety and a somatic stressor) and cognitive anxiety was investigated in Study 1.2.1 (cognitive trait anxiety and a cognitive stressor). To avail a full test of ACT in terms of updating, measures of performance effectiveness and processing efficiency were collected (and analysed separately using multiple regression). Mental effort was included in the models.

Hypotheses

After controlling for depression, the predictions followed ACT, which suggests that anxiety impairs the updating function, efficiency more so than effectiveness, and only under stressful conditions. It was predicted that there would be no relationship between trait anxiety and situational stress on updating effectiveness, however it was anticipated that the updating efficiency data would reveal three-way (trait anxiety x situational stress x mental effort) interactions such that higher trait anxiety would be associated with lower efficiency but that this relationship would be restricted to those in the high stress condition and who reported lower effort. It was expected that this relationship would hold for both somatic and cognitive anxiety.

Measurement of Updating Performance

Updating effectiveness. Updating effectiveness was indexed using the weighted reading span scoring technique. Weighted scoring allocates more points to trials with more sentences, specifically: correct at the two sentence set-length, each trial equals 4 points; correct at the three sentence set-length, each trial equals 9 points; correct at the four sentence set-length, each trial equals 16 points; correct at the five sentence set-length, each trial equal 25 points; and correct at the six sentence set-length , each trial equals 36 points. Correct trials required participants to accurately recall all the last-words (in the correct order) and demonstrate that they understood the content (i.e., processing) by answering the true/false questions with >85% accuracy (see Conway et al., 2005). A total weighted score on the reading span task involved summing the points for each correctly recalled trial. Possible total weighted scores ranged from 4 to 378.

Updating efficiency. Updating efficiency was determined on the basis of the relationship between updating effectiveness (accuracy) and RT. To aid interpretability, the ratio was multiplied by 1000 (cf. Edwards, Moore et al., 2015), such that processing efficiency was calculated using the following equation:

$$\textit{Updating Efficiency} = \left[\frac{\textit{Weighted Reading Span Score}}{\textit{RT on Correct Trials}} \right] \textit{X 1000}$$

Study 1.2.1 Somatic Anxiety and Updating Performance

Participants

Ninety undergraduate students participated, aged between 18 and 55 years (*M* = 24.68 years, *SD* = 8.51; 64 females). In line with the procedure described earlier, assignment to the shock safe and shock threat groups was determined randomly, and the groups were balanced for sex and age.

Validity of SRQ as an Index of Situational Stress

Confirmation that the SRQ was an adequate measure of situational stress in the sample was confirmed by finding of a positive correlation between baseline SRQ and STICSA State Somatic scale scores, $r(90) = .37$, $p < .001$.

Manipulation Check

To qualify the threat of electric shock as an effective situational stress manipulation procedure, composite scores on the SRQ were entered into a 2 x 2 repeated measures ANOVA with Time (baseline vs. post-manipulation) and Group (shock safe vs. shock threat) as the factors. There was no significant main effect of Group, $F < 1$. The main effect of Time, $F(1, 88) = 64.69$, $MSE = 14.02$, $p < .001$, $\eta^2 = .42$, and the Time x Group interaction, $F(1, 88) = 5.33$, $p = .023$, $\eta^2 = .06$, reached significance. Follow up *t*-tests revealed that at baseline, there was no difference in composite SRQ reported by individuals in the shock threat (M = 11.89, SD = 5.06) and shock safe (M = 13.51, SD = 5.40) conditions, $t(1, 88) = 1.47$, $p = .145$, and despite increases in SRQ composite scores following the stress manipulation, with those in the shock threat group reporting marginally higher SRQ scores (M = 17.19, SD = 7.47) than those safe from shock (M = 16.71, SD = 7.01), these effects were not significant, $t < 1$.

Results

Data Diagnostics and Assumption Checking

RTs < 200 ms were removed and RTs ± 3*SD* from an individual's mean score were removed prior to analyses (< 2% of trials). The data were inspected visually using box-plots. Predictor and criterion variables were screened for univariate outliers using the criterion, *z*-scores > 3.50 for multivariate outliers using computation of Mahalanobis Distance and Cook's D (i.e., $p < .001$). Two univariate outliers were identified, one for updating effectiveness and one for updating efficiency. No multivariate outliers were detected. Analyses were conducted with the two outliers included and removed and due to no change in the pattern of the results, the cases were retained. The full data set met the assumptions of linearity and homoscedasticity and is reported (N = 90).

Descriptive Statistics

Table 11 displays the means and standard deviations, and zero-order and inter-correlations between predictors and criterions. As seen in the table, there was a significant negative correlation between mental effort and performance effectiveness, such that those who reported investing higher mental effort performed with lower effectiveness. Somatic trait anxiety was positively related to both depression and effort; those who reported greater trait anxiety also tended to report higher depression and invest greater effort. Further, there was a significant positive inter-correlation between depression and mental effort; those reporting higher depression also reported higher mental effort.

Table 11.

Means, Standard Deviations, Zero-order and Inter-correlations of Depression, Somatic Trait Anxiety, Mental Effort, Updating Effectiveness and Updating Efficiency on the Reading Span Task.

	M	*SD*	Depression	Somatic Trait Anxiety	Mental Effort
Depression	6.14	6.13			
Somatic Trait Anxiety	15.18	3.81	.30**		
Mental Effort	96.83	25.98	.18*	.27**	
Updating Effectiveness	32.62	21.16	-.09	-.08	-.18*
Updating Efficiency	3.27	1.07	-.15	.03	-.10

NOTE: $p < .01$** $p < .05$*

Main Analyses

Separate moderated multiple regression analyses were performed to determine whether somatic trait anxiety, situational stress, mental effort and their interactions predicted updating effectiveness and updating efficiency. For each analysis, depression was entered at Step 1, the main effects (somatic trait anxiety, situational stress and mental effort) were added at Step 2, the two-way interaction terms were entered at Step 3, and at Step 4 of the model, the three-way interaction term (somatic trait anxiety x situational stress x mental effort) was included.

Updating Effectiveness in Somatic Anxiety

Table 12 displays the unstandardised coefficients, beta weights and 95% confidence intervals for all variables. At Step 1, depression accounted for < 1% of the variance in updating effectiveness, R = .09, F < 1. At Step 2, the addition of the main effects did not add to the prediction of effectiveness, R = .19, ΔR^2 = .03, ΔF < 1, and the model (accounting for 4% of the variance in effectiveness) was not significant, F < 1. At Step 3, with the inclusion of the two-way interaction terms, the model accounted for 7% of the variance in effectiveness, R = .27, ΔR^2 = .04, however, ΔF (3, 82) = 1.06, p = .373 and the overall model, F < 1, were not significant. At Step 4, with the addition of the three-way interaction term, the full model accounted for 8% of the variance in effectiveness, R = .28, ΔR^2 = .01, however, ΔF < 1, and the full model, F <1, were not significant.

Updating Efficiency in Somatic Anxiety

The unstandardised coefficients, beta weights and 95% confidence intervals for all variables in the model are shown in Table 13. Depression was included as a covariate at Step 1 and accounted for < 1% of the variance in updating efficiency, R = .15, F = 2.09, p = .152. The component main effects were entered at Step 2, and the change in R^2 accounted for 5% of the variance in efficiency, however, R = .23, ΔR^2 = .03, ΔF <1, and the overall model, F (4, 89) = 1.35, p = .316, were not significant. At Step 3, the addition of the two-way interaction terms did not produce a change in R^2, R = .33, ΔR^2 = .06, ΔF (3, 79) = 1.69, p = .176, and the model, accounting for 11% of the variance in efficiency, was not significant, F (7, 89) = 1.43, p = .206. At Step 4, the three-way interaction

Table 12.
Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Updating Effectiveness

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	34.55	3.17		28.24	40.86
	Depression	-.31	.37	-.09	-1.04	.42
Step 2	(Constant)	33.85	3.32		27.25	40.45
	Depression	-.20	.40	-.06	-.99	.59
	Somatic Trait Anxiety	-.11	.64	-.02	-1.38	1.15
	Situational Stress	.23	2.34	.01	-4.43	4.88
	Mental Effort	-.14	.09	-.17	-.32	.05
Step 3	(Constant)	34.11	3.40		27.34	40.88
	Depression	-.19	.40	-.06	-.99	.60
	Somatic Trait Anxiety	.21	.70	.04	-1.18	1.61
	Situational Stress	.39	2.34	.02	-4.27	5.05
	Mental Effort	-.16	.09	-.20	-.34	.02
	Somatic Trait Anxiety X Situational Stress	.19	.68	.03	-.15	1.53
	Situational Stress X Mental Effort	.17	.10	.21	-.03	.37
	Somatic Trait Anxiety X Mental Effort	-.04	.03	-.19	-.09	.02
Step 4	(Constant)	34.02	3.42		27.22	40.82
	Depression	-.17	.40	-.05	-.97	.63
	Somatic Trait Anxiety	.11	.72	.02	-1.33	1.54
	Situational Stress	.08	2.40	-.05	-4.70	4.86
	Mental Effort	-.20	.11	-.25	-.42	.02
	Somatic Trait Anxiety X Situational Stress	.08	.70	.02	-1.31	1.47
	Situational Stress X Mental Effort	.20	.11	.24	-.02	.42
	Somatic Trait Anxiety X Mental Effort	-.05	.03	-.24	-.11	.02
	Somatic Trait Anxiety X Situational Stress X Mental Effort	.02	.03	.11	-.04	.08

$p < .05$*

Table 13.
Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Updating Efficiency

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	3.44	.16		3.12	3.75
	Depression	-.03	.02	-.15	-.06	.01
Step 2	(Constant)	3.41	.17		3.08	3.74
	Depression	-.02	.02	-.13	-.06	.02
	Somatic Trait Anxiety	.03	.03	.11	-.03	.09
	Situational Stress	-.14	.12	-.13	-.37	.09
	Mental Effort	-.00	.01	-.09	-.03	.09
Step 3	(Constant)	3.36	.17		3.02	3.69
	Depression	-.02	.02	-.12	-.06	.02
	Somatic Trait Anxiety	.02	.04	.08	-.05	.09
	Situational Stress	-.14	.12	-.13	-.37	.09
	Mental Effort	-.00	.01	-.11	-.01	.01
	Somatic Trait Anxiety X Situational Stress	.06	.03	.21	-.01	.13
	Situational Stress X Mental Effort	.00	.01	.09	-.01	.01
	Somatic Trait Anxiety X Mental Effort	.00	.00	-.02	-.00	.00
Step 4	(Constant)	3.37	.17		3.03	3.70
	Depression	-.02	.02	-.13	-.06	.02
	Somatic Trait Anxiety	.03	.04	.11	-.04	.10
	Situational Stress	-.11	.12	-.10	-.34	.13
	Mental Effort	-.00	.01	-.02	-.01	.01
	Somatic Trait Anxiety X Situational Stress	.07	.03	.25	.00	.14
	Situational Stress X Mental Effort	.00	.01	.03	-.01	.01
	Somatic Trait Anxiety X Mental Effort	.00	.00	.07	-.00	.00
	Somatic Trait Anxiety X Situational Stress X Mental Effort	-.00	.00	-.20	-.01	.00

$p < .05$*

term was entered into the model, however the change in R^2 was not significant, $R = .35$, $\Delta R^2 = .02$, $\Delta F(1, 81) = 1.36$, $p = .247$, and the full model which accounted for 12% of the variance in updating efficiency was not significant, $F(8, 89) = 1.42$, $p = .199$.

Study 1.2.2 Cognitive Anxiety and Updating Performance

Participants

Participants comprised 90 students, aged between 18 and 55 years (M = 24.06 years, SD = 8.31, 72 were female). In line with the procedure described earlier, assignment to the ego safe and ego threat groups was conducted randomly, such that participants in the safe condition in Study 1.2.1 served as controls (i.e., ego safe) for the 45 participants in the ego threat condition.

Validity of SRQ as an Index of Situational Stress

Support for the SRQ as an index situational stress was confirmed by a positive correlation between baseline SRQ and STICSA State Cognitive scale scores, $r(90) = .48$, $p < .001$.

Manipulation Check

The efficacy of the ego threat instructions as a means of elevating situational stress was examined using a 2 x 2 repeated measures ANOVA with Time (baseline vs. post-manipulation) and Group (shock safe vs. shock threat) as the factors and composite SRQ scores as the dependent variable. There was no significant main effect of Group, $F(1, 88) = 1.43$, $MSE = 65.83$, $p = .236$, however the main effect of Time, $F(1, 88) = 35.26$, $MSE = 21.57$, $p < .001$, $\eta^2 = .29$ was significant. The Time x Group interaction, however, $F(1, 88) = 1.73$, $p = .192$, $\eta^2 = .02$, was not significant. The main effect of Time was such that SRQ scores were higher post-manipulation (ego safe *M* = 16.71, *SD* = 7.01; ego threat *M* = 19.07, *SD* = 7.78) than at baseline (ego safe *M* = 13.51, *SD* = 5.40; ego threat *M* = 14.04, *SD* = 5.99).

Results

Data Diagnostics and Assumption Checking

Following removal of RTs < 200 ms and RTs ± 3*SD* from an individual's mean score (constituting < 2% of the trials), the dataset was inspected visually using box-plots and screen for univariate and multivariate outliers, as in Study 1.2.1. One case met criteria for a univariate outlier and multivariate outlier for performance efficiency, however after conducting the analyses with and without the extreme case, the pattern of data remained unchanged. Therefore, the case was retained and the full data set is reported (*N* = 90).

Descriptive Statistics

The relevant means and standard deviations, and zero-order and inter-correlations between predictors and criterions are shown in Table 14. There was a significant positive inter-correlation between cognitive trait anxiety and depression, such that those who reported higher cognitive trait anxiety reported higher depression, and a positive inter-correlation between cognitive trait anxiety and mental effort, such that those who reported higher cognitive trait anxiety reported higher mental effort. There was also a significant positive inter-correlation between depression and mental effort, with those reporting higher depression also reporting investing greater effort.

Table 14.

Means, Standard Deviations, Zero-order and Inter-correlations of Depression, Cognitive Trait Anxiety, Mental Effort, Updating Effectiveness and Updating Efficiency on the Reading Span Task.

	M	*SD*	Depression	Cognitive Trait Anxiety	Mental Effort
Depression	6.81	6.43			
Cognitive Trait Anxiety	18.40	5.19	.61***		
Mental Effort	95.00	27.05	.20*	.26**	
Updating Effectiveness	32.83	18.47	-.04	.04	-.06
Updating Efficiency	3.21	1.27	-.06	-.01	-.05

NOTE: $p < .001$*** $p < .01$** $p < .05$*

Main Analyses

To determine whether cognitive trait anxiety, situational stress, mental effort and their combined contributions predict updating effectiveness and efficiency, separate moderated multiple regression analyses were conducted. For each analysis, depression was included as a covariate at Step 1; main effects (cognitive trait anxiety, situational stress and mental effort) were included at Step 2; at Step 3, the two-way interaction terms (calculated using mean-centred scores) were included; and at Step 4, the three-way interaction term (cognitive trait anxiety x situational stress x mental effort) was added.

Updating Effectiveness in Cognitive Anxiety

The unstandardised coefficients, beta weights and 95% confidence intervals for all variables are shown in Table 15. At Step 1, depression accounted

Table 15.
Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Updating Effectiveness

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	33.69	2.86		28.00	39.37
	Depression	-.13	.31	-.04	-.73	.48
Step 2	(Constant)	34.79	3.34		28.16	41.42
	Depression	-.29	.39	-.10	-1.07	.50
	Cognitive Trait Anxiety	.43	.49	.12	-.55	1.41
	Situational Stress	-.44	2.03	-.02	4.48	3.60
	Mental Effort	-.05	.08	-.07	-.20	.11
Step 3	(Constant)	34.67	3.52		27.66	41.68
	Depression	-.27	.40	-.09	-1.07	.54
	Cognitive Trait Anxiety	.37	.51	.10	.65	1.39
	Situational Stress	-.48	2.06	-.03	-4.59	3.63
	Mental Effort	-.04	.08	-.06	-.20	.12
	Cognitive Trait Anxiety X Situational Stress	.33	.42	.09	-.51	1.16
	Situational Stress X Mental Effort	-.03	.08	-.04	-.18	.13
	Cognitive Trait Anxiety X Mental Effort	.00	.02	-.00	-.03	.03
Step 4	(Constant)	34.55	3.56		27.47	41.64
	Depression	-.26	.41	-.09	-1.07	.56
	Cognitive Trait Anxiety	.40	.52	.11	-.64	1.43
	Situational Stress	-.34	2.13	-.02	-4.57	3.89
	Mental Effort	-.04	.08	-.05	-.20	.12
	Cognitive Trait Anxiety X Situational Stress	.34	.42	.10	-.50	1.18
	Situational Stress X Mental Effort	-.02	.08	-.04	-.18	.14
	Cognitive Trait Anxiety X Mental Effort	.00	.02	-.00	-.03	.03
	Cognitive Trait Anxiety X Situational Stress X Mental Effort	-.01	.02	-.04	-.04	.03

$p < .05$*

for < 1% of the variance in updating effectiveness, R = .04, F < 1. At Step 2, with the inclusion of the main effects the model accounted for < 2% of the variance in effectiveness, R = .12, ΔR^2 = .01, ΔF < 1, and the model was not significant, F <1. At Step 3, the inclusion of the two-way interaction terms did not increase the explainable variance in effectiveness, R = .15, ΔR^2 = .01, ΔF <1, and the overall model that accounted for 2 % of variance in the criterion, F < 1, was not significant. At Step 4, the full model (including the three-way interaction term) accounted for 2% of the variance in effectiveness, R = .15, ΔR^2 = .10, however, ΔF < 1, and the full model, F < 1, did not reach significance.

Updating Efficiency in Cognitive Anxiety

Table 16 displays the unstandardised coefficients, beta weights and 95% confidence intervals for all variables. Depression accounted for < 1% of the variance in updating efficiency at Step 1, R = .06, F <1. At Step 2, the main effects failed to increase R^2, R = .11, ΔR^2 = .01, ΔF <1, and the overall model accounted for 1% of variance, F < 1. At Step 3, with the inclusion of the two-way interaction terms, R = .16, ΔR^2 = .01, ΔF < 1, the model accounted for 2% of the variance in efficiency, F < 1. At Step 4, the full model accounted for 4% of variance in efficiency, however the inclusion of the three-way interaction term reflected no significant change in R^2, R = .21, ΔR^2 = .02, ΔF (1, 81) = 1.62, p = .206, and the full model was not significant, F < 1.

Discussion of Anxiety and Updating Performance

Study 1.2 examined the relationship between trait anxiety, stress and effort on updating effectiveness and efficiency. ACT suggests that performance deficits in anxiety are observable only under stressful conditions. Thus separate observations were conducted to examine the performance of individuals high in somatic trait anxiety under a somatic situational stress (i.e., threat of electric

Table 16.
Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Updating Efficiency

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	3.30	.19		2.91	3.69
	Depression	-.01	.02	-.06	-.05	.03
Step 2	(Constant)	3.31	.23		2.86	3.77
	Depression	-.01	.03	-.07	-.07	.04
	Cognitive Trait Anxiety	.01	.03	.05	-.06	.08
	Situational Stress	-.10	.14	-.08	-.37	.18
	Mental Effort	-.00	.01	-.04	-.01	.01
Step 3	(Constant)	3.32	.24		2.84	3.80
	Depression	-.02	.03	-.08	-.07	.04
	Cognitive Trait Anxiety	.02	.04	.07	-.05	.09
	Situational Stress	-.10	.14	-.08	-.38	.18
	Mental Effort	-.00	.01	-.04	-.01	.01
	Cognitive Trait Anxiety X Situational Stress	-.01	.03	-.05	-.07	.05
	Situational Stress X Mental Effort	.01	.01	.10	-.01	.01
	Cognitive Trait Anxiety X Mental Effort	.00	.00	-.05	-.00	.00
Step 4	(Constant)	3.36	.24		2.87	3.84
	Depression	-.02	.03	-.10	-.07	.04
	Somatic Trait Anxiety	.01	.04	.04	-.06	.08
	Situational Stress	-.14	.14	-.11	-.43	.15
	Mental Effort	-.00	.01	-.07	-.01	.01
	Cognitive Trait Anxiety X Situational Stress	-.02	.03	-.07	-.07	.04
	Situational Stress X Mental Effort	.00	.01	.09	-.01	.02
	Cognitive Trait Anxiety X Mental Effort	.00	.00	-.05	-.00	.00
	Cognitive Trait Anxiety X Situational Stress X Mental Effort	.00	.00	.15	-.00	.00

$p < .05$*

shock) and cognitive trait-anxious individuals' performance under cognitive situational stress (i.e., ego threat) using the reading span task.

The predictions made here, however, were not supported for somatic anxiety (see Study 1.2.1) or cognitive anxiety (see Study 1.2.2) on either updating effectiveness or efficiency. The data indicated that on the reading span task, updating effectiveness and processing efficiency did not vary as a function of trait anxiety, situational stress or effort, nor their interactions.

In contrast to other studies (e.g., Calvo et al., 1992; Darke, 1988; Sorg & Whitney, 1992) the data from Study 1.2 revealed no relationship between anxiety (somatic or cognitive) and updating effectiveness. There are several reasons why this may be the case. One difference between previous work that reported associations between anxiety and updating effectiveness and the approach taken here lies in the measures of anxiety used. For example, Darke (1988) and Calvo et al. (1992) employed measures of test anxiety, whereas the current study employed indices of somatic and cognitive trait anxiety. One explanation for the differential patterns of results might therefore be that updating processes are more susceptible to anxiety associated with evaluative testing rather than the enduring somatic and cognitive symptoms investigated here.

Sorg and Whitney (1992) employed a measure of trait anxiety and a situational stress manipulation involving playing competitive video games. Their data revealed that those individuals higher in trait anxiety were lower in updating effectiveness in the stressful condition. Despite the similarities between their approach and the one taken here, the present study failed to replicate Sorg and Whitney's results. A potential explanation for these differences might be that Sorg and Whitney did not include a processing check as was done in the present work, such that it might have been possible for their participants to recall a greater number of last words at the expense of content processing. Storing last words while processing the sentence content for information in order to correctly answer the true/false questions (such were the requirements of the current task) may have overloaded the cognitive system to the extent that individual differences in anxiety and effort, and the stress manipulations (both somatic and cognitive), were unable to reveal significant performance differences in the data.

It is also plausible that a floor effect in the present data may have confounded the relationship between anxiety and updating effectiveness. Updating effectiveness was operationalised using a weighted reading span scoring procedure that has been used by others (e.g., Darke, 1988). In the present study possible scores ranged between 4 and 378, however, inspection of the means and standard deviations between situational stress groups revealed low scores (i.e., < 10% accuracy) and little variability, i.e., shock threat (M = 33.22, SD = 25.27), ego threat (M = 32.02, SD = 16.33), and safe (M = 33.64, SD = 20.55). Despite using the exact sentences from the original Daneman and Carpenter (1980) study, it seems likely that including the true/false semantic processing check may have made the task overly difficult, thus reducing the variance in performance.

ACT predicts that updating efficiency deficits will be found in anxious individuals performing under stressful conditions, however neither the threat of shock (somatic stressor) nor ego-threat instructions (cognitive stressor) produced updating efficiency deficits as a function of either somatic or cognitive trait anxiety. To date there is no empirical literature for comparison of reading span efficiency, however the present data contradicts studies that have reported anxiety-related updating efficiency deficits on other updating tasks (e.g., *n*-back; Wong et al., 2013), yet concur with other studies that have not observed anxiety-linked efficiency impairments (e.g., Fales et al., 2008; Walkenhorst & Crowe, 2009). While other work has used RT alone (e.g., Fales et al.; Walkenhorst & Crowe; Wong et al.), the efficiency ratio used here represents a novel approach to understanding the nature of this relationship and controls for the interpretational difficulties associated with previous approaches. Nonetheless given the close relationship been this ratio and the measure of effectiveness, it seems entirely plausible that performance floor effects might have limited the likelihood of revealing an association between the key variables of interest and updating efficiency.

Taken together, the findings of Study 1.2 and its associated difficulties suggest that the relationship between anxiety and updating warrants further exploration. A methodological solution might be to reduce the length of the sentences (i.e., reduce the number of words in each sentence) to make the task less demanding and create greater variance in weighted span scores. This approach was adopted in Study 2.1.

Study 1.3: Anxiety and Inhibitory Performance

Study 1.3 investigated the inter-relationships between trait anxiety, situational stress, mental effort and inhibition using a version of the Go-No-Go task. In accord with the other approaches in Study 1, trait anxiety was delineated into the somatic and cognitive dimensions using the STICSA (Ree et al., 2000), situational stress was induced using a somatic stress induction (i.e., shock threat) or a cognitive stress induction (i.e., ego threat), and mental effort was included in the model.

Hypotheses

After controlling for depression, the hypotheses were based on ACT. It was predicted that there would be no relationship between anxiety, stress and effort on inhibitory effectiveness, however a three-way (trait anxiety x situational stress x mental effort) interaction was predicted on inhibitory efficiency, such that higher trait anxiety would be associated with lower efficiency under higher situational stress, and that the relationship would be buffered by mental effort. The same pattern was predicted for somatic and cognitive anxiety.

Measurement of Inhibitory Performance

Inhibitory effectiveness. Inhibitory effectiveness was indexed using the signal detection theory parameter of stimulus sensitivity (*d’*; Pastore & Scheirer, 1974; see Stanislaw & Todorov, 1999 for a review). The variable *d’* accounts for the discrimination in response to different stimuli, thus accounting for the proportion of NoGo Errors and Correct Go trials, and has been used in other studies (e.g., Pacheco-Unguetti et al., 2010; Wong et al., 2013). Thus, inhibitory effectiveness was calculated using the following equation:

$$\textit{Inhibitory Effectiveness} = \quad z\,(\textit{Correct Go}) - z\,(\textit{NoGo Errors})$$

Inhibitory efficiency. To determine a measure of inhibitory efficiency that fits with ACT (i.e., the relationship between inhibitory accuracy and RT), efficiency was operationalised as the relationship between stimuli sensitivity *(d')* and RT on Correct trials. To aid interpretation of the results, the ratio was multiplied by 1000 (cf. Edwards, Moore et al., 2015; Hoffman & Schraw, 2009). Thus, we calculated processing efficiency using the following equation:

$$\textit{Inhibitory Efficiency} = \left[\frac{z\,(\textit{Correct Go}) - z\,(\textit{NoGo Errors})}{\textit{Mean RT on Correct Go Trials}} \right] \times 1000$$

Study 1.3.1 Somatic Anxiety and Inhibitory Performance

Participants

Data from two participants were replaced due to equipment failure, returning the sample to 90 undergraduate students. After data cleaning, data from three further participants were eliminated on the basis of exclusion criteria for outliers (see below), leaving a final sample of 87 participants aged between 18 and 55 years (*M* = 24.68 years, *SD* = 8.51; 64 females). Assignment to the shock safe and shock threat groups was conducted as per the procedure described earlier. Sex was proportionately distributed between the shock safe and shock threat conditions and the groups were comparable with respect to age, $t(85) < 1$.

Validity of SRQ as an Index of Situational Stress

Correlational analyses was conducted between composite SRQ scores at baseline and scores on the STICSA State Somatic scale to determine the efficacy of the SRQ as an appropriate measure of situational stress in the sample. Support for the SRQ as a satisfactory index of situational stress was confirmed with a positive relationship between the measures, $r(87) = .34$, $p = .001$.

Manipulation Check

To determine the efficacy of the threat of electric shock as a situational stress induction procedure, composite scores on the SRQ were entered into a 2 x 2 repeated measures ANOVA with Time (baseline vs. post-manipulation) and Group (shock safe vs. shock threat) as the factors. There was no significant main effect of Group, $F(1, 85) = 2.32$, $MSE = 44.06$, $p = .131$. The main effect of Time, $F(1, 85) = 36.92$, $MSE = 13.38$, $p < .001$, $\eta^2 = .30$, and the Time x Group interaction, $F(1, 85) = 15.80$, $p < .001$, $\eta^2 = .16$, reached significance. Follow up *t*-tests revealed that at baseline, there was no difference in composite SRQ reported by individuals in the shock threat ($M = 12.40$, $SD = 4.58$) and shock safe ($M = 13.07$, $SD = 5.28$) conditions, $t\ (1, 85) = 1.37$, $p = .173$, however following the stress manipulation those in the shock threat group ($M = 17.98$, $SD = 6.26$) showed significantly higher SRQ scores than those in the shock safe group ($M = 14.24$, $SD = 5.16$, $t(1, 85) = 4.64$, $p < .001$.

Results

Data Diagnostics and Assumption Checking

Anticipatory RTs (< 200 ms) and RTs ± 3*SD* from each participant's mean score were removed prior to analyses (< 1% of trials). Predictor and criterion variables were screened for univariate outliers using the criterion, *z*-scores > 3.50, and box-plots were examined visually. A total of three univariate outliers were removed, such that two outliers were detected for inhibitory effectiveness (*z*-score = -5.78 and -4.78) and one outlier was found for inhibitory efficiency (*z*-score = 3.80). Multivariate outliers were screened using computation of Mahalanobis Distance and Cook's D, however no highly influential cases were detected (*p*

< .001). The final data set of 87 participants met the assumptions of linearity and homoscedasticity, and is reported (*N* = 87).

Descriptive Statistics

Table 17 displays the relevant means and standard deviations, and zero-order and inter-correlations between predictors and criterions. As can be seen there were significant negative correlations between mental effort and effectiveness and efficiency, such that those who reported higher effort performed with lower effectiveness and lower efficiency. There was a significant positive inter-correlation between somatic trait anxiety and depression, such that those who reported higher somatic trait anxiety also tended to report higher depression. Furthermore there was a significant positive inter-correlation between somatic trait anxiety and mental effort, with those reporting higher symptoms of somatic trait anxiety also reporting higher mental effort.

Main Analyses

Moderated multiple regression analyses were performed to determine whether somatic trait anxiety, situational stress, mental effort and their interactions predicted performance effectiveness and processing efficiency. For each analysis, depression was controlled for at Step 1, the component main effects (somatic trait anxiety, situational stress and mental effort) were entered at Step 2, the two-way interaction terms were entered at Step 3, and the interaction term including all three predictors (somatic trait anxiety x situational stress x mental effort) was entered at Step 4.

Table 17.

Means, Standard Deviations, Zero-order and Inter-correlations of Depression, Somatic Trait Anxiety, Mental Effort, Inhibitory Effectiveness and Inhibitory Efficiency on the Go-No-Go Task.

	M	*SD*	Depression	Somatic Trait Anxiety	Mental Effort
Depression	6.13	6.15			
Somatic Trait Anxiety	15.28	3.82	.32***		
Mental Effort	58.14	33.01	-.05	.23*	
Inhibitory Effectiveness	.00	1.31	-.01	-.07	-.33***
Inhibitory Efficiency	.19	2.68	-.00	-.06	-.33***

NOTE: $p < .001$*** $p < .01$** $p < .05$*

Inhibitory Effectiveness in Somatic Anxiety

Table 18 shows the unstandardised coefficients, beta weights and 95% confidence intervals for all variables. At Step 1, depression accounted for < 1% of the variance in performance effectiveness, $R = .01$, $F < 1$. At Step 2, the addition of the main effects brought about a significant increase in R^2, $R = .34$, $\Delta R^2 = .11$, ΔF (3, 82) = 3.44, $p = .021$, and the model accounted for 11% of the variance in effectiveness, which was significant, F (4, 82) = 2.58, $p = .043$. In terms of unique contributions, the only significant predictor of effectiveness was mental effort which accounted for 11% of explainable variance; as such, higher mental effort was associated with lower effectiveness, $t = 3.15$, $p = .002$. At Step 3, with the inclusion of the two-way interaction terms, the model accounted for 12% of the

Table 18.
Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Inhibitory Effectiveness

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	.17	.20		-.23	.57
	Depression	-.00	.02	-.01	-.05	.04
Step 2	(Constant)	.21	.20		-.19	.61
	Depression	-.01	.02	-.04	-.06	.04
	Somatic Trait Anxiety	.01	.04	.02	-.07	.09
	Situational Stress	.05	.14	.04	-.24	.33
	Mental Effort	-.01	.00	-.34*	-.02	-.01
Step 3	(Constant)	.24	.21		-.18	.66
	Depression	-.01	.03	-.07	-.07	.04
	Somatic Trait Anxiety	.00	.04	.01	-.08	.08
	Situational Stress	.06	.15	.04	-.24	.35
	Mental Effort	-.01	.00	-.35	-.02	-.01
	Somatic Trait Anxiety X Situational Stress	.02	.04	.06	-.06	.10
	Situational Stress X Mental Effort	-.01	.01	-.12	-.01	.01
	Somatic Trait Anxiety X Mental Effort	.00	.00	.02	-.00	.00
Step 4	(Constant)	.25	.21		-.17	.68
	Depression	-.01	.03	-.06	-.06	.04
	Somatic Trait Anxiety	.00	.04	.03	-.08	.08
	Situational Stress	.03	.15	.03	-.26	.33
	Mental Effort	-.02	.01	-.40	-.03	-.01
	Somatic Trait Anxiety X Situational Stress	.02	.04	.05	-.06	.09
	Situational Stress X Mental Effort	-.00	.01	.10	-.01	.01
	Somatic Trait Anxiety X Mental Effort	.00	.00	-.03	-.00	.00
	Somatic Trait Anxiety X Situational Stress X Mental Effort	.00	.00	.12	-.00	.00

$p < .05$*

variance in effectiveness, R = .45, ΔR^2 = .01, however the increase in R^2 was not significant, $\Delta F < 1$, and the overall model, F (7, 79) = 1.60, p = .148, failed to reach significance. At Step 4, with the addition of the three-way interaction term, the full model accounted for 13% of the variance in effectiveness, R = .36, ΔR^2 = .01, however the incremental increase in R^2 was not significant, $\Delta F < 1$, and the full model, F (8, 78) = 1.48, p = .177, was not significant.

Inhibitory Efficiency in Somatic Anxiety

The unstandardised coefficients, beta weights and 95% confidence intervals for all variables are shown in Table 19. Depression was entered at Step 1 and accounted for < 1% of the variance in processing efficiency, R = .00, $F < 1$. At Step 2, the main effects were included and the change in R^2 accounted for a further 11% of the variance in inhibitory efficiency, R = .33, ΔR^2 = .11, ΔF (3, 82) = 3.42, p = .021, and the overall model, F (4, 82) = 2.57, p = .044, reached significance. Mental effort was identified as contributing 11% of the unique variance in the criterion, such that high mental effort predicted lower efficiency, t = 3.24, p = .002. With the inclusion of the two- way interaction terms at Step 3, there was no significant change in R^2, R = .35, ΔR^2 = .01, ΔF (3, 79) < 1, and the model, accounting for 12% of the variance in efficiency, was not significant, F (7, 79) = 1.59, p = .150. At Step 4, the three-way interaction term was included in the model, however the change in R^2 was not significant, ΔR^2 = .01, $\Delta F < 1$, and the full model, which accounted for 13% of the variance in processing efficiency, was not significant, F (8, 78) = 1.50, p = .171.

Table 19.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Inhibitory Efficiency

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	.20	.41		-.62	1.01
	Depression	-.00	.05	-.00	-.10	.09
Step 2	(Constant)	.28	.41		-.54	1.10
	Depression	.01	.05	-.03	-.11	.09
	Somatic Trait Anxiety	.01	.08	.02	-.15	.17
	Situational Stress	.08	.29	.03	-.50	.67
	Mental Effort	-.03	.01	-.34*	-.05	-.01
Step 3	(Constant)	.34	.43		-.52	1.20
	Depression	-.03	.05	-.06	-.13	.08
	Somatic Trait Anxiety	.01	.08	.01	-.16	.17
	Situational Stress	.11	.30	.04	-.49	.70
	Mental Effort	-.03	.01	-.35	-.05	-.01
	Somatic Trait Anxiety X Situational Stress	.04	.08	.05	-.12	.20
	Situational Stress X Mental Effort	-.01	.01	-.12	-.03	.01
	Somatic Trait Anxiety X Mental Effort	.00	.00	.03	-.00	.00
Step 4	(Constant)	.38	.44		-.49	1.24
	Depression	-.02	.05	-.05	-.13	.08
	Somatic Trait Anxiety	.00	.08	.00	-.16	.17
	Situational Stress	.06	.30	.02	-.55	.66
	Mental Effort	-.03	.01	-.40	-.05	-.01
	Somatic Trait Anxiety X Situational Stress	.03	.08	.04	-.13	.18
	Situational Stress X Mental Effort	-.01	.01	-.10	-.03	.01
	Somatic Trait Anxiety X Mental Effort	.00	.00	-.03	-.01	.00
	Somatic Trait Anxiety X Situational Stress X Mental Effort	.00	.00	.13	-.00	.01

$p < .05$*

Study 1.3.2 Cognitive Anxiety and Inhibitory Performance

Participants

Recruitment and prerequisite procedures were identical other studies in the present series. Participants in the safe condition in Study 1.3.1 served as low stress controls (i.e., ego safe) for the 45 participants in the ego threat condition. The final sample of 90 undergraduate psychology students were aged between 18 and 55 years (*M* = 24.06 years, *SD* = 8.31; 72 females).

Validity of SRQ as an Index of Situational Stress

A significant positive correlation between composite SRQ scores at baseline and scores on the STICSA State Cognitive scale, $r(87) = .35$, $p < .001$, confirmed the SRQ as an appropriate measure of situational stress.

Manipulation Check

To establish the effectiveness of the ego threat instructions as a means of heightening situational stress, a 2 x 2 repeated measures ANOVA was conducted with Time (baseline vs. post-manipulation) and Group (shock threat vs. shock safe) as the factors. Composite SRQ scores served as the dependent variable. The main effect of Group was not significant, however the main effect of Time, $F(1, 85) = 16.69$, $MSE = 20.00$, $p < .001$, $\eta^2 = .16$, and the Time x Group interaction, $F(1, 85) = 5.60$, $p = .020$, $\eta^2 = .06$, were significant. There was no difference in SRQ scores between the ego threat (*M* = 13.16, *SD* = 5.71) and ego safe (*M* = 13.07, *SD* = 5.28) groups at baseline, $t < 1$, however individuals in the ego threat condition (*M* = 17.53, *SD* = 7.48) showed significantly higher SRQ scores than those in the ego safe condition (*M* = 14.24, *SD* = 5.16) following the stress manipulation, $t(85) = 4.64$, $p < .001$. Results thus confirmed the efficacy of the stress induction procedure.

Results

Data Diagnostics and Assumption Checking

Data cleaning procedures were the same as the somatic anxiety sample. The same three univariate outliers (from Study 1.3.1) were removed (i.e., they were participants in the safe condition), such that two outliers were detected for performance effectiveness (z-score = -5.78 and -4.78) and one outlier was found for processing efficiency (z-score = 3.80). No additional univariate or multivariate outliers were identified, leaving a final data set of 87 participants (N = 87).

Descriptive Statistics

Table 20 shows the means, standard deviations, zero-order and inter-correlations of depression, cognitive trait anxiety, mental effort, performance effectiveness and processing efficiency. As can be seen in the table, there were significant negative zero-order correlations between mental effort and effectiveness and efficiency, such that those who reported higher effort performed with lower effectiveness and lower efficiency. There was also a significant positive inter-correlation between depression and trait anxiety; those who reported higher depression also tended to report higher cognitive trait anxiety.

Main Analyses

Analyses consistent with those for the somatic anxiety data (see Study 1.3.1) were performed on the cognitive anxiety data to determine whether cognitive trait anxiety, situational stress, mental effort and their interactions predicted performance effectiveness and processing efficiency. Separate moderated regression analyses were conducted on the inhibitory effectiveness and inhibitory efficiency data.

Table 20.

Means, Standard Deviations, Zero-order and Inter-correlations of Depression, Cognitive Trait Anxiety, Mental Effort, Inhibitory Effectiveness and Inhibitory Efficiency on the Go-No-Go Task.

	M	*SD*	Depression	Cognitive Trait Anxiety	Mental Effort
Depression	6.82	6.29			
Cognitive Trait Anxiety	18.26	4.97	.58***		
Mental Effort	59.99	31.63	-.15	-.03	
Inhibitory Effectiveness	.00	1.72	.03	-.06	-.43***
Inhibitory Efficiency	-.15	3.57	.03	-.06	-.42***

NOTE: $p < .001$***

Inhibitory Effectiveness in Cognitive Anxiety

The unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step as shown in Table 21. At Step 1, depression accounted for < 1% of the variance in performance effectiveness, $R = .03$, $F < 1$. At Step 2, the main effects accounted for 19% of the variance in effectiveness, $R = .44$, $\Delta R^2 = .19$, which was significant, ΔF (3, 82) = 6.50, $p = .001$, and the model was significant, F (4, 82) = 4.90, $p = .001$. Mental effort (18%) was the only significant unique predictor of effectiveness, such that higher effort was associated with lower effectiveness. With the two-way interaction terms included at Step 3, the model accounted for 21% of the variance in the criterion, $R = .45$, however the increase in explainable variance failed to reach significance, $\Delta R^2 = .01$, $\Delta F < 1$, and the overall model remained significant, F (7, 79) = 2.91, $p =$

Table 21.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Inhibitory Effectiveness

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	-.06	.27		-.60	.49
	Depression	.01	.03	.03	-.05	.07
Step 2	(Constant)	-.02	.29		-.59	.56
	Depression	.00	.03	.01	-.07	.07
	Cognitive Trait Anxiety	-.03	.04	-.08	-.11	.06
	Situational Stress	.00	.17	.00	-.34	.35
	Mental Effort	-.02	.01	-.44*	-.04	-.01
Step 3	(Constant)	.05	.30		-.55	.65
	Depression	-.01	.04	-.03	-.08	.06
	Cognitive Trait Anxiety	-.01	.05	-.03	-.10	.08
	Situational Stress	.01	.18	.01	-.34	.36
	Mental Effort	-.02	.01	-.41	-.03	-.01
	Cognitive Trait Anxiety X Situational Stress	.00	.04	.01	-.07	.07
	Situational Stress X Mental Effort	-.00	.01	-.03	-.01	.01
	Cognitive Trait Anxiety X Mental Effort	-.00	.00	-.11	-.00	.00
Step 4	(Constant)	.00	.30		-.59	.59
	Depression	-.00	.04	-.01	-.07	.07
	Cognitive Trait Anxiety	-.02	.05	-.06	-.11	.07
	Situational Stress	.03	.17	.02	-.31	.37
	Mental Effort	-.02	.01	-.45	-.04	-.01
	Cognitive Trait Anxiety X Situational Stress	-.01	.04	-.03	-.08	.06
	Situational Stress X Mental Effort	-.00	.01	-.08	-.02	.01
	Cognitive Trait Anxiety X Mental Effort	-.00	.00	-.16	-.00	.00
	Cognitive Trait Anxiety X Situational Stress X Mental Effort	.00	.00	.22*	.00	.00

$p < .05$*

.009. With the three-way interaction term included at Step 4, the full model accounted for 24% of the variance in effectiveness, R = .49, the increment was significant, $\Delta R^2 = .04$, ΔF (1, 78) = 3.93, p = .048, and the full model also reached significance, F(8, 78) = 3.13, p = .004.

To decompose the three-way interaction and perform tests of simple slopes at high and low levels of trait anxiety and mental effort we used the Interactions in Multiple Linear Regression with SPSS and Excel (IRSE; Meier, 2008) program. Figure 5 shows the pattern of the interaction plotted at ± 1 *SD* from the mean score on each variable.

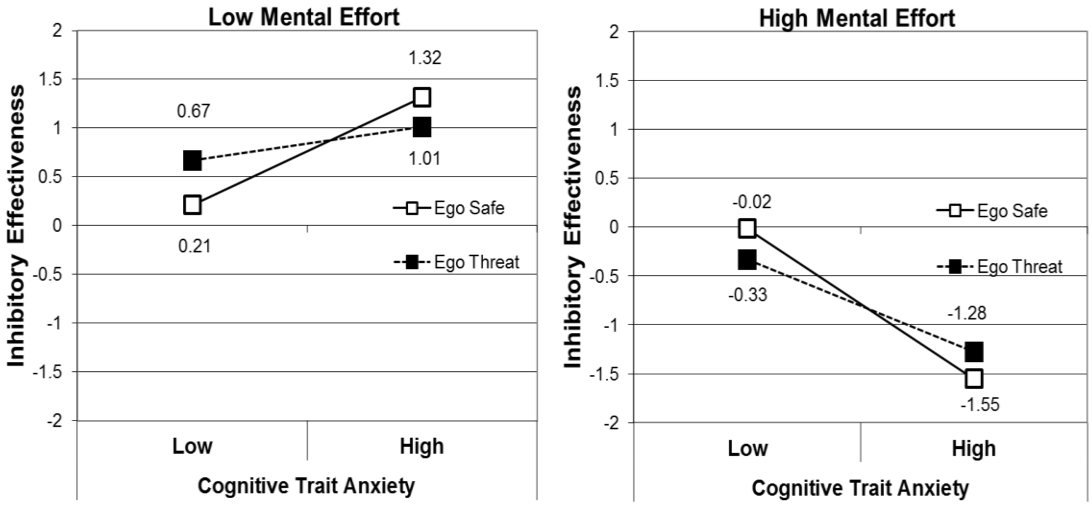

Figure 5. Relationship between cognitive trait anxiety, stress, mental effort, and inhibitory effectiveness.

The left panel shows that at lower mental effort (- 1*SD*) trait anxiety was not associated with inhibitory effectiveness in the ego threat or ego safe conditions, β = .02, $t < 1$, and β = .06, t = 1.79, p = .078, respectively. As can be seen in the right panel, at higher mental effort (+ 1 *SD*), trait anxiety was not associated with inhibitory effectiveness in the ego threat condition, β = -.06, t = 1.70, p = .093. However in the ego safe condition, those who reported higher trait anxiety demonstrated significantly lower effectiveness, β = -.27, *t* = 3.09, *p* = .003.

Inhibitory Efficiency in Cognitive Anxiety

Table 22 displays the unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step. At Step 1, depression accounted for < 1% of the variance in processing efficiency, *R* = .04, *F* < 1. There was a significant increase in explainable variance at Step 2. The inclusion of the main effects accounted for 19% of the variance in processing efficiency, *R* = .43, ΔR^2 = .18, Δ*F* (3, 82) = 6.17, *p* = .001, and the overall model was significant, *F*(4, 82) = 4.66, *p* = .002. Upon inspection of the individual contributions of the variables, mental effort was the only significant predictor and accounted for 17% of the unique variance in inhibitory efficiency, such that higher effort was associated with lower efficiency. At Step 3, with the inclusion of the two-way interaction terms, the model accounted for 20% of the variance in the criterion, *R* = .44, however the increment in variance was not significant, ΔR^2 = .01, Δ *F* (3, 79) < 1, although the model remained significant, *F* (7, 79) = 2.77, *p* = .012. At Step 4, the addition of the three-way interaction term brought about a significant increase in R^2, ΔR^2 = .04, Δ*F*(1, 78) = 3.95, *p* = .046, and the full model accounted for 24% of the variance in processing efficiency, which was significant, *F* (8, 78) = 3.00, *p* = .006. These results suggest that processing efficiency varied as a function of cognitive trait anxiety, situational stress and mental effort.

IRSE (Meier, 2008) software was used to decompose the interaction and perform tests of simple slopes at high and low values on the cognitive trait anxiety and mental effort scales (calculated at ± 1 *SD* from the mean score on each). Figure 6 shows the pattern of the interaction. The left panel shows that at lower mental effort (- 1 *SD*), there was no relationship between trait anxiety and

Table 22.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Inhibitory Efficiency

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	-.28	.57		-1.41	.86
	Depression	.02	.06	.03	-.10	.14
Step 2	(Constant)	-.22	.60		-1.41	.98
	Depression	.01	.07	.02	-.13	.15
	Cognitive Trait Anxiety	-.06	.09	-.09	-.24	.11
	Situational Stress	.01	.36	.00	-.71	.73
	Mental Effort	-.05	.01	-.42*	-.07	-.03
Step 3	(Constant)	-.07	.63		-1.33	1.18
	Depression	-.01	.08	-.02	-.16	.14
	Cognitive Trait Anxiety	-.03	.10	-.05	-.22	.16
	Situational Stress	.03	.37	.01	-.70	.76
	Mental Effort	-.05	.01	-.40	-.07	-.02
	Cognitive Trait Anxiety X Situational Stress	.01	.08	.01	-.14	.16
	Situational Stress X Mental Effort	-.01	.01	-.04	-.03	.02
	Cognitive Trait Anxiety X Mental Effort	-.00	.00	-.10	-.01	.00
Step 4	(Constant)	-.18	.62		-1.42	1.05
	Depression	.00	.07	.00	-.15	.15
	Cognitive Trait Anxiety	-.05	.09	-.07	-.24	.13
	Situational Stress	.07	.36	.02	-.65	.78
	Mental Effort	-.05	.01	-.44	-.07	-.03
	Cognitive Trait Anxiety X Situational Stress	-.01	.08	-.02	-.16	.14
	Situational Stress X Mental Effort	-.01	.01	-.09	-.03	.01
	Cognitive Trait Anxiety X Mental Effort	-.00	.00	-.15	-.01	.00
	Cognitive Trait Anxiety X Situational Stress X Mental Effort	.00	.00	.22*	.00	.03

$p < .05$*

inhibitory efficiency in the ego threat condition, $\beta = .03$, $t < 1$. For those in the ego safe condition however, there was a tendency for higher trait anxiety to be associated with higher efficiency, yet this effect failed to reach significance, $\beta = .07$, $t = 1.94$, $p = .056$. The right panel shows that at higher mental effort (+ 1 *SD*), higher trait anxiety was marginally associated with lower inhibitory efficiency in the ego threat condition, $\beta = -.08$, $t = 1.98$, $p = .050$, and significantly in the ego safe condition, $\beta = -.11$, $t = 3.44$, $p = .001$.

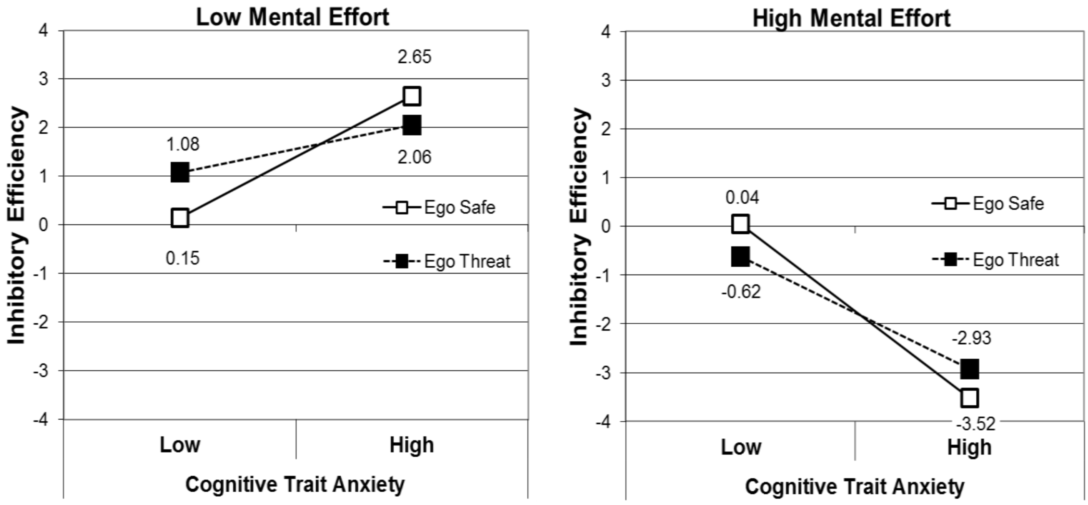

Figure 6. Relationship between cognitive trait anxiety, stress, mental effort, and inhibitory efficiency.

Discussion of Anxiety and Inhibitory Performance

Study 1.3 investigated the relationship between somatic and cognitive trait anxiety, somatic and cognitive stressors, and mental effort in predicting inhibitory control using the Go-No-Go task. A number of procedural problems in the current literature were controlled, including appropriate measures of inhibitory effectiveness and efficiency. For somatic anxiety the data suggested that the predictors did not combine to predict effectiveness or efficiency; mental effort alone was related to both criteria, such that higher effort was related to lower inhibitory effectiveness and efficiency. For cognitive anxiety there was a significant interaction between trait anxiety, situational stress and mental effort. Specifically, at lower mental effort, trait anxiety was not associated with effectiveness or efficiency, whereas at higher mental effort, higher trait anxiety was predictive of lower effectiveness in the low stress condition, and lower efficiency irrespective of situational stress.

Inhibitory effectiveness and efficiency did not vary with the interactive effects of somatic trait anxiety, situational stress and/or effort. The data concurred with other studies using the Go-No-Go task that used both number of errors (Righi et al., 2009) and stimulus sensitivity (*d'*; Pacheco-Unguetti et al., 2010; Wong et al., 2013) as the measures of effectiveness. The results were also consistent with Derakshan, Ansari, et al., (2009) and Ansari and Derakshan (2010), who employed the antisaccade task and failed to find a reliable relationship between anxiety and accuracy. The data however were inconsistent with previous reports suggesting that higher anxiety is related to lower inhibitory efficiency (e.g., Ansari & Derakshan, 2010; Derakshan, Ansari, et al., 2009; Pacheco-Unguetti et al.; Wong et al.). An important methodological distinction between the approach employed here and that of Ansari and Derakshan, Derakshan, Ansari et al., Pacheco-Unguetti et al. (2010) and Wong et al. (2013) was that the current study employed a measure specific to somatic trait anxiety and a somatic stress manipulation, whereas they used subscales of the State Trait Anxiety Inventory (Spielberger et al., 1983), which captures the combined cognitive and somatic symptoms of anxiety. Perhaps, therefore, the most parsimonious account for the differential patterns of data between these earlier studies and those reported here is that inhibitory effectiveness and efficiency deficits might be unrelated to the somatic components of anxiety, and better explained by its cognitive symptoms.

The data revealed interactive relationships between cognitive trait anxiety, situational stress and mental effort on inhibitory effectiveness and efficiency. Results suggested that poorer effectiveness was associated with higher cognitive trait anxiety at higher effort and low stress (nb. a similar trend was evident for those in the high cognitive stress condition but the effect did not quite reach statistical significance). These data are therefore inconsistent with the findings of others (Ansari & Derakshan, 2010; Derakshan, Ansari, et al., 2009; Righi et al., 2009; Pacheco-Unguetti et al., 2010; Wong et al., 2013) who did not report a relationship between anxiety and inhibitory effectiveness. The exact reason for the discrepant findings across studies is unclear. One explanation might lie in differences between the dependent measures used. For example, Ansari and Derakshan (2010), and Derakshan, Ansari, et al. (2009) used the antisaccade task and number of errors as the criterion, and Righi et al. (2009) employed the Go-No-Go task and number of errors as the criterion. It is therefore tempting to conclude that the current approach, which accounted for discrimination between errors on NoGo trials and correct responses on Go trials (i.e., *d'*), might reflect a more sensitive measurement of effectiveness than errors alone. Other studies, however, have used the Go-No-Go task and *d'* as the measure of effectiveness (e.g., Pacheco-Unguetti et al.; Wong et al.), and failed to find a relationship between anxiety and effectiveness. The disparity of data patterns across studies is therefore unlikely to be explained by the tasks and/or measures of effectiveness. Perhaps the simplest explanation is that poorer inhibitory effectiveness is more closely associated with cognitive anxiety as opposed to measures that capture both cognitive and somatic symptoms of anxiety. Importantly, the data suggest that this relationship is restricted to conditions in which cognitive stress is low and self-reported mental effort is high (see below for further discussion).

The efficiency data provided further support for the idea that cognitive trait anxiety is related to deficits in inhibitory processing. At lower effort, cognitive trait anxiety was not associated with inhibitory efficiency, whereas at higher effort, higher cognitive trait anxiety was linked to lower efficiency in both ego safe and ego threat conditions. These data are conceptually consistent with previous reports demonstrating that anxiety is associated with lower efficiency on tasks of inhibition (e.g., Derakshan, Ansari, et al., 2009; Pacheco-Unguetti et al., 2010; Righi et al., 2009; Wong et al., 2013). Importantly, the findings reported here confirm the robustness of this association across tasks (antisaccade; Go-No-Go) and measures of efficiency, and discount the possibility of a speed-accuracy confound as an alternative explanation for the results.

It should be noted that a main effect of effort was observed on all tests, such that *higher* effort was associated *lower* effectiveness and efficiency, and independently of the measure of trait anxiety and/or stress manipulation. Furthermore, the interactive relationships between cognitive anxiety and situational stress on effectiveness and efficiency were restricted to those who reported higher mental effort, whereas it was hypothesised that this relationship would be limited to those who reported lower effort. ACT predicts that effort buffers against the effects of trait anxiety and stress, and recent reports have linked anxiety to deficits in shifting (Edwards, Edwards et al., 2015) and phonological efficiency (Study 1.1) at lower but not higher effort. As such, the finding that higher effort was associated with lower efficiency in the present study is puzzling. Kurzban, Duckworth, Kable, and Myers (2013) argued that under some conditions higher perceived effort can be associated with lower performance, particularly on repetitive tasks that involve attending to two or more criteria at once. According to Kurzban et al., the need for criterion prioritisation (momentarily prioritise one criterion over another) can lead to lower performance across time despite a concurrent increase in the subjective experience of effort, at least on relatively simple tasks. The structure of the Go-No-Go task employed in the present experiment seems to fit with the necessary preconditions described by Kurzban et al. as it was repetitive (256 trials), required simultaneous attention to two or more criteria (inhibit a response on target present trials vs. initiate response on target absent trials) and response prioritisation (speed vs. accuracy). If Kurzban et al.'s explanation is to be accepted for the inverse relationship between effort and performance observed here, the data also suggest that this phenomenon might be further exacerbated by cognitive anxiety and stress, and that it manifests both in terms of inhibitory effectiveness and efficiency. The theoretical perspective of Yerkes and Dodson (1908) may also constitute a descriptive account for the pattern of the relationship between effort and inhibitory efficiency found here (i.e., increased effort predicts poorer efficiency). Specifically, the results reported here may represent the inverted U relationship described by Yerkes and Dodson, such that the exertion of too much effort leads to poorer processing.

ACT (Eysenck et al., 2007) predicts that anxiety disrupts the balance between top-down and bottom-up attentional systems, with preferential resource allocation given to the stimulus driven system over the goal-driven system in the presence of threat. The current procedure permitted an assessment of the contribution of internal threat to inhibitory performance by employing only neutral stimuli (rather than threat stimuli) on the central tasks. Importantly, the data established that internal threat contributes to deficits in inhibitory performance. A limitation of this approach, however, is that the approach adopted does not permit confirmation of whether the presence of external threat (e.g., stimulus threat content) further moderates the interrelationships between cognitive anxiety, situational stress and effort. The question is examined in Study 2.2.

Study 1.4: Anxiety and Shifting Performance

Study 1.4 tested the predictions of ACT by examining the relationship between trait anxiety, situational stress and mental effort on shifting effectiveness and efficiency using the WCST. Consistent with the other studies in this series, the predictive model included somatic and cognitive trait anxiety, somatic and cognitive situational stress and mental effort. The data for somatic and cognitive anxiety were again analysed separately.

Hypotheses

After controlling for depression, the hypotheses for the current study were guided by the evidence describing the anxiety-shifting link and were based on the predictions derived from ACT. It was expected that there would be no relationship between anxiety and shifting effectiveness, however, it was predicted that shifting efficiency would vary with the combined associations of trait anxiety, situational stress and mental effort. Specifically, it was hypothesised that higher trait anxiety would be associated with lower efficiency in the high stress conditions, and this relationship would be moderated by mental effort.

Measurement of Shifting Performance

Shifting effectiveness. In accord with Goodwin and Sher (1992) and Caselli and colleagues (2004) the number of perseverative errors on the WCST were recorded. However, as this measure is an index of an inability to shift, shifting effectiveness (or ability to shift) was operationalized as the percentage of responses that were not perseverative errors. Thus, shifting effectiveness was calculated as follows:

Shifting Effectiveness = 100% - Percentage of Perseverative Errors

Shifting efficiency. To determine a measure of shifting efficiency that fits with ACT (i.e., the relationship between accuracy and RT), shifting efficiency was operationalised as the inverse of shifting inefficiency. Shifting efficiency, therefore, was interpreted as the relationship between the number of trials where a participant was not able to shift (i.e., number of perseverative errors) and their mean RT for those trials. To aid interpretation of the results, the ratio was multiplied by 1000 (cf. Edwards, Moore et al., 2015; Hoffman & Schraw, 2009). Shifting efficiency was calculated using the following equation:

$$\textit{Shifting Efficiency} = 1 - \left[\frac{\textit{Number of Perseverative Errors}}{\textit{Mean RT on Perseverative Error Trials}} \right] \times 1000$$

Study 1.4.1 Somatic Anxiety and Shifting Performance

Participants

Participants comprised 90 undergraduate university students aged between 18 and 55 years (*M* = = 24.68 years, *SD* = 8.51; 64 female). Participants were randomly assigned to either the shock safe (9 males, 36 females) or shock threat (17 males, 28 females) condition based on their arrival at the laboratory. The groups were comparable with respect to sex and age, $t(88) < 1$.

Validity of SRQ as an Index of Situational Stress

To determine the ability of the SRQ to measure somatic situational stress in the sample, a bivariate correlation was conducted between composite SRQ scores at baseline and scores on the STICSA State Somatic scale. There was a significant positive relationship between the measures, $r(90) = .32$, $p = .002$, confirming the SRQ as an appropriate index of somatic situational stress.

Manipulation Check

To confirm the ability of the threat of electric shock to induce somatic situational stress in the sample, a 2 x 2 repeated measures ANOVA with Time (baseline vs. post-manipulation) and Group (ego threat vs. ego safe) as the factors was conducted on the composite SRQ scores. There was no significant main effect of Group, $F(1, 88) < 1$, however the main effect of Time, $F(1, 88) = 82.51$, $MSE = 15.64$, $p < .001$, $\eta^2 = .48$, and the Time x Group interaction, $F(1, 88) = 17.50$, $p < .001$, $\eta^2 = .17$, was significant. Follow up *t*-tests revealed that at baseline, there was no difference in composite SRQ reported by individuals in the shock threat ($M = 11.89$, $SD = 5.06$) and shock safe ($M = 13.51$, $SD = 5.40$) conditions, $t(1, 88) = 1.47$, $p = .145$, however following the stress manipulation those in the shock threat group ($M = 19.71$, $SD = 7.35$) showed significantly higher SRQ scores than their shock safe counterparts ($M = 16.40$, $SD = 6.49$, $t(1, 88) = 2.26$, $p = .026$.

Results

Data Diagnostics and Assumption Checking

Prior to analyses, response times < 200 ms and ± 3*SD* from each participant's mean score were removed (< 1% of trials), and the predictor and criterion variables were screened for outliers and normality. Univariate outliers were considered significant with *z*-scores > 3.50. Using this criterion, one univariate outlier was identified for processing efficiency and the same case was identified as a multivariate outlier using Mahalanobis Distance at $p < .001$. Analyses were conducted with this outlier included and removed, and conceptually the pattern of results did not change, therefore the case was retained. All variables were within acceptable limits for normality and tests for skewness and kurtosis were acceptable with consideration to the sample (non-clinical, undergraduate students). The assumptions of linearity and homoscedasticity were adequately met. Untransformed variables were used in all analyses and the full data set was reported (N = 90).

Descriptive Statistics

Table 23 shows the zero-order correlations between the predictors and criterion variables, and the inter-correlations among the predictors. As can be seen, there were no significant zero-order correlations between the predictors and performance effectiveness or processing efficiency. There was a significant positive inter-correlation between depression and somatic trait anxiety, such that higher depression was associated with higher somatic trait anxiety. Further, there was a significant positive inter-correlation between somatic trait anxiety and mental effort, such that those who reported higher anxiety also tended to report higher effort.

Main Analyses

Separate moderated multiple regression analyses were conducted to determine whether somatic trait anxiety, somatic situational stress, mental effort, and their interactions predicted effectiveness and efficiency on the WCST. For each test, at Step 1, depression was entered as a covariate; at Step 2 the main effects (somatic trait anxiety, situational stress and mental effort) were entered; at Step 3 the two-way interaction terms were entered; and at Step 4 the three-way interaction term (somatic trait anxiety x situational stress x mental effort) was entered. Interaction terms were calculated using mean-centred anxiety and effort scores.

Table 23.

Means, Standard Deviations, Zero-order and Inter-correlations of Depression, Cognitive Trait Anxiety, Mental Effort, and Shifting Effectiveness and Shifting Efficiency on the WCST.

	M	*SD*	Depression	Somatic Trait Anxiety	Mental Effort
Depression	6.14	6.13			
Somatic Trait Anxiety	15.18	3.81	.30**		
Mental Effort	64.39	30.84	.10	.21*	
Shifting Effectiveness	85.80	6.88	-.06	-.05	-.12
Shifting Efficiency	990.44	5.55	-.07	-.06	-.07

NOTE: $p < .05$*, $p < .01$**, $p < .001$***

Shifting Effectiveness in Somatic Anxiety

The unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step are shown in Table 24. At Step 1, depression accounted for < 1% of the variance in effectiveness, $R = .06$, $F < 1$. At Step 2, with the inclusion of the main effects, the model accounted for 2% of the variance in effectiveness, $R = .13$, and the increases in explainable variance was not significant, $\Delta R^2 = .01$, $\Delta F < 1$, and the model was not significant, $F < 1$. At Step 3, with the addition of the two-way interaction terms, the model accounted for 3% of the variance in the criterion, $R = .16$, however the increment was not significant, $\Delta R^2 = .01$, $\Delta F < 1$, and the overall model failed to reach significance, F (7, 89) < 1. At Step 4, the full model accounted for 3% of the variance in effectiveness, but the unique contribution of the three-way interaction term was not

Table 24.
Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Shifting Effectiveness

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	86.20	1.03		84.15	88.25
	Depression	-.07	.12	-.06	-.30	.17
Step 2	(Constant)	86.05	1.09		83.89	88.21
	Depression	-.04	.13	-.04	-.30	.22
	Somatic Trait Anxiety	-.02	.21	-.01	-.43	.40
	Situational Stress	-.22	.77	-.03	-1.74	1.31
	Mental Effort	-.03	.03	-.11	-.07	-.02
Step 3	(Constant)	86.02	1.12		83.80	88.24
	Depression	-.04	.13	-.04	-.30	.22
	Somatic Trait Anxiety	-.03	.22	-.02	-.46	.40
	Situational Stress	-.24	.78	-.04	-1.79	1.31
	Mental Effort	-.02	.03	-.11	-.07	.03
	Somatic Trait Anxiety X Situational Stress	-.14	.22	-.07	-.57	.30
	Situational Stress X Mental Effort	.01	.03	.05	-.04	.06
	Somatic Trait Anxiety X Mental Effort	.00	.01	.07	-.01	.02
Step 4	(Constant)	86.02	1.12		83.79	88.26
	Depression	-.04	.13	-.04	-.30	.23
	Somatic Trait Anxiety	-.04	.23	-.02	-.30	.23
	Situational Stress	-.25	.79	-.04	-1.82	1.31
	Mental Effort	-.03	.03	-.11	-.08	.03
	Somatic Trait Anxiety X Situational Stress	-.14	.22	-.08	-.08	.03
	Situational Stress X Mental Effort	.01	.03	.05	-.04	.06
	Somatic Trait Anxiety X Mental Effort	.00	.01	.06	-.01	.02
	Somatic Trait Anxiety X Situational Stress X Mental Effort	.00	.01	.02	-.01	.01

$p < .05$*

significant, $R = .17$, $\Delta R^2 = .00$, $\Delta F < 1$, and the full model was not significant, $F < 1$. These results suggest that shifting effectiveness was unrelated to somatic anxiety (i.e., somatic trait anxiety or somatic situational stress) and mental effort.

Shifting Efficiency in Somatic Anxiety

The unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step of the model are shown in Table 25. Depression accounted for < 1% of the variance in processing efficiency at Step 1, $R = .07$, $F < 1$. When the main effects were included in the model at Step 2, the model accounted for 1% of the variance in efficiency, however there was no significant increase in R^2, $R = .10$, $\Delta R^2 = .01$, $\Delta F < 1$, and the model was not significant, $F < 1$. At Step 3, with the two-way interaction term included, the model accounted for 3% of the variance in the criterion, $R = .18$, and the increment was not significant, $\Delta R^2 = .02$, $\Delta F < 1$, nor was the model, $F < 1$. At Step 4, the inclusion of three-way interaction term meant the model accounted for 7% of the variance in processing efficiency, however the increase in explainable variance was not significant, $R = .26$, $\Delta R^2 = .04$, $\Delta F = 3.15$, $p = .080$, and the full model, $F < 1$, failed to reach significance. These results suggest that shifting efficiency did not vary as a function of somatic anxiety or mental effort, or their combined contributions.

Study 1.4.2 Cognitive Anxiety and Shifting Performance

Participants

A sample of 90 undergraduate psychology students aged between 18 and 55 years ($M = 24.06$ years; $SD = 8.31$) participated (72 were female). Participants in the safe condition in Study 1.4.1 served as low stress controls (i.e., ego safe) for the 45 participants under ego threat instructions here.

Table 25.
Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Shifting Efficiency

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	990.83	.83		989.17	992.48
	Depression	-.06	.10	-.07	-.26	.13
Step 2	(Constant)	990.70	.88		988.94	992.45
	Depression	-.04	.11	-.05	-.25	.17
	Somatic Trait Anxiety	-.05	.17	-.03	-.38	.29
	Situational Stress	-.18	.62	-.03	-1.42	1.05
	Mental Effort	-.01	.02	-.05	-.05	.03
Step 3	(Constant)	990.73	.90		988.94	992.52
	Depression	-.04	.12	-.05	-.25	.17
	Somatic Trait Anxiety	-.05	.17	-.03	-.39	.30
	Situational Stress	-.20	.63	-.04	-1.44	1.05
	Mental Effort	-.01	.02	-.04	-.05	.03
	Somatic Trait Anxiety X Situational Stress	-.19	.18	-.13	-.54	.16
	Situational Stress X Mental Effort	.02	.02	.11	-.02	.06
	Somatic Trait Anxiety X Mental Effort	.00	.01	.05	-.01	.01
Step 4	(Constant)	990.71	.89		988.95	992.48
	Depression	-.04	.11	-.05	-.25	.17
	Somatic Trait Anxiety	-.14	.18	-.10	-.50	.22
	Situational Stress	-.33	.62	-.06	-1.56	.91
	Mental Effort	-.02	.02	-.11	-.06	.02
	Somatic Trait Anxiety X Situational Stress	-.21	.17	-.14	-.56	.14
	Situational Stress X Mental Effort	.02	.02	.13	-.02	.07
	Somatic Trait Anxiety X Mental Effort	.00	.01	-.01	-.01	.01
	Somatic Trait Anxiety X Situational Stress X Mental Effort	.01	.01	.23	-.00	.02

$p < .05$*

Validity of SRQ as an Index of Situational Stress

Confirmation that the SRQ was an appropriate measure of situational stress was confirmed by the significant positive correlation between composite SRQ scores at baseline and scores on the STICSA State Cognitive scale, $r(90) = .37$, $p = .001$.

Manipulation Check

In accord with Study 1.1, 1.2, & 1.3, the efficacy of the ego threat instructions as a situational stress induction procedure was examined using a 2 x 2 repeated measures ANOVA with Time (baseline vs. post-manipulation) and Group (ego threat vs. ego safe) as the factors, and scores on the SRQ as the dependent variable. The main effect of Group was non-significant, however the main effect of Time, $F(1, 89) = 31.08$, $MSE = 862.50$, $p < .001$, $\eta^2 = .26$, and the Time x Group interaction, $F(1, 89) = 5.47$, $MSE = 293.20$, $p = .022$, $\eta^2 = .06$, were significant. The interaction reflected the fact that at baseline, there was no difference in composite SRQ scores between the ego threat ($M = 14.11$, $SD = 6.04$) and ego safe ($M = 14.18$, $SD = 5.66$) groups, $t < 1$, however following the stress manipulation individuals in the ego threat condition ($M = 20.36$, $SD = 7.80$) showed significantly higher SRQ scores than those in the ego safe condition ($M = 16.73$, $SD = 6.81$, $t(1, 87) = 2.34$, $p = .021$.

Results

Data Diagnostics and Assumption Checking

Response times < 200 ms and ± 3*SD* from each participant's mean score were removed (< 1% of trials). Prior to the main analyses, the data were screened for outliers and normality. Univariate outliers were considered significant with *z*-scores > 3.50. One outlier for performance effectiveness and one outlier for processing efficiency were identified using this criterion. Visual inspection of the values in box-plots confirmed the outliers as realistic in a student sample, and the data from these participants were retained. Mahalanobis Distance and Cook's D were computed to detect the presence of multivariate outliers and highly influential cases. One multivariate outlier was detected with $p < .001$. Analyses were performed with this outlier included and removed and as the substantive pattern of results did not change, the case was retained. All variables were within acceptable limits for normality, and tests for skewness and kurtosis were acceptable with consideration to the sample (non-clinical, undergraduate students). The assumptions of linearity and homoscedasticity were adequately met. The full data set was reported (N = 90).

Descriptive Statistics

Zero-order correlations between the predictors and criterion variables, and the inter-correlations among the predictors are shown in Table 26. As shown in the table, there were no significant zero-order correlations between the predictors and effectiveness or efficiency. The only significant inter-correlation was the relationship between Depression and Cognitive Trait Anxiety, such that those who reported higher depression also tended to report higher cognitive trait anxiety.

Main Analyses

Separate moderated multiple regression analyses were conducted to determine whether cognitive trait anxiety, situational stress, mental effort and their interactions predicted performance effectiveness and processing efficiency. For each test, depression was entered at Step 1; the main effects (cognitive trait anxiety, situational stress and mental effort) were entered at Step2; the two-way interaction terms were entered at Step 3; and the three-way interaction term (cognitive trait anxiety x situational stress x mental effort) was entered at Step 4.

Table 26.

Means, Standard Deviations, Zero-order and Inter-correlations of Depression, Cognitive Trait Anxiety, Mental Effort, and Shifting Effectiveness and Shifting Efficiency on the WCST.

	M	*SD*	Depression	Cognitive Trait Anxiety	Mental Effort
Depression	6.81	6.43			
Cognitive Trait Anxiety	18.40	5.19	.61***		
Mental Effort	66.11	30.12	-.02	.12	
Shifting Effectiveness	85.36	7.36	-.03	-.19	.04
Shifting Efficiency	989.86	6.21	.04	-.20	.05

NOTE: $p < .001$***

Shifting Effectiveness in Cognitive Anxiety

Table 27 shows the unstandardised coefficients, Beta weights and 95% confidence intervals for all variables at each step. At Step 1, depression accounted for < 1% of the variance in performance effectiveness, $R = .03$, $F < 1$. At Step 2, the main effects accounted for 6% of the variance in effectiveness, $R = .24$, however the increase in explainable variance was not significant, $\Delta R^2 = .06$, ΔF (3, 85) = 1.64, $p = .187$, and the model was not significant, F (4, 89) = 1.25, $p = .298$. With the inclusion of the two-way interaction terms at Step 3, the model accounted for 8% of the variance in the criterion, $R = .28$; the increment however was not significant, $\Delta R^2 = .02$, $\Delta F < 1$, and the model was not significant, F (7,

Table 27.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Shifting Effectiveness

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	85.57	1.14		83.31	87.83
	Depression	-.03	.12	-.03	-.27	.21
Step 2	(Constant)	84.18	1.31		81.59	86.78
	Depression	.17	.16	.15	-.14	.48
	Cognitive Trait Anxiety	-.42	.19	-.29	-.80	-.04
	Situational Stress	.09	.78	.01	-1.47	1.64
	Mental Effort	.02	.03	.08	-.03	.07
Step 3	(Constant)	84.29	1.37		81.56	87.02
	Depression	.17	.16	.15	-.16	.49
	Cognitive Trait Anxiety	-.40	.20	-.28	-.79	.00
	Situational Stress	.09	.79	.01	-1.48	1.65
	Mental Effort	.02	.03	.09	-.038	.07
	Cognitive Trait Anxiety X Situational Stress	-.16	.15	-.11	-.47	.15
	Situational Stress X Mental Effort	-.02	.03	-.09	-.07	.03
	Cognitive Trait Anxiety X Mental Effort	-.00	.01	-.01	-.01	.01
Step 4	(Constant)	84.30	1.37		81.57	87.02
	Depression	.17	.16	.15	-.15	.49
	Cognitive Trait Anxiety	-.38	.20	-.27	-.77	.02
	Situational Stress	-.02	.79	-.00	-1.60	1.55
	Mental Effort	.02	.03	.08	-.03	.07
	Cognitive Trait Anxiety X Situational Stress	-.18	.15	-.13	-.48	.13
	Situational Stress X Mental Effort	-.02	.03	-.10	-.08	.03
	Cognitive Trait Anxiety X Mental Effort	-.00	.01	-.05	-.01	.01
	Cognitive Trait Anxiety X Situational Stress X Mental Effort	.01	.01	.13	-.00	.02

p < .05*

89) = 1.00, p = .437. At Step 4, the full model accounted for 9% of the variance in effectiveness, but the unique contribution of the three-way interaction term was not significant, R = .31, ΔR^2 = .02, ΔF (1, 81) = 1.34, p = .251, and the full model failed to reach significance, F (8, 89) = 1.05, p = .409.

Shifting Efficiency in Cognitive Anxiety

Table 28 shows the unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step. At Step 1, depression accounted for < 1% of the variance in processing efficiency, R = .04, F < 1. At Step 2, there was a significant increase in R^2 with the component main effects accounting for 9% of the variance in processing efficiency, R = .30, ΔR^2 = .09, ΔF (3, 85) = 2.81, p = .044, however the overall model failed to reach significance, F (4, 89) = 2.14, p = .082. With the inclusion of the two-way interaction terms at Step 3, the model accounted for 13% of the variance in the criterion, R = .36, however the increment was not reliable, ΔR^2 = .04, ΔF (3, 82) = 1.08, p = .361, and the model was not significant, F (7, 89) = 1.69, p = .122. At Step 4, the addition of the three-way interaction term brought about a significant increase in R^2, ΔR^2 = .05, ΔF (1, 81) = 4.66, p = .034, and the full model accounted for 17% of the variance in processing efficiency, which was significant, F (8, 89) = 2.13, p = .042. These results suggest that processing efficiency varied as a function of cognitive trait anxiety, situational stress and mental effort.

IRSE (Meier, 2008) software was used to decompose the interaction and perform tests of simple slopes at high and low values on the trait anxiety and mental effort scales (calculated at ± 1 *SD* from the mean score on each). Figure 7 shows the pattern of the interaction. The right panel shows that at higher mental effort (+ 1 SD), higher cognitive trait anxiety was associated with poorer

Table 28.
Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Shifting Efficiency

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	989.60	.96		987.68	991.51
	Depression	.04	.10	.04	-.17	.24
Step 2	(Constant)	988.12	1.08		985.97	990.26
	Depression	.26	.13	.27	.00	.51
	Cognitive Trait Anxiety	-.45	.16	-.38	-.76	-.13
	Situational Stress	.91	.65	.03	-1.10	1.48
	Mental Effort	.02	.02	.10	-.02	.06
Step 3	(Constant)	988.29	1.13		986.05	990.54
	Depression	.24	.13	.25	-.02	.50
	Cognitive Trait Anxiety	-.42	.16	-.35	-.74	-.09
	Situational Stress	.20	.65	.03	-1.09	1.48
	Mental Effort	.02	.02	.10	-.02	.06
	Cognitive Trait Anxiety X Situational Stress	-.22	.13	-.19	-.47	.03
	Situational Stress X Mental Effort	-.00	.02	-.01	-.05	.04
	Cognitive Trait Anxiety X Mental Effort	.00	.00	.01	-.01	.01
Step 4	(Constant)	988.31	1.10		986.11	990.50
	Depression	.24	.13	.25	-.02	.50
	Cognitive Trait Anxiety	-.40	.16	-.33	-.72	-.08
	Situational Stress	.03	.64	.01	-1.24	1.30
	Mental Effort	.02	.02	.09	-.02	.06
	Cognitive Trait Anxiety X Situational Stress	-.25	.12	-.21	-.49	.00
	Situational Stress X Mental Effort	-.01	.02	-.03	-.05	.04
	Cognitive Trait Anxiety X Mental Effort	-.00	.00	-.06	-.01	.01
	Cognitive Trait Anxiety X Situational Stress X Mental Effort	.01	.00	.23*	.00	.02

$p < .05$*

efficiency in both the ego safe, β = -.36, t = 1.92, p = .050, and ego threat conditions, β = -.38, t = 2.54, p = .013. The left panel shows that at lower mental effort (- 1 SD), cognitive trait anxiety varied as a function of situational stress and the test for the differences between slopes was significant, t = 2.86, p = .005. Under ego threat, cognitive trait anxiety was a significant negative predictor of shifting efficiency, β = -.71, t = 3.45, p = .001, such that those who reported higher cognitive trait anxiety demonstrated lower efficiency. In the ego safe condition, a similar trend emerged, however the slope failed to reach significance, β = -.28, t = 1.53, p = .131.

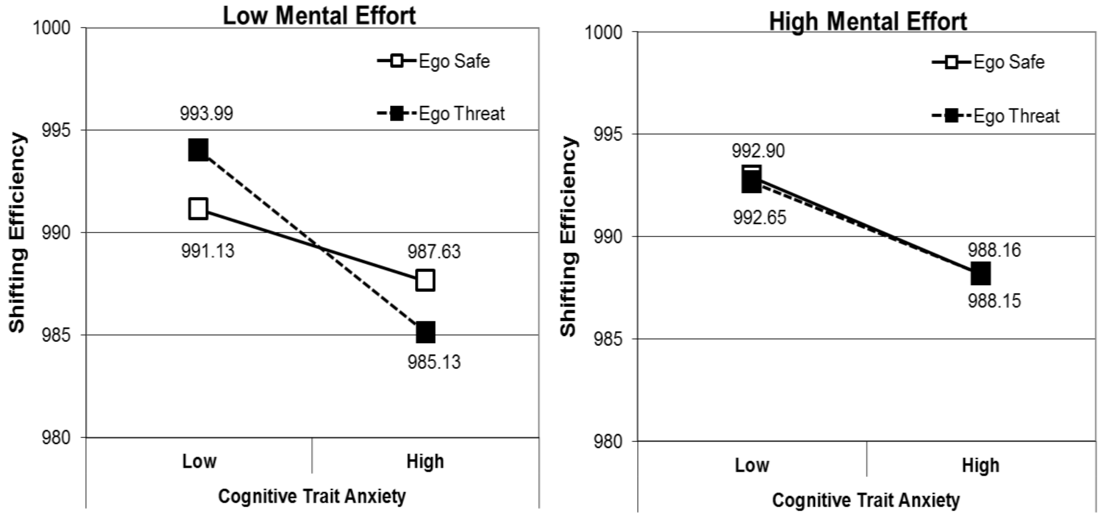

Figure 7. Relationship between cognitive trait anxiety, situational stress, mental effort, and shifting efficiency.

Discussion of Anxiety and Shifting Performance

The present study provided a systematic test of the relationship between trait anxiety, situational stress and mental effort on shifting effectiveness and efficiency. After controlling for depression, the data confirmed that somatic trait anxiety, somatic stress, and effort were not associated with either shifting effectiveness or efficiency. The results also suggested that cognitive trait anxiety, cognitive stress and effort did not predict performance effectiveness. However for processing efficiency, there was a significant interaction between cognitive trait anxiety, stress and effort. At higher effort, higher trait anxiety was associated with poorer efficiency in both the high and low stress conditions. At lower effort, trait anxiety did not predict efficiency in the ego safe condition, however the relationship was highly significant and most pronounced for those in the high stress condition.

The data indicated that shifting effectiveness did not vary as a function of somatic or cognitive trait anxiety, situational stress or effort. The data reported here therefore contradict previous reports that higher anxiety is associated with poorer accuracy on shifting tasks (e.g., Ansari et al., 2008; Derakshan, Smyth et al., 2009) and specifically, more perseverative errors on the WCST (e.g., Caselli et al., 2004; Goodwin & Sher, 1992). It is important to note that despite using different indices of performance effectiveness on the WCST between studies (i.e., we used the inverse proportion of the percentage of perseverative errors, whereas Caselli et al. and Goodwin and Sher used the percentage of perseverative errors), the scoring algorithms are mathematically equivalent and therefore cannot account for differences in the patterns of findings. The data are however consistent with other studies that have failed to find a predictive relationship between anxiety and shifting effectiveness (e.g., Edwards et al., 2014).

The reason for the mixed results between studies is unclear. One explanation might be that the link between anxiety and shifting effectiveness is task and/or sample specific. For example, the mixed pro- and anti-saccade task (Ansari et al., 2008) and a mathematical task-switching paradigm (Derakshan, Smyth et al., 2009) have both demonstrated efficacy in revealing anxiety-related effectiveness deficits in healthy individuals, whereas we used the WCST which has predominantly been used in neuropsychological studies (see Miyake et al., 2000). The fact that Caselli et al. (2004) and Goodwin and Sher (1992) reported anxiety-related effectiveness deficits in sub-clinical samples, whereas we did not observe this relationship in a non-select sample, raises the possibility that the WCST may be too easy for normal, healthy undergraduates and that more demanding tasks are required to reveal shifting deficits in effectiveness in such samples.

An alternative possibility is that processes other than shifting might vary between the WCST and the other attentional-shifting tasks (e.g., problem-solving or decision making ability) and/or that other factors such as motivation and/or age (our M = 24 years vs. Caselli et al. M = 55 years vs. Goodwin & Sher M not reported) might vary between samples. It is difficult to specify precisely the nature of the relationship between anxiety and shifting effectiveness in the absence of systematic investigations into the role played by such variables. Perhaps the soundest explanation for the relationship between anxiety and shifting effectiveness is that it is tenuous at best, and seems to be influenced by subtle procedural and sampling variations across studies.

The results also suggested that shifting efficiency was not predicted by somatic trait anxiety, somatic stress, effort, or their interactions. Perhaps the simplest explanation for these results is that somatic anxiety and stress do not combine and manifest within the cognitive system in such a way as to consume sufficient resources for their separate and/or combined effects to attenuate the efficiency of shifting processes. The data did however confirm that cognitive trait anxiety was associated with poorer shifting efficiency, and that this relationship was most pronounced at lower effort and under higher situational stress (i.e., ego threat). Despite different indices of processing efficiency, our data were conceptually similar to those reported by Goodwin and Sher (1992) and confirm that cognitive anxiety confers an efficiency cost on WCST performance. The data also confirm that this relationship is robust, as it tends to hold across samples and experimental paradigms (Ansari et al., 2008; Derakshan, Smyth et al., 2009; Edwards, Moore et al., 2015).

The results offer mixed support for the central assumptions of ACT (Eysenck et al., 2007). The data are consistent with the assumption that cognitive anxiety impairs processing efficiency to a greater extent than performance effectiveness on tasks involving the shifting function. However, in addressing the potential account that anxious individuals recruit additional effort to avoid performance effectiveness deficits, it was expected that invested mental effort would predict effectiveness, yet this was not the case. This null finding raises the possibility that individuals higher in anxiety rely on cognitive resources other than mental effort (e.g., motivation) in order to achieve accuracy equivalent to their less anxious counterparts, at least in a non-clinical university undergraduate sample. This possibility is investigated in Series 2.

The pattern of shifting efficiency data supports the broader assumption of ACT that anxiety (trait anxiety and situational stress collectively) is associated with processing efficiency deficits on shifting tasks. The data however suggest that these deficits are restricted to cognitive manifestations of anxiety and stress, rather than somatic ones. Importantly, the index of efficiency used allowed an investigation into the cost of shifting efficiency by accounting for individual differences in effectiveness (c.f. Edwards, Moore et al., 2015) and was based directly on the respective definition from ACT. The finding that mental effort buffers the anxiety-stress-efficiency link has important implications for ACT. Contrary to the predictions of ACT, at higher effort, trait anxiety alone predicted poorer shifting efficiency independently of situational stress. Full support for ACT was observed at lower effort, with trait anxiety predicting poorer shifting efficiency in the high stress but not low stress condition.

Study 1.4 provided the first systematic investigation into the relationship between somatic and cognitive trait anxiety, situational stress and mental effort on shifting effectiveness and efficiency. A novel measure of efficiency capable of controlling for individual differences in performance accuracy was employed. After controlling for depression, our data indicated that somatic anxiety, somatic stress, effort and their interactions were not associated with shifting effectiveness or efficiency. Our results also suggested that cognitive anxiety, cognitive stress and effort were not related to effectiveness, but interacted to predict efficiency. At higher effort, higher trait anxiety was associated with poorer efficiency independently of situational stress, whereas at lower effort this relationship was highly significant and most pronounced for those in the high stress condition. The data are important for ACT because they are the first to confirm that cognitive trait anxiety and situational stress interact to impair shifting efficiency to a greater extent than effectiveness, and that effort plays an important role in moderating this relationship.

Chapter Summary

The studies reported in Chapter 4 investigated the inter-relationships between trait anxiety, situational stress and invested mental effort in predicting phonological, updating, inhibitory, and shifting effectiveness and efficiency. The approach taken here made an important distinction between somatic and cognitive anxiety and stress and as such, their interrelationships with each of the cognitive functions were investigated separately. In Study 1.1 the data confirmed that cognitive anxiety, stress, and effort combined to predict phonological efficiency (but not effectiveness) on both simple (forward span) and complex (backward span) tasks, such that higher trait anxiety was associated with lower efficiency at lower, but not higher effort, and these patterns were only observed in the high stress conditions. In Study 1.2, the data suggested that somatic and cognitive anxiety, stress, and effort were not associated with updating effectiveness or efficiency. One interpretation of these results is to accept there is no relationship between these variables and the updating function. Alternatively, perhaps the task employed was too difficult, which in turn produced a floor effect in the data. This possibility was addressed in a modified replication of the study (see Study 2.1), which is reported in Chapter 6. Study 1.3 suggested that cognitive trait anxiety, stress, and effort interacted to predict inhibitory effectiveness and efficiency. Higher trait anxiety was associated with lower effectiveness at low stress and higher effort, whereas higher trait anxiety predicted lower efficiency at higher effort, irrespective of the stress manipulation. Study 1.4 indicated that higher cognitive trait anxiety, stress, and effort interacted to predict shifting efficiency, but not effectiveness. Specifically, higher trait anxiety was associated with lower efficiency irrespective of stress at higher effort, and with lower efficiency at lower effort in the high stress condition only. The evidence for relationships between somatic anxiety, stress and effort on each function was somewhat less compelling than for cognitive anxiety. With the exception that somatic anxiety predicted facilitated phonological efficiency at low stress, it was not associated with either effectiveness or efficiency on the other functions. To this end, the experiments reported in Chapter 6 did not include somatic anxiety and somatic stress as factors.

The studies reported in Chapter 4 accounted for multiple methodological problems in the current literature and provided a robust test of the predictions of

ACT. Although the data revealed that effort moderated the relationship between cognitive trait anxiety and situational stress on phonological, inhibition and shifting tasks, the present approach did not clarify which factors might underpin individual differences in invested effort, and whether they too are associated with anxiety. For example, ACT suggests that motivation is associated with effort and predicts that high-anxious individuals have higher motivation for somewhat demanding tasks with clear goals, yet they have low motivation for tasks that lack clear goals and rely on low cognitive load. Although there is some evidence to support this notion (e.g., Hayes, MacLeod, & Hammond, 2009), no studies have examined the role of motivation on the anxiety-performance relationship using executive tasks (i.e., inhibition, shifting or updating). This question is addressed in Chapter 6.

A final limitation of the approach adopted in the current chapter concerns the nature of stimuli employed. Each study employed neutral stimuli and so the methodology did not permit an investigation into whether threat and neutral stimuli have differential effects on the effectiveness and efficiency with which material is processed. ACT specifies that anxiety over-stimulates the stimulus driven attentional system at the expense of top down processing to the extent that threat material is preferentially processed. This interpretation seems entirely plausible given the volume of work that has confirmed attentional biases for threat in anxiety (see Bar-Haim et al., 2007 for a review). As such, the preferential allocation of resources to threat would seem more closely related to attentional processes (inhibition and shifting) as opposed to those functions associated with memory (phonological processing and updating). Thus the inhibition and shifting studies reported in Chapter 6 investigated whether threat and neutral material have differential effects on performance effectiveness and processing efficiency.

CHAPTER 5: EXPERIMENTAL SERIES 2: GENERAL METHOD

Introduction

Experimental Series 1 tested the predictions of ACT with respect to the relationship between trait anxiety, situational stress, effort, and phonological, updating, inhibitory and shifting performance. Despite confirming empirical support for many of the assumptions of ACT, there were several issues that warranted further investigation. First, Study 1.2 did not produce data confirming a relationship between anxiety and updating performance, and one possible account for the null result was that the reading span task was too difficult (i.e., floor effect). Second, despite data confirming that effort moderated the relationships between anxiety and performance on phonological, inhibition and shifting tasks, it remains to be tested whether individual differences in motivation might also buffer the anxiety-cognitive performance link, and further, test this predictive model on an updating task. Third, Study 1.3 and 1.4 examined the relationship between anxiety and processes linked closely to attention (i.e., inhibition and shifting), however the tasks used in those studies employed neutral stimuli only. A comprehensive test of ACT requires an investigation of inhibitory and shifting performance on tasks that include both neutral and threat-related stimuli. Experimental Series 2 is a three-study investigation that addresses these issues.

The present chapter includes an overview of the empirical work that has investigated the role of motivation in anxiety-cognitive performance literature, and reviews work that has examined attentional biases for threat in anxiety. The chapter describes and justifies the methodology used in this experimental series (i.e., Study 2.1, Study 2.2, and Study 2.3).

Motivation and Attentional Control Theory

According the Locke and Latham (2002) it is almost an axiom to say that cognition and motivation go together to affect performance, such that thinking (cognition) requires some degree of value-directed effort (motivation). Several fields of psychology, such as personality, and organisational and social psychology, have taken motivation as a construct of study which has resulted in numerous theories to describe and account for its relationship to behaviour and thought (e.g., Bandura & Cervone, 1986; Hollenbeck, Williams, & Klein, 1989; Locke & Latham, 1990).

The goal setting theory focusses on motivation with respect to the relationship between goals and task performance (Locke & Latham, 1990) and aligns closely to the interpretation of motivation described by ACT. The goal setting theory suggests that higher levels of performance are achieved when the goal is moderately difficult relative to when the goal is easy or ambiguous. Furthermore, goals that are both desirable and achievable are more likely to motivate people to mobilise effort to control their behaviour to attain them (Locke & Latham, 2002). Thus, motivation is interpreted as being synonymous with goal commitment or the individual’s determination to achieve a goal (see Klein, Wesson, Hollenback, Wright, & DeShon, 2001).

As a brief review, ACT proposes that highly anxious individuals are aware of processing deficits (i.e., worrisome thoughts consuming available cognitive resources) and use compensatory strategies such as deploying additional mental effort to achieve comparable performance effectiveness to their low-anxious counterparts. However, the increase in effort to overcome anxiety-related performance shortfalls comes at the cost of poorer processing efficiency. In the most recent reviews of ACT (Berggren & Derakshan, 2012; Eysenck &

Derakshan, 2011), the authors suggest that like effort, motivation plays an important role in moderating the relationship between anxiety and cognitive performance. Specifically, ACT suggests that if goals of the task are clear, anxious individuals will likely experience increased motivation, and in turn engage more cognitive resources, resulting in better performance than those lower in anxiety (Eysenck & Derakshan, 2011).

Evidence from recent neuroimaging studies suggests that individuals performing a cognitive task in a high motivation condition displayed greater neural connectivity in areas specific to cognitive control (i.e., medial and lateral prefrontal cortex) compared to participants in a low motivation condition (e.g., Kouneiher, Charron, & Koechlin, 2009; Szatkowska, Bogorodzki, Wolak, Marchewka, & Szeszkowski, 2008). These studies, however, did not investigate the influence of anxiety on these processes. There is limited literature regarding the relationship between anxiety, motivation and cognitive performance, and no studies to date have precisely clarified the motivation-anxiety link using executive tasks (i.e., updating, inhibition, shifting). However, the finding that motivation and cognitive control subserve the same hierarchical function has implications for ACT. If motivation varies with cognitive control (in accord with ACT) and anxiety, then individual differences in motivation need to be measured and included in the statistical modelling to offer a more complete understanding of the relationship between anxiety and performance.

Some studies have employed external incentives, or rewards, to investigate the association between anxiety, motivation and cognitive performance. For example, Calvo (1985) and Eysenck (1985) used monetary incentives to induce motivation in high and low anxious groups performing cognitive tasks (i.e., a reasoning task and letter-transformation task, respectively). Both authors reported no relationship between anxiety, motivation and performance in high-anxious individuals, however enhanced performance was noted for those lower in anxiety. According to ACT, those higher in anxiety use greater processing resources than their low-anxious counterparts and therefore it is possible that the high-anxious individuals were at full processing-capacity thereby offering less scope for incentives to enhance their performance. In other work, Hayes, MacLeod and Hammond (Experiment 3 & 4, 2009) reported that high anxious individuals performed worse on an incidental learning task in a low motivational condition relative to those on an intentional learning task in a high motivational condition. Consistent with ACT, these data suggest that anxious individuals may have been motivated to recruit additional resources to improve performance when the task was intentional, with clear goals.

As noted, there are limited empirical studies to form the baseline for the assumptions of ACT that the relationship between anxiety and cognitive performance is moderated by individual differences in motivation. Further empirical investigations are required to confirm this theoretical account. One of the aims of the current series of experimental studies was to clarify the anxiety-motivation link on updating, inhibition, and shifting processes.

Attentional Bias for Threat

ACT is premised on the idea that anxiety impairs attentional control by causing an imbalance between the top-down (i.e., goal-driven) and the bottom up (i.e., stimulus driven) attentional systems. In anxious individuals, the stimulus driven system becomes overactive, which in turn reduces the cognitive resources required to complete ongoing goal-driven activities. According to ACT, cognitive resources are preferentially allocated to internal and external stimulus-driven inputs, which manifest as facilitated engagement and delayed disengagement from material representing threat-related stimuli of evolutionary significance. Under this model, worrisome thoughts operate as internally generated threat-related stimuli. In Chapter 4, the data from studies that examined the relationship between anxiety and cognitive performance on tasks using neutral stimuli were reported. The interrelationships between trait anxiety, stress and performance on attentional tasks employing threat-related stimuli are examined in Study 2.2 and 2.3, and the data from these studies are reported in Chapter 6.

A wealth of literature provides support for the notion that compared to those lower in anxiety, high-anxious individuals preferentially attend to threat-related stimuli (e.g., Koster, Crombez, Verschuere, & De Houwer, 2004; Koster, Verschuere, Crombez, & Van Damme, 2005) and have difficulty disengaging from threat (e.g., Fox, Russo, Bowels, & Dutton, 2001; Yiend & Mathews, 2001). According to ACT, attentional control is thought to be more related to difficulties disengaging from threat-related stimuli, such that it refers to the degree to which the threat stimulus holds attention and impedes switching from the threat to another stimulus (e.g. Derryberry & Reed, 2002; see also Cisler & Koster, 2010). ACT suggests that in the presence of threat-related stimuli, anxiety enhances the detection of threat (i.e., bottom-up processing) and hinders performance that requires switching attention from it (i.e., top-down regulatory control).

Attentional biases for threat in anxiety have been observed on numerous tasks, for example, the emotional Stroop (e.g., Edwards et al., 2006; MacLeod & Mathews, 1988), dot-probe (e.g., MacLeod & Mathews, 1988; Mogg & Bradley, 1998), antisaccade (e.g., Derakshan, Ansari et al., 2009; Reinholdt-Dunne et al., 2012), spatial cuing (e.g., Bar-Haim et al., 2007; Cisler, Bacon, & Williams, 2009), and visual search tasks (e.g., Cisler et al., 2009; Rinck, Becker, Kellerman & Roth, 2003). In a prototypical version of the emotional Stroop task (Stroop, 1935), participants are presented with threat-related (e.g., cancer, danger) and neutral words (e.g., table, chair) in letter strings of various colours (e.g., red, green, blue, and yellow), and the participants' task is to name the colour of the lettering as quickly and accurately as possible while ignoring the semantic content of the item. An attentional bias for threat is inferred on the basis of longer colour-naming latencies on threat-related trials relative to neutral word trials, presumably because the content of the item engages cognitive resources at the expense of performing the colour-naming task. For example, Edwards et al. (2006) used a modified version of the emotional Stroop to examine the relationships between trait anxiety and situational stress in the processing of emotional material. Under conditions in which participants had conscious access to the items, their data suggested that trait anxiety and stress combined interactively to predict selective attentional processes. Specifically, high trait anxious participants who were performing under a high stress condition (i.e., threat of electric shock) were slower to colour-name threat items relative to control items, compared to participants who reported lower trait anxiety and/or when in the low stress condition. Similar data using the emotional Stroop have confirmed that compared to non-anxious controls, anxious individuals often take longer to name the colour of threat-related compared to neutral items, which is taken as evidence of an attentional bias to threat (e.g., MacLeod & Rutherford, 1992; Miller & Patrick, 2000).

Despite the efficacy of the emotional Stroop in demonstrating the automatic nature of attentional biases for threat in anxiety, there are a number of inherent interpretational difficulties associated with the task, the most important of which is that the mechanisms underpinning the response are not well understood (for reviews see e.g., Mogg & Bradley, 1998; Williams, Watts, MacLeod, & Mathews, 1997). To overcome problems associated with the Stroop, a number of researchers turned to modified versions of the dot-probe task, which can be used to determine the allocation of spatial attention on the basis of manual reaction times to visual probes (e.g., MacLeod, Mathews, & Tata, 1986). In the dot-probe task, participants are presented with threat and neutral words in the upper and lower (or left and right) portions of the computer screen. Following presentation of the items, the screen is then blanked and a probe is presented in the location occupied of one of the words. The participants' task is to press a button identifying the location (or shape status) of the probe as quickly and accurately as possible. Attentional biases to threat are inferred on the basis of faster reaction times to probes replacing threat words relative to neutral words, presumably because the participants' attention was directed to that portion of the visual display. Multiple studies have demonstrated that anxious individuals are faster at responding to probes replacing threat than neutral words (e.g., MacLeod, Mathews, & Tata; for reviews see e.g., Bar-Haim et al., 2007; Mogg & Bradley, 1998). Although data from dot-probe studies have demonstrated attentional biases for threat-related stimuli, the structure of the task cannot confirm whether anxiety is associated with inhibitory or shifting deficits as the task does not require competition for attention, and participants may simply choose to direct their attention towards threat (see Edwards, Burt, & Lipp, 2010). An appropriate test of the inhibition and shifting functions requires competition for cognitive resources such that participants must inhibit a response to one stimulus (or aspect of a stimulus) in preference to another, and for shifting they must redirect their response (or response set) from one stimulus or event type to another.

The antisaccade task is a widely-used and appropriate measure of inhibitory control, such that to saccade away from a target the participant is required to inhibit a reflexive prosaccade towards a target stimulus (see also Chapter 2). In a study using the antisaccade task, Derakshan, Ansari et al. (Experiment 2; 2009) found that relative to those lower in anxiety, high-anxious individuals took longer to saccade away from threat-related stimuli (inhibitory efficiency for threat differentiation), however there were no differences in error rates (inhibitory effectiveness for threat differentiation). These data support the notion that anxious individuals experience poorer inhibitory efficiency, but not effectiveness, in the presence of threat. Further replication of these results using other tasks is required to confirm the robustness of the conclusion that anxiety is associated with threat-related inhibitory deficits.

To-date, few studies have included both neutral and threat material in the Go-No-Go task or the WCST as indices of inhibition and shifting, respectively. Furthermore, the use of these tasks and appropriate measures of effectiveness and efficiency in a single study investigating the unique and interactive replationships between trait anxiety, situational stress, and motivation is required to provide a robust test of the predictions of ACT. This work was undertaken in the present thesis and the results are described in Study 2.2 and 2.3 (see Chapter 6).

General Method

Experimental Series 2 examined the inter-relationships between cognitive trait anxiety, situational stress and motivation in predicting updating, inhibitory and shifting effectiveness and efficiency. Study 2.1 investigated updating performance using a simplified (shortened) version of the reading span task and explored whether mental effort (Study 2.1.1) and motivation (Study 2.1.2) moderated the relationship between anxiety and performance. The relationships between cognitive trait anxiety, situational stress, and motivation in predicting differential threat processing on inhibitory (Study 2.2) and shifting (Study 2.3) tasks were examined.

Participants

In accord with Experimental Series 1, undergraduate students were recruited from the Bond University Psychology Participation Pool, and only those who reported English as their native language, who had normal or corrected to normal vision, and who had normal colour vison were invited to participate. Ninety-four undergraduate psychology students (aged between 18 and 53 years, *M* = 26.25, *SD* = 9.62) were recruited, and of these 22 were male and 72 were female. In return for participation students received research credit towards an introductory psychology subject. All were provided a handout describing features of anxiety and depression and details of the university's counselling service.

Participants provided written informed consent and then completed the psychometric measures. Consistent with the recruitment criteria specified in Experimental Series 1, individuals who scored in the extremely severe range (above 28) on the DASS- Depression scale were excluded. Of the original sample of 94, two participants were released due to high depression, one participant was excluded because he was not a native speaker of English, and one participant exercised her right to withdraw.

Based on their arrival at the laboratory, participants were systematically assigned to either low- situational stress (ego safe) or high- situational stress (ego threat) groups, such that every second participant was allocated to the stress manipulation condition. Final sample demographic details are provided in the corresponding empirical sections that follow.

Stress Induction

The ego treat instructions used in Experimental Series 2 were identical to those employed in Experimental Series 1. As a brief review, participants in the ego threat condition were told that their performance was related to their intelligence and that it was being evaluated against other volunteers. Immediately following the practice trials, participants were told that their performance was somewhat slower and less accurate than others. This instructions was repeated during breaks. Those in the ego safe condition were told their participation was greatly appreciated, and that most people find the tasks quite interesting.

Facilities and Equipment

Data collection took place in a sound-attenuated laboratory in the Cognitive Psychology Laboratories of the School of Psychology at Bond University.

Experimental Hardware

All stimuli were presented on an ACER E1-531 laptop computer with an Intel B960 processor running at 2.2 GHz connected to a 17-inch monitor. Participants wore a Dick Smith PC headset microphone which was connected to the laptop and captured their vocal responses.

Experimental Software

The presentation of stimuli for tasks was controlled using Visual Basic 6.0 software. The software also recorded RT latencies (ms) and errors.

Cognitive Tasks

The measures of updating (reading span task), inhibition (Go-No-Go task), and shifting (WCST) employed in Experimental Series 1 were employed in Experimental Series 2. Tasks were presented in a counterbalanced order using a Latin square design. Based on participants’ order of arrival at the laboratory, three task sequences were administered: Sequence A contained reading span, then WCST, and Go-No-Go; Sequence B contained WCST, Go-No-Go, and reading span; and Sequence C contained Go-No-Go, reading span, and WCST.

Reading Span Task

The reading span task was conceptually similar to the one used in Study 1.2. However, the 25 sentences from Daneman and Carpenter's (1980) reading span test, and the five practice sentences from Masson and Miller's (1983) study, were shortened to make the memory task less difficult and to reduce the likelihood of a potential floor-effect confound in the data. All sentences contained 12 words each, and each ended in a different word. The associated true/false questions employed for the cloze test were also reduced and simplified. Appendix J contains the list of sentences used. Task administration and scoring procedures (i.e., weighted reading span score) were identical to those used for the reading span task employed in Study 1.2.

Go-No-Go Task

The administration and scoring procedures for the Go-No-Go task were the same as for Study 1.3 (see Chapter 3). Participants were instructed to respond to any word that did not contain the letter 'a' (i.e. target-absent trials or Go trials) and inhibit a response to any word that did contain the letter 'a' (i.e., target-present trials or No-Go trials). Following two blocks of practice trials containing neutral words, there were 16 test blocks, each containing 16 words. Half the blocks employed neutral words and half employed threat-related words. The threat-related and control stimuli were derived from a subset of items used by Edwards et al. (2006), and were balanced for length and frequency using counts from the British National Corpus of approximately 89 million words (Kilgarriff, 1998). Appendix K contains the list of threat-related and neutral words used.

Within each block, half of the items contained the target letter ‘a’ such that there were equal numbers of target-absent and target-present words. Two stimulus sets (A and B) were constructed, and the blocks were presented in a fixed randomised order with no more than two trial types (threat-related or neutral) presented in sequence. Set B was the reverse of Set A to ensure that any sequencing effects that occurred inadvertently in the randomisation process were balanced across participants. The sets were administered alternately to each situational stress group based on their arrival at the laboratory. Following Study 1.3, the dependent variables were derived from the accuracy and response time data based on the relationship between the number of correct Go responses and No-Go errors for the threat and neutral trials. Further details of the scoring procedure are below.

Wisconsin Card Sorting Task

The administration and scoring procedures used for the WCST in Study 2.3 were identical to those employed in Study 1.4 (see Chapter 3), such that participants were shown 128 stimulus cards and asked to match them to four fixed target cards. For this task, the 65mm x 65 mm cards were divided into two 64 card blocks (A and B) such that one block (A) contained only neutral target cards and neutral stimulus cards, and (B) contained only threat-related target cards and corresponding threat-related stimulus cards. Neutral target and stimulus cards were those used in Study 1.4 (see Appendix E) and threat-related target cards and a list of the threat-related words used for the stimulus cards are included in Appendix L. The threat-related and neutral words were balanced for length and frequency (see Appendix L). Based on their arrival at the laboratory participants in each situational stress group completed the blocks in a counterbalanced order, such that half completed set A then B, whereas the other half completed the reverse order. The score of interest was the percentage of perseverative errors (i.e., errors made when the participant continued to unsuccessfully use a matching category after being told their selections were incorrect).

Psychometric Measures

DASS-21 (Lovibond & Lovibond, 1995)

The DASS is a 21 item self-report measure designed to assess depression, anxiety and stress symptoms over the past week. Only scores from the Depression subscale were included in the analyses. Further details of administration, scoring, and reliability and validity can be found in Chapter 3.

STICSA (Ree et al., 2000)

The STICSA is a self-report measure of the somatic and cognitive dimensions of state and trait anxiety. Only scores on the Cognitive subscales were analysed in the studies reported in the present chapter. Further details of administration, scoring, reliability and validity are described in Chapter 3.

RSME (Zijlstra, 1993)

The RSME is a visual analogue scale designed to measure self-reported mental effort. A full description is provided in Chapter 3.

SRQ

The SRQ is a measure of situational stress and its properties are described in Chapter 3.

The Revised HWK Goal Commitment Scale (HWK; Klein et al., 2001)

The HWK is a 5-item self-report measure of goal commitment and determination to reach a goal (Klein et al., 2001).

Scoring. Participants respond to statements using a 5-point Likert scale with anchors 1= *strongly disagree* and 5 = *strongly agree*. The items are as follows: (1) *It's hard to take this goal seriously*, (2) *Quite frankly, I don't care if I achieve this goal or not*, (3) *I am strongly committed to pursuing this goal*, (4) *It* *wouldn't take much to abandon this goal*, and (5) *I think this is a good goal to shoot for*. Negative item statements are reverse scored (i.e., items 1, 2, & 4). Possible scores on the measure range from 5 to 25, with higher scores reflecting greater goal commitment and motivation.

Reliability and validity. Factor analytic studies have found the HWK scale to be uni-dimensional, indicating it measures motivations as a single construct. The questionnaire has been reported to have satisfactory internal consistency, $\alpha = .74$ and $\alpha = .82$ (Klein et al., 2001; Vergara & Roberts, 2011, respectively). In a study examining the validity of the revised HWK, Jaros (2009) reported that the five items align with the determination to achieve a goal (cf. Locke & Latham, 1990).

Experimental Series 2

The series of experiments reported in the following chapter builds on the existing empirical work that has examined the relationships between anxiety, situational stress, and motivation on cognitive performance (i.e., updating, inhibitory and shifting), and extends the findings from the studies reported in Experimental Series 1. In each study, cognitive trait anxiety was operationalised using the cognitive trait scale from the STICSA (Ree et al., 2000) and situational stress was manipulated using ego threat instructions. Motivation was measured using the short five-item HWK scale. To permit comparison with the data reported in Experimental Series 1, the reading span task was employed as the measure of updating, the Go-No-Go task as the measure of inhibition, and the WCST as the index of shifting performance. To enable an investigation into how attentional biases for threat are related to the anxiety-performance relationship, the inhibition and shifting tasks contained threat-related and neutral stimuli. Performance effectiveness was operationalised as the quality of performance and processing efficiency was indexed by the ratio of accuracy to RT (cf. Series 1). Scores on the DASS-Depression subscale (Lovibond & Lovibond, 1995) were treated as a covariate in data analyses.

Procedure

Participants were tested individually in a sound-attenuated laboratory, and the procedure took approximately 120 minutes for each. Upon arrival at the laboratory they provided written informed consent and then completed the STICSA, DASS, and the SRQ (i.e., SRQ at baseline). Two participants who scored above 28 (extremely severe) on the DASS Depression Scale were thanked and released (in accord with the University's ethics requirements). The three tasks were undertaken in a counter-balanced order based on participants' order of arrival at the laboratory, and they were randomly assigned to either the low situational stress (ego safe) or high situational stress condition (ego threat) conditions, such that every second participant was allocated to the ego threat condition. Instructions for the stress manipulation were provided prior to the first task. Following these instructions, participants completed the SRQ a second time (i.e., SRQ at post-manipulation). They were then provided with instructions for the first task and completed the HWK. Prior to undertaking each task they were reminded to work as quickly and accurately as possible. The stress induction instructions were repeated immediately prior to completing each task, and followed by administration of the SRQ. Participants also completed the RSME following the reading span task only. Upon completion of the three tasks participants were thanked, debriefed and released.

CHAPTER 6: EXPERIMENTAL SERIES 2

Study 2.1: Anxiety and Updating Performance

Study 2.1 examined the relationship between cognitive trait anxiety, situational stress and updating performance. Separate statistical models were used to investigate the moderating effects of mental effort (Study 2.1.1) and motivation (Study 2.1.2) on these relationships. Cognitive trait anxiety was operationalised using the cognitive dimension of the STICSA (Ree et al., 2000), situational stress was manipulated using ego-threat instructions, and mental effort and motivation were indexed using the RSME (Zijlstra, 1993) and HWK (Klein et al., 2001), respectively. Study 2.1 employed a revised version of the reading span task to reduce the possibility of a floor effect confound (i.e., the task was too difficult) in Study 1.2.

Hypotheses

After controlling for depression, the predictions were guided by empirical support for the relationship between anxiety and updating performance (see Chapter 2) and ACT (see Chapter 1), which suggests that anxiety impairs updating performance under stressful conditions and that performance deficits will be more pronounced on efficiency than effectiveness. For Study 2.1.1, the prediction was that there would be no relationship between cognitive trait anxiety and situational stress on updating effectiveness. However, it was anticipated that updating efficiency would vary with trait anxiety, situational stress, and effort, such that high trait anxiety would be related to lower efficiency and that this relationship would be restricted to those who reported lower effort in the ego threat condition. For Study 2.1.2, it was predicted that the separate and combined associations of trait anxiety, situational stress and motivation would not be associated with updating effectiveness, yet the relationships between these factors would combine to predict updating efficiency deficits. In particular, it was hypothesised higher trait anxiety would be associated with lower efficiency when performing under ego threat instructions, and that this relationship would be restricted to those who reported lower task motivation.

Measurement of Updating Performance

Updating effectiveness. In accord with Study 1.2, updating effectiveness was operationalised using a weighted reading span score (see Chapter 3). For review, the total weighted score on the reading span task involved summing the points for each correctly recalled trial, where trials in two sentence set-lengths scored 4 points, three sentence set-lengths scored 9 points, four sentence set-lengths scored 16 points, five sentence set-lengths scored 25 points, and six sentence set-lengths scored 36 points (maximum total weighted score = 378).

Updating efficiency. Updating efficiency was operationalised in accord with Study 1.2 that defined it as the ratio of updating effectiveness relative to RT on correct trials. Updating efficiency was calculated using the following equation:

$$\textit{Updating Efficiency} = \left[\frac{\textit{Weighted Reading Span Score}}{\textit{RT on Correct Trials}} \right] \textit{X 1000}$$

Participants

Participants comprised 90 undergraduate students, aged between 18 and 53 years (*M* = 26.66 years, *SD* = 9.90), and 70 were female. Based on their order of arrival at the laboratory they were assigned to either the ego safe or ego threat groups. The groups did not differ on age, $t(88) = 1.08$, $p = .285$, n.s., and sex distributions were approximately equivalent in the ego safe (36 females; 9 males) and ego threat (38 females; 7 males) groups.

Validity of SRQ as an Index of Situational Stress

To determine the efficacy of the SRQ as a measure of cognitive situational stress in the sample, a bivariate correlation was conducted between composite SRQ scores at baseline and STICSA State Cognitive scale scores. The results revealed a significant positive correlation between the measures, $r(90) = .49$, $p < .001$, confirming the SRQ to be an appropriate index of situational stress.

Manipulation Check

To qualify the ego threat instructions as an effective situational stress manipulation procedure, composite SRQ scores were entered into a 2 x 2 repeated measures ANOVA with Time (baseline vs. post-manipulation) and Group (ego safe vs. ego threat) as the factors. The only significant effect to emerge was a main effect of Time, $F(1, 88) = 15.22$, $MSE = 31.12$, $p < .001$, $\eta^2 = .15$; irrespective of the stress manipulation SRQ scores were higher post-manipulation ($M = 15.69$; $SD = 6.41$) than at baseline ($M = 12.44$; $SD = 6.16$). The main effect of Group, $F(1, 88) = 1.25$, $MSE = 48.17$, $p = .267$, and the Time x Group interaction, $F < 1$, failed to reach significance.

Study 2.1.1 Anxiety, Effort and Updating Performance

Data Diagnostics and Assumption Checking

Data cleaning was conducted in accordance with Study 1.2. Anticipatory RTs (< 200 ms) and RTs ± 3*SD* from an individual's mean were removed (< 1% of trials). There were no univariate (*z*-scores < 3.50) or multivariate (Mahalanobis Distance $p < .001$) outliers on updating effectiveness or updating efficiency. The full data set is reported ($N = 90$).

Descriptive Statistics

The means, standard deviations, zero-order and inter-correlations of predictor and criterion variables are shown in Table 29. As can be seen, there was a significant positive zero-order correlation between mental effort and performance effectiveness, such that those who reported investing more mental effort also tended to have higher effectiveness. Further, there was a significant positive inter-correlation between cognitive trait anxiety and depression, such that those who reported higher cognitive trait anxiety also reported higher depression.

Main Analyses

Separate moderated multiple regression analyses were conducted to determine whether cognitive trait anxiety, situational stress, mental effort and their interactions predicted effectiveness and efficiency on the reading span task. At Step 1, depression was entered as a covariate, at Step 2 the main effects (cognitive trait anxiety, situational stress and mental effort) were included, at Step 3 the two-way interaction terms were entered, and at Step 4 the three-way interaction (cognitive trait anxiety x situational stress x mental effort) was entered.

Table 29.

Means, Standard Deviations, Zero-order and Inter-correlations of Depression, Cognitive Trait Anxiety, Mental Effort, Updating Effectiveness and Updating Efficiency on the Reading Span Task.

	M	*SD*	Depression	Cognitive Trait Anxiety	Mental Effort
Depression	7.58	7.27			
Cognitive Trait Anxiety	18.10	5.47	.68***		
Mental Effort	106.68	24.64	-.08	.02	
Updating Effectiveness	47.42	40.47	-.00	.10	.25**
Updating Efficiency	3.29	1.78	.02	.03	.12

NOTE: $p < .001$*** $p < .01$**

Updating Effectiveness

The unstandardised coefficients, beta weights and 95% confidence intervals for all variables can be seen in Table 30. At Step 1, depression accounted for < 1% of the variance in updating effectiveness, $R < .01$, $F < 1$. At Step 2, with the addition of the component main effects, the model accounted 14% of the variance in effectiveness, $R = .37$; the increase in explainable variance was significant, $\Delta R^2 = .14$, ΔF (3, 85) = 4.53, $p = .005$, and the model was significant, F (4, 89) = 3.39, $p = .013$. Both situational stress and mental effort made unique contributions in terms of predicting updating effectiveness. Mental effort accounted for 6% of explainable variance, such that higher mental effort was related to higher effectiveness, $t = 2.30$, $p = .024$, and situational stress accounted for 7% of explainable variance with those in the ego threat group (high stress condition) displaying poorer effectiveness than those in the ego safe group (low stress condition), $t = 2.47$, $p = .016$. At Step 3, the two-way interaction terms were entered and the model accounted for 18% on variance in the criterion, $R = .42$, however the increase in R^2 was not significant, $\Delta R^2 = .04$, ΔF (3, 82) = 1.41, $p = .247$, although the overall model remained significant, F(7, 89) = 2.57, $p = .019$. At Step 4, with the inclusion of the three-way interaction term, the model accounted for 19% of the variance in updating effectiveness, however although the overall model remained significant, F (8, 89) = 2.34, $p = .026$, the incremental increase in R^2 was not significant, $R = .43$, $\Delta R^2 = .01$, $\Delta F < 1$.

Table 30.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Updating Effectiveness

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	47.47	6.21		35.12	59.81
	Depression	-.01	.59	-.00	-1.19	1.17
Step 2	(Constant)	51.83	7.09		37.73	65.92
	Depression	-.58	.77	-.10	-2.11	.95
	Cognitive Trait Anxiety	1.47	1.03	.20	-.57	3.51
	Situational Stress	10.14	4.10	.25*	1.98	18.29
	Mental Effort	.38	.17	.23*	.05	.72
Step 3	(Constant)	51.04	7.12		36.88	65.19
	Depression	-.49	.77	-.09	-2.01	1.03
	Cognitive Trait Anxiety	1.56	1.04	.21	-.50	3.62
	Situational Stress	10.14	4.10	.25	1.99	18.29
	Mental Effort	.48	.17	.29	.14	.82
	Cognitive Trait Anxiety X Situational Stress	.14	.80	.02	-1.45	1.73
	Situational Stress X Mental Effort	.35	.17	.21	.00	.69
	Cognitive Trait Anxiety X Mental Effort	-.00	.03	-.01	-.07	.06
Step 4	(Constant)	51.55	7.15		37.33	65.78
	Depression	-.50	.77	-.09	-2.03	1.02
	Cognitive Trait Anxiety	1.78	1.07	.24	-.34	3.90
	Situational Stress	10.33	4.11	.26	2.15	18.50
	Mental Effort	.50	.18	.31	.15	.85
	Cognitive Trait Anxiety X Situational Stress	.19	.80	.03	-1.41	1.79
	Situational Stress X Mental Effort	.34	.17	.21	-.01	.69
	Cognitive Trait Anxiety X Mental Effort	.01	.03	.02	-.06	.07
	Cognitive Trait Anxiety X Situational Stress X Mental Effort	.03	.03	.10	-.04	.10

$p < .05$*

Updating Efficiency

Table 31 displays the unstandardised coefficients, beta weights and 95% confidence intervals for all variables. At Step 1, depression accounted for < 1% of the variance in updating efficiency, $R = .02$, $F < 1$. At Step 2, the component main effects brought no incremental increase in R^2, $R = .28$, $\Delta R^2 = .08$, ΔF (3, 85) = 2.33, $p = .081$, and the overall model that accounted for 8% of variance in updating efficiency was not significant, $F(4, 89) = 1.74$, $p = .148$. At Step 3, the inclusion of the two-way interaction terms meant the model accounted for 10% of the variance in the criterion, $R = .31$, however the increment in explainable variance was not significant, $\Delta R^2 = .02$, $\Delta F < 1$, and the model, F (7, 89) = 1.26, $p = .279$, was not significant. At Step 4, the full model accounted for 10% of variance in efficiency, $R = .31$; the addition of the three-way interaction term reflected no significant change in R^2, $\Delta R^2 = .00$, $\Delta F < 1$, and the full model was not significant, $F(8, 89) = 1.11$, $p = .366$.

Study 2.1.2. Anxiety, Motivation and Updating Performance

Data Diagnostics and Assumption Checking

Study 2.1.2 employed the same data as for Study 2.1.1 and included the HWK data as the measure of motivation. The full set of 90 participants was again screened for univariate and multivariate outliers. No cases met criteria for univariate (*z*-scores < 3.50) or multivariate outliers (Mahalanobis Distance $p < .001$) for performance effectiveness or processing efficiency, thus the full data set was retained ($N = 90$).

Table 31.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Updating Efficiency

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	3.30	.27		2.75	3.85
	Depression	.01	.03	.02	-.05	.06
Step 2	(Constant)	3.36	.32		2.72	4.00
	Depression	-.01	.04	-.04	-.08	.06
	Cognitive Trait Anxiety	.03	.05	.08	-.07	.12
	Situational Stress	.44	.19	.25	.07	.81
	Mental Effort	.01	.01	.11	-.01	.02
Step 3	(Constant)	3.38	.33		2.72	4.03
	Depression	-.01	.04	-.04	-.08	.06
	Cognitive Trait Anxiety	.03	.05	.10	-.06	.13
	Situational Stress	.46	.19	.26	.08	.84
	Mental Effort	.01	.01	.14	-.01	.03
	Cognitive Trait Anxiety X Situational Stress	.03	.04	.10	-.04	.11
	Situational Stress X Mental Effort	.01	.00	.12	-.01	.03
	Cognitive Trait Anxiety X Mental Effort	.01	.00	.08	-.00	.00
Step 4	(Constant)	3.39	.33		2.72	4.05
	Depression	-.01	.04	-.04	-.08	.06
	Somatic Trait Anxiety	.04	.05	.11	-.06	.14
	Situational Stress	.50	.19	.26	.08	.84
	Mental Effort	.01	.01	.15	-.01	.03
	Cognitive Trait Anxiety X Situational Stress	.03	.04	.10	-.04	.11
	Situational Stress X Mental Effort	.01	.01	.12	-.01	.02
	Cognitive Trait Anxiety X Mental Effort	.00	.00	.10	-.00	.00
	Cognitive Trait Anxiety X Situational Stress X Mental Effort	.00	.00	.04	-.00	.00

p < .05*

Descriptive Statistics

Table 32 displays the means, standard deviations, zero-order and inter-correlations of predictor and criterion variables. As shown, the only significant effect to emerge was the positive inter-correlation (reported above) between cognitive trait anxiety and depression, such that those who reported higher symptoms of cognitive trait anxiety also reported higher depression.

Table 32.

Means, Standard Deviations, Zero-order and Inter-correlations of Depression, Cognitive Trait Anxiety, Motivation, Updating Effectiveness and Updating Efficiency on the Reading Span Task.

	M	*SD*	Depression	Cognitive Trait Anxiety	Motivation
Depression	7.58	7.27			
Cognitive Trait Anxiety	18.10	5.47	.68***		
Motivation	20.42	4.08	-.04	.09	
Updating Effectiveness	47.42	40.47	-.00	.10	.16
Updating Efficiency	3.29	1.78	.02	.03	-.06

NOTE: $p < .001$***

Main Analyses

Analyses were performed to determine whether cognitive trait anxiety, situational stress, motivation and their interactions predicted performance effectiveness and processing efficiency on the updating data.

Updating Effectiveness

Table 33 displays the unstandardised coefficients, beta weights and 95% confidence intervals for all variables. At Step 1, depression accounted for < 1% of the variance in updating effectiveness, *R* < .01, *F* < 1. At Step 2, with the addition of the main effects the model accounted 10% of the variance in effectiveness, *R* = .31, the increment was significant, $\Delta R^2 = .10$, ΔF (3, 85) = 3.01, *p* = .034, and the model approached significance, *F* (4, 89) = 2.26, *p* = .069. Situational stress accounted for 6% of the unique explainable variance in updating effectiveness; those who performed under ego threat instructions were less effective on the updating task than those in the ego safe condition, *t* = 2.32, *p* = .022. With the inclusion of the two-way interaction terms at Step 3, the model accounted for 11% of variance in the criterion, *R* = .33, however the increase in explainable variance $\Delta R^2 = .01$, $\Delta F < 1$, and the overall model were not significant *F* (7, 89) = 1.46, *p* = .194. At Step 4, the addition of the three-way interaction term meant the overall model accounted for 11% of the variance in updating effectiveness, *R* = .33, however the increment, $\Delta R^2 < .01$, $\Delta F < 1$, and full model, *F* (8, 89) = 1.26, *p* = .276, were not significant.

Updating Efficiency

The unstandardised coefficients, beta weights and 95% confidence intervals for all variables are shown in Table 34. Depression accounted for < 1% of the variance in updating efficiency at Step 1, *R* = .01, *F* <1. At Step 2, the model accounted for 7% of the variance in efficiency, *R* = .27, however the increment, $\Delta R^2 = .07$, ΔF (3, 85) = 2.25, *p* = .089, and model failed to reach significance, *F* (4, 89) = 1.68, *p* = .161. At Step 3, the model accounted for 16%

Table 33.
Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Updating Effectiveness

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	47.47	6.21		35.12	59.81
	Depression	-.01	.59	-.00	-1.19	1.17
Step 2	(Constant)	52.59	7.27		38.13	67.04
	Depression	-.68	.78	-.12	-2.25	.89
	Cognitive Trait Anxiety	1.52	1.06	.21	-.59	3.63
	Situational Stress	9.85	4.24	.25	1.42	18.27
	Motivation	1.26	1.18	.11	-1.07	3.60
Step 3	(Constant)	52.76	7.41		38.01	67.51
	Depression	-.73	.81	-.13	-.234	.88
	Cognitive Trait Anxiety	1.35	1.14	.18	-.91	3.61
	Situational Stress	10.71	4.35	.27	2.07	19.35
	Motivation	1.78	1.28	.16	-.76	4.33
	Cognitive Trait Anxiety X Situational Stress	.33	.83	.05	-1.31	1.98
	Situational Stress X Motivation	-.29	1.23	-.03	-2.74	2.16
	Cognitive Trait Anxiety X Motivation	.31	.27	.14	-.23	.86
Step 4	(Constant)	52.71	7.71		37.37	68.04
	Depression	-.72	.83	-.13	-2.38	.93
	Cognitive Trait Anxiety	1.35	1.19	.18	-1.03	3.72
	Situational Stress	10.72	4.38	.27	2.00	19.44
	Motivation	1.78	1.29	.16	-.77	4.34
	Cognitive Trait Anxiety X Situational Stress	.34	.85	.05	-1.35	2.02
	Situational Stress X Motivation	-.31	1.36	-.03	-3.00	2.39
	Cognitive Trait Anxiety X Motivation	.31	.28	.13	-.24	.87
	Cognitive Trait Anxiety X Situational Stress X Motivation	-.01	.29	-.00	-.58	.56

$p < .05$*

Table 34.
Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Updating Efficiency

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	3.30	.27		2.76	3.85
	Depression	-.00	.03	-.01	-.05	.05
Step 2	(Constant)	3.43	.32		2.79	4.08
	Depression	-.02	.04	-.07	-.09	.05
	Cognitive Trait Anxiety	.04	.05	.12	-.06	.13
	Situational Stress	.50	.19	.27	.10	.85
	Motivation	-.05	.05	-.10	-.15	.05
Step 3	(Constant)	3.42	.32		2.79	4.05
	Depression	-.02	.04	-.06	-.08	.05
	Cognitive Trait Anxiety	.01	.05	.02	-.09	.10
	Situational Stress	.56	.19	.32	.19	.93
	Motivation	.00	.06	.00	-.11	.11
	Cognitive Trait Anxiety X Situational Stress	.04	.04	.12	-.03	.11
	Situational Stress X Motivation	-.09	.05	-.19	-.20	.01
	Cognitive Trait Anxiety X Motivation	.03	.01	.29*	.01	.05
Step 4	(Constant)	3.37	.33		2.72	4.03
	Depression	-.01	.04	-.05	-.08	.06
	Somatic Trait Anxiety	-.00	.05	-.00	-.10	.10
	Situational Stress	.57	.19	.32	.20	.94
	Motivation	.00	.06	.00	-.11	.11
	Cognitive Trait Anxiety X Situational Stress	.04	.04	.13	-.03	.11
	Situational Stress X Motivation	-.11	.06	-.22	-.22	.01
	Cognitive Trait Anxiety X Motivation	.03	.01	.28	.01	.05
	Cognitive Trait Anxiety X Situational Stress X Motivation	-.01	.01	-.06	-.03	.02

$p < .05$*

of the variance in efficiency, R = .40 and there was a significant change in R^2, ΔR^2 = .09, ΔF (3, 82) = 2.87, p = .041, and the model also reached significance, F(7, 89) = 2.26, p = .037. The two-way interaction between cognitive trait anxiety x motivation explained 7% of the unique variance in updating efficiency which was significant, t = 2.49, p = .015. The pattern of this interaction is discussed below. The interactions between cognitive trait anxiety x situational stress and situational stress x motivation were not significant. At Step 4, the inclusion of the three-way interaction term meant the overall model accounted for 17% of the variance in the criterion, R = .41, however there was no significant change in R^2, $\Delta R^2 < .01$, $\Delta F < 1$. At Step 4 the full model remained marginally significant, F (8, 89) = 2.00, p = .057.

IRSE software (Meier, 2008) was used to decompose the two-way interaction between cognitive trait anxiety and motivation and conduct tests of simple slopes. Figure 8 shows the pattern of the interaction plotted at ± 1 SD from the mean score of cognitive trait anxiety and motivation. As can be seen, higher cognitive trait anxiety was associated with higher updating efficiency at higher motivation, β = .20, t = 3.56, p = .001, whereas higher cognitive trait anxiety was related to lower efficiency at lower motivation, β = -.20, t = 2.42, p = .018.

Discussion of Anxiety and Updating Performance

Study 2.1 investigated the relationships between cognitive trait anxiety and situational stress on updating effectiveness and efficiency. The predictions followed those specified by ACT which suggests that anxiety impairs the updating function under stressful conditions. Specifically, updating effectiveness deficits may not be evident under conditions in which anxious individuals are able to invest additional cognitive resources such as mental effort and/or motivation on the task, however the effort cost is revealed as poorer updating efficiency. Accordingly, separate analyses were carried out to explore whether mental effort (Study 2.1.1) and motivation (Study 2.2) moderated the relationships between anxiety, stress and updating performance.

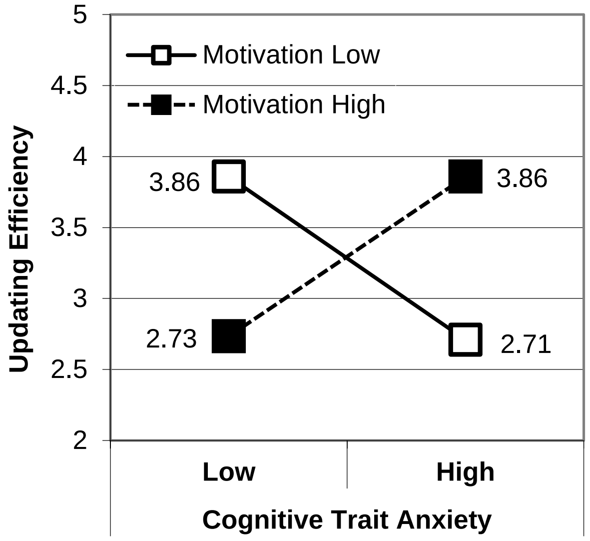

Figure 8. Relationship between cognitive trait anxiety, motivation and updating efficiency.

Study 2.1.1 tested the prediction that updating effectiveness would vary independently of the combined associations between cognitive trait anxiety, situational stress and mental effort. The data supported this prediction as there were no combined or moderated links between trait anxiety, situational stress, and effort on updating effectiveness. There were however significant unique main effects between mental effort and effectiveness, and situational stress and effectiveness. Specifically, higher effort predicted higher effectiveness, and poorer effectiveness was associated with higher situational stress (ego threat), relative to lower stress (ego safe).

Although the data from Study 2.1.1 are consistent with other studies that did not observe anxiety-related deficits in performance accuracy using both the *n*-back (e.g., Walkenhorst & Crowe, 2009; Wong et al., 2013) and reading span (e.g., Harris & Cumming, 2003) tasks, they are in contrast to other studies reporting that higher anxiety was associated with poorer accuracy the reading span task (e.g., Calvo et al., 1992; Darke, 1988; Sorg & Whitney, 1992). Perhaps the differences between results reported in the present experiment and those reported by Darke, Calvo et al., and Sorg and Whitney might be explained by the different indices of anxiety used. For example, Darke examined test anxiety and situational stress (manipulated using ego threat instructions), Calvo et al. investigated test anxiety and situational stress (manipulated using ego threat instructions), Sorg and Whitney included trait anxiety and situational stress (manipulated by playing competitive video games), whereas Study 2.1.1 used a measure of cognitive trait anxiety and ego threat instructions. Given the different measures of anxiety and stress manipulations employed across studies, it seems plausible that subtle variations in how these factors are operationalised might have a profound effect on the probability of revealing anxiety-related deficits in updating effectiveness.

Importantly however, there are now two confirmed reports demonstrating that poorer updating effectiveness might be more closely linked to situational stress than trait anxiety. For example, the data from Study 2.1.1 revealed a significant unique relationship between situational stress and effectiveness such that those in the ego threat condition were less effective on last word recall performance than those in the ego safe condition. These data are conceptually consistent with those reported by Vytal et al. (2012) who found lower performance effectiveness on the *n*-back task in those participants who performed under stressful conditions, relative to those who performed under low stress conditions. Considered together, these results suggest that situational stress alone might be an important predictor of updating effectiveness. Although it is tempting to conclude that this relationship is somewhat robust as it holds across different measures of updating (i.e., the n-back and reading span tasks), further replications of these data across tasks is required before this explanation can gain further acceptance.

Updating efficiency did not vary as a function of trait anxiety, situational stress, mental effort, or their interactions, and as such, did the data did not support the predictions of ACT. In the absence of published performance efficiency data from studies employing the reading span task, the results of the present study were compared to data derived from earlier work using the *n*-back task. The results from Study 2.1.1 are inconsistent with those reported Wong et al. (2013) who found that highly trait anxious individuals took longer to identify previously presented items on the *n*-back relative to their low-anxious counterparts. Although the exact reasons for the differential patterns of data between Study 2.1.1 and Wong et al. are unclear, perhaps the most parsimonious explanation might lie in the different tasks (reading span vs. *n*-back) and indices of updating efficiency used (their index was RT, whereas the ratio of effectiveness to RT was used here). The present efficiency results are however consistent with other studies that did not report anxiety-linked updating efficiency deficits (e.g., Fales et al., 2008; Vytal et al., 2012; Walkenhorst & Crowe, 2009, Study 1.2). Together, these data suggest that the relationships between trait anxiety, situational stress and updating effectiveness are not robust, and are likely sensitive to subtle differences in the indices of anxiety, tasks, and measures of effectiveness employed.

It is important to note that mental effort was a positive predictor of updating effectiveness, such that those who reported greater effort were more effective on the updating task. Although these data are consistent with the notion that effort improves performance accuracy, there was no evidence that trait anxiety and/or situational stress were positively associated with effort. Notwithstanding a potential floor effect in the Study 1.2 data, the results from Study 2.1.1 also failed to find interactive relationships between trait anxiety, situational stress and mental effort on updating performance despite using an easier task and subsequently more sensitive measures of effectiveness and efficiency. Therefore, the data from the two studies reported in the present thesis (Study 1.2 and Study 2.1.1) suggest that trait anxiety, situational stress, and mental effort do not interact in such a way as to affect the performance of highly anxious individuals in the manner specified by ACT.

Study 2.1.2 examined whether motivation buffered the relationship between trait anxiety, situational stress and updating performance. In accord with the assumptions of ACT, it was hypothesised that trait anxiety, situational stress and motivation would not interact to predict updating effectiveness. It was also hypothesised high trait anxiety would be associated with lower efficiency when performing under ego threat instructions, and that this relationship would be restricted to those who reported lower task motivation.

Consistent with the prediction for updating effectiveness, the results suggested that trait anxiety, situational stress, and motivation did not interact to predict performance accuracy on the reading span task. Although these data are incongruent with those reported by Hayes et al. (2009) who found that high anxious individuals performed better in an incidental learning paradigm under high motivational conditions than did less motivated participants, they are consistent with Calvo (1985) who reported that anxiety and motivation were unrelated to performance on a reasoning task. These data suggest that performance effectiveness on tasks requiring ongoing concentration (updating and reasoning) is less sensitive to anxiety and motivation than are tasks in which performance is ancillary.

The prediction for updating efficiency was partially supported. The data indicated that motivation and cognitive trait anxiety interact to predict efficiency, but that this relationship is not further moderated by situational stress. The observed interaction was such that at higher motivation, higher trait anxiety predicted greater efficiency, whereas at lower motivation, higher trait anxiety was associated with poorer efficiency. It was not possible to reconcile the updating efficiency data with previous empirical investigations into the relationship between anxiety, motivation and updating, as neither Calvo nor Hayes et al. included RT in their measures. In related work however, Eysenck (1985) reported that high trait anxious individuals' mean solution times on correct trials (efficiency) on a letter transformation task did not differ between low and high motivation conditions. Although these results are discordant from the updating efficiency data reported in the present study, the task employed by Eysenck was not an assessment of updating, but rather a computation task involving multiple components of working memory. The data reported in the present study are the first to confirm a relationship between trait anxiety and updating efficiency, and that this relationship is moderated by motivation.

Despite revealing the important role of motivation in updating effectiveness and efficiency, there are some important theoretical considerations with respect to the operationalisation of this construct that require consideration. For example, Humphreys and Revelle (1984) suggest that motivation has both a personality and a situational dimension, such that individuals with high trait-like motives (to achieve) are also prone to increased achievement motivation when faced with an achievement-situation. Motives (personality trait) may therefore vary with trait anxiety and updating performance. Despite employing the HWK to index goal-directed achievement motivation for the current task, the absence of a measure of trait-motives makes this notion purely speculative. As such, future studies should explore the motive-motivation connection and how these factors relate to anxiety and updating performance.

In summary, Study 2.1 investigated systematically whether cognitive trait anxiety and situational stress interact to predict updating effectiveness and efficiency, and whether these relationships were further moderated by mental effort (Study 2.1.1) and motivation (Study 2.1.2). The results afforded only partial support for ACT. Specifically, the updating effectiveness data indicated that performance deficits manifest under high stress conditions, whereas the efficiency data confirmed that trait anxiety and motivation interact to predict updating efficiency. In accord with ACT, higher trait anxiety and higher motivation combined to predict more efficient updating, whereas higher trait anxiety and lower motivation were associated with poorer efficiency. Importantly, the present procedures were able to confirm that it is motivation, rather than effort, that plays an important role in moderating the relationship between anxiety and updating efficiency.

Study 2.2: Anxiety and Inhibitory Threat Differentiation

Study 2.2 examined the separate and combined relationships between cognitive trait anxiety, situational stress, motivation and inhibitory control, using a Go-No-Go task that included an equal proportion of neutral and threat-related words. Cognitive trait anxiety was indexed by the cognitive dimension of the STICSA (Ree et al., 2000), situational stress was induced using ego-threat instructions, and motivation operationalised using the HWK (Klein et al., 2001). In order to develop an inhibitory control measure for threat words relative to neutral words, a threat differential index was calculated. For inhibitory effectiveness the index was derived by contrasting the quality of performance on threat relative to neutral words (inhibitory effectiveness index), whereas the efficiency index was determined using the effectiveness index divided by the difference between RTs on threat words compared to neutral words (inhibitory efficiency index). These measures are described more fully below.

Hypotheses

After controlling for depression, the predictions were derived from ACT (see Chapter 1) which suggests that anxiety impairs the inhibition function and that impairments are greater in the presence of threat- relative to neutral- stimuli. Furthermore threat inhibitory deficits were predicted to be more pronounced on the measure of efficiency than effectiveness. Thus, no relationship between cognitive trait anxiety, situational stress, motivation and the inhibitory effectiveness index was predicted. However, the efficiency of threat inhibition was expected to vary with the inter-relationships between trait anxiety, situational stress, and motivation, such that higher trait anxiety would predict poorer threat inhibition efficiency, and that this relationship would be restricted to those who reported lower motivation in the ego threat condition.

Measurement of Inhibitory Threat Differentiation

Inhibitory effectiveness index. A threat differential index was created to enable a comparison of inhibitory effectiveness on threat words relative to neutral words in the Go-No-Go task. As in Study 1.3, inhibitory effectiveness was indexed as the stimulus sensitivity parameter from signal detection theory (*d'*; Pastore & Scheirer, 1974; see Stanislaw & Todorov, 1999 for a review), and accordingly, inhibitory effectiveness scores for threat and neutral words were calculated separately (i.e., d'_{threat} & $d'_{neutral}$). The inhibitory effectiveness index was calculated by deducting the measure of effectiveness for neutral words from effectiveness for threat words, such that negative scores represented poorer inhibitory effectiveness on threat words compared to neutral words, whereas positive scores represented better performance on threat words relative to neutral words. The following equation was used to calculate the threat effectiveness index:

$$\textit{Inhibitory Effectiveness Index} = d'_{threat} - d'_{neutral}$$

NOTE:

d'_{threat} = inhibitory effectiveness on threat words (see Study 1.3)

$d'_{neutral}$ = inhibitory effectiveness on neutral words (see Study 1.3)

Inhibitory efficiency index. To contrast inhibitory efficiency for threat words with neutral words in the Go-No-Go task, an inhibitory efficiency index was created. In accordance with Study 1.3, inhibitory efficiency was indexed as the relationship between stimulus sensitivity and RT on Correct Go trials, hence efficiency scores for threat words and neutral words were calculated separately. The inhibitory efficiency index was calculated by deducting the measure of inhibitory efficiency for neutral words from the efficiency for threat words. Following the inhibitory effectiveness index described above, negative inhibitory efficiency index scores represented poorer inhibitory efficiency on threat relative to neutral words trials, whereas positive scores were indicative of more efficient inhibitory processing on threat trials that neutral trials. The inhibitory efficiency index was calculated using the following equation:

$$\text{Inhibitory Efficiency Index} = \left[\frac{d'_{threat}}{\text{Mean RT on Correct Go Trials}_{threat}} - \frac{d'_{neutral}}{\text{Mean RT on Correct Go Trials}_{neutral}} \right] X\ 1000$$

Participants

The same sample from Study 2.1 was used; 90 undergraduate psychology students aged between 17 and 56 years (*M* = 27.67 years; *SD* = 11.81) participated (74 were female).

Validity of SRQ as an Index of Situational Stress

As the same sample was employed as for Study 2.1, support for the SRQ as an appropriate index of situational stress in the sample was established earlier (i.e., positive correlation between SRQ scores at baseline and STICSA State Cognitive scale, see Study 2.1).

Manipulation Check

To determine the efficacy of the ego-threat instructions as a means of elevating situational stress, SRQ scores were used as the dependent variable in a 2 x 2 repeated measures ANOVA with Time (baseline vs. post-manipulation) and Group (ego threat vs. ego safe) as the factors. The main effect of Group was not significant, $F(1, 89) = 3.58$, $MSE = 29.97$, $p = .068$, $\eta^2 = .04$, however the main effect of Time, $F(1, 89) = 12.58$, $MSE = 17.48$, $p = .001$, $\eta^2 = .13$, and the Time x Group interaction, $F(1, 89) = 4.81$, $p = .031$, $\eta^2 = .05$, were significant. Follow up *t*-tests revealed that whereas there was no difference in composite SRQ scores between the ego threat (*M* = 12.89, *SD* = 6.80) and ego safe (*M* = 12.04, *SD* = 5.50) groups at baseline, $t < 1$, following the ego threat instructions individuals in the ego threat condition (*M* = 16.42, *SD* = 7.16) had significantly higher SRQ scores than those in the ego safe condition (*M* = 12.84, *SD* = 5.20), $t(1, 88) = 2.68$, $p = .009$. Thus the effectiveness of the manipulation was confirmed.

Results

Data Diagnostics and Assumption Checking

Data cleaning procedures were the same as in Study 1.3, such that RT < 200 ms were considered anticipatory and were removed as were RTs ± 3 *SD* from each participant's mean score (< 1% of trials). No univariate or multivariate outliers were identified (using the same criteria as Study 1.3) leaving a final data set of 90 participants (*N* = 90).

Descriptive Statistics

Table 35 shows the means, standard deviations, zero-order and inter-correlations of depression, cognitive trait anxiety, motivation, performance effectiveness threat differential index and processing efficiency threat differential index. As seen in the table, there was a significant positive inter-correlation between depression and cognitive trait anxiety, such that those who reported higher symptoms of depression also tended to report higher cognitive trait anxiety. There were significant zero-order correlations between motivation and inhibitory effectiveness and efficiency threat differential indices; those who reported higher motivation performed with better inhibitory effectiveness and efficiency for threat words relative to neutral words.

Table 35.

Means, Standard Deviations, Zero-order and Inter-correlations of Depression, Cognitive Trait Anxiety, Motivation, Inhibitory Effectiveness Index and Inhibitory Efficiency Index on the Go-No-Go Task.

	M	*SD*	Depression	Cognitive Trait Anxiety	Motivation
Depression	7.51	7.27			
Cognitive Trait Anxiety	18.10	5.47	.68***		
Motivation	20.88	3.83	-.06	.11	
Inhibitory Effectiveness Index	.03	.86	-.06	.08	.23*
Inhibitory Efficiency Index	.10	1.75	.05	.07	.22*

NOTE: $p < .001$***, $p < .05$*

Main Analyses

To determine whether cognitive trait anxiety, situational stress, motivation and their interactions predicted scores on the threat differential effectiveness and efficiency indices, separate moderated regression analyses were conducted on each measure. For these analyses, depression was entered at Step 1, the main effects (cognitive trait anxiety, situational stress, and motivation) were included at Step 2, the two-way interactions terms were entered at Step 3, and the three-way interaction (cognitive trait anxiety x situational stress, x motivation) was included at Step 4. Mean centred scores were used to calculate the multiplicative interaction terms.

Inhibitory Effectiveness Index

Table 36 shows the unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step of the model. Depression was

Table 36.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Inhibitory Effectiveness Index

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	-.02	.13		-.28	.25
	Depression	.01	.01	.06	-.02	.03
Step 2	(Constant)	-.02	.16		-.34	.30
	Depression	.01	.02	.06	-.03	.04
	Cognitive Trait Anxiety	.00	.02	.01	-.05	.05
	Situational Stress	.00	.10	.00	-.18	.18
	Motivation	.05	.03	.23	.00	.10
Step 3	(Constant)	.03	.16		-.28	.34
	Depression	.01	.02	.07	-.03	.04
	Cognitive Trait Anxiety	.01	.02	.06	-.04	.06
	Situational Stress	-.01	.09	-.01	-.18	.17
	Motivation	.02	.03	.07	-.04	.07
	Cognitive Trait Anxiety X Situational Stress	.00	.02	.03	-.03	.04
	Situational Stress X Motivation	-.05	.03	-.21*	-.10	.00
	Cognitive Trait Anxiety X Motivation	-.01	.01	-.23	-.02	.00
Step 4	(Constant)	.04	.16		-.28	.35
	Depression	.01	.02	.06	-.03	.04
	Cognitive Trait Anxiety	.01	.02	.07	-.04	.06
	Situational Stress	-.01	.09	-.01	-.19	.17
	Motivation	.02	.03	.07	-.04	.07
	Cognitive Trait Anxiety X Situational Stress	.00	.02	.02	-.03	.04
	Situational Stress X Motivation	-.04	.03	-.19	-.10	.01
	Cognitive Trait Anxiety X Motivation	-.01	.01	-.21	-.02	.00
	Cognitive Trait Anxiety X Situational Stress X Motivation	.00	.01	.06	-.01	.02

$p < .05$*

entered at Step 1, and accounted for < 1% of the variance in effectiveness threat differentiation, R = .06, F < 1. The main effects were added at Step 2, and accounted for 6% of the variance in threat differentiation, R = .24, however the increment, ΔR^2 = .06, $\Delta F(3, 85)$ = 1.66, p = .182, and model, $F(4, 89)$ = 1.31, p = .272, were not significant. At Step 3, the contribution of the two-way interaction terms meant the model accounted for 15% of the variance in the criterion, R = .39, and the increment in explainable variance was significant, ΔR^2 = .09, ΔF (3, 82) = 3.00, p = .035, and the model was significant, $F(7, 89)$ = 2.19, p = .043. There was a significant two-way interaction between situational stress x motivation that accounted 4% of variance in efficiency (see below). The cognitive trait anxiety x situational stress interaction and the cognitive trait anxiety x motivation interaction were not significant. At Step 4, with the inclusion of the three-way interaction term, the overall model accounted for 15% of the variance in the threat differentiation effectiveness, R = .39, however the increment, ΔR^2 < .01, $\Delta F(1, 81)$ < 1, and the overall model were not significant, $F(8, 89)$ = 1.83, p = .083.

To decompose the two-way interaction between situational stress and motivation, tests of simple slopes were performed using the IRSE program (Meier, 2008). Figure 9 shows the pattern of the interaction plotted at ± 1 *SD* from the mean score on motivation at each level of situational stress (ego safe vs. ego threat). As seen in the figure, there was a trend for higher motivation to be associated with poor inhibitory effectiveness on threat relative to control trials in both the ego safe and ego threat conditions. The reliability of these effects however, failed to reach significance in ego safe and ego threat conditions, β = .17, t = 1.16, p = .248, β = -.20, t = 1.34, p = .184, respectively.

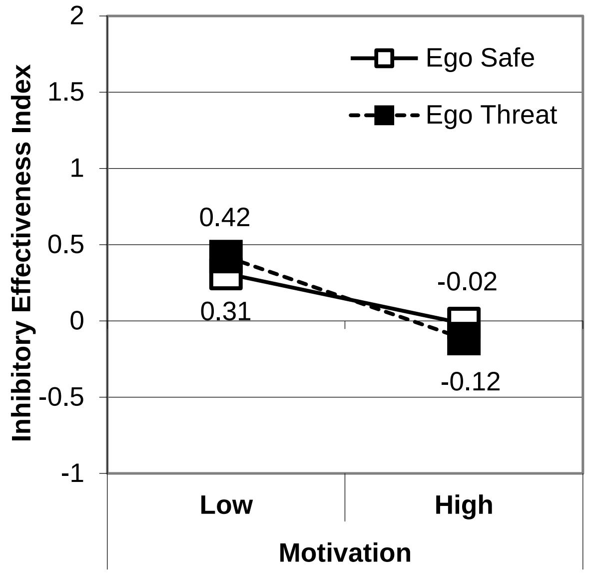

Figure 9. Relationship between cognitive trait anxiety, motivation, and inhibitory effectiveness index. (*Note*: Negative scores represent poorer inhibitory effectiveness on threat relative to neutral words, whereas positive scores represent better inhibitory effectiveness on threat compared to neutral words).

Inhibitory Efficiency Index

Table 37 displays the unstandardised coefficients, beta weights and 95% confidence intervals for all variables at each step. At Step 1, depression accounted for < 1% of the variance in the threat inhibitory efficiency index, $R = .05$, $F < 1$. At Step 2, with the inclusion of the main effects the model accounted for 5% of the variance in threat inhibitory efficiency, $R = .23$, however the increment was not significant, $\Delta R^2 = .05$, ΔF (3, 85) = 1.53, $p = .212$, and the overall model was not significant, F (4, 89) = 1.21, $p = .311$. At Step 3, with the inclusion of the two-way interaction terms, the model accounted for 15% of the variance in the criterion, $R = .38$. The increment in explainable variance, $\Delta R^2 = .09$, ΔF (3, 82) = 2.93, $p = .039$, and full model were significant, F (7, 89) = 2.02, $p = .046$.

Table 37.

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Inhibitory Efficiency Index

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	.00	.27		-.53	.53
	Depression	.10	.03	.05	-.04	.06
Step 2	(Constant)	-.01	.32		-.65	.63
	Depression	.02	.04	.06	-.06	.09
	Cognitive Trait Anxiety	.00	.05	.01	-.09	.10
	Situational Stress	-.01	.19	-.01	-.38	.36
	Motivation	.10	.05	.23	.00	.20
Step 3	(Constant)	.09	.32		-.54	.08
	Depression	.02	.03	.07	-.05	.08
	Cognitive Trait Anxiety	.01	.05	.04	-.08	.11
	Situational Stress	-.02	.18	-.01	-.38	.34
	Motivation	.03	.06	.07	-.08	.14
	Cognitive Trait Anxiety X Situational Stress	.10	.04	.03	-.06	.08
	Situational Stress X Motivation	-.10	.05	-.22*	-.20	-.00
	Cognitive Trait Anxiety X Motivation	-.02	.01	-.21	-.05	.00
Step 4	(Constant)	.09	.32		-.54	.73
	Depression	.02	.04	.07	-.05	.08
	Cognitive Trait Anxiety	.02	.05	.05	-.08	.11
	Situational Stress	-.02	.18	-.01	-.39	.34
	Motivation	.03	.06	.07	-.08	.14
	Cognitive Trait Anxiety X Situational Stress	.01	.04	.02	-.06	.08
	Situational Stress X Motivation	-.10	.06	-.21	-.21	.02
	Cognitive Trait Anxiety X Motivation	-.02	.01	-.20	-.05	.01
	Cognitive Trait Anxiety X Situational Stress X Motivation	.00	.01	.03	-.02	.03

p < .05*

The situational stress x motivation interaction accounted significantly and uniquely for 4% of the variance in threat inhibitory efficiency. The pattern of this two-way interaction is described below. The cognitive trait anxiety x situational stress and cognitive trait anxiety x motivation interactions failed to reach significance. At Step 4, the three-way interaction term did not add significantly to the explainable variance in threat inhibitory efficiency, $\Delta R^2 = .00$, ΔF (1, 81) < 1, and the full model which accounted for 15% of the variance in the criterion, *R* = .38, was not significant, *F* (8, 89) = 1.73, *p* = .103.

IRSE (Meier, 2008) software was used to interpret the pattern of the situational stress x motivation interaction and perform tests of simple slopes at high and low values on the motivation scale (calculated at ± 1 *SD* from the mean score on each). Figure 10 shows the pattern of the interaction. As shown in the figure, at both levels of situational stress there was a tendency for higher motivation to be related to poorer inhibitory efficiency on threat relative to neutral trials. In the ego safe condition however, this effect failed to reach significance, β = .77, *t* = 1.76, *p* = .081, whereas in the ego threat condition higher motivation was related to significantly poorer inhibitory efficiency for threat words relative to neutral words, β = -.85, *t* = 2.16, *p* = .034.

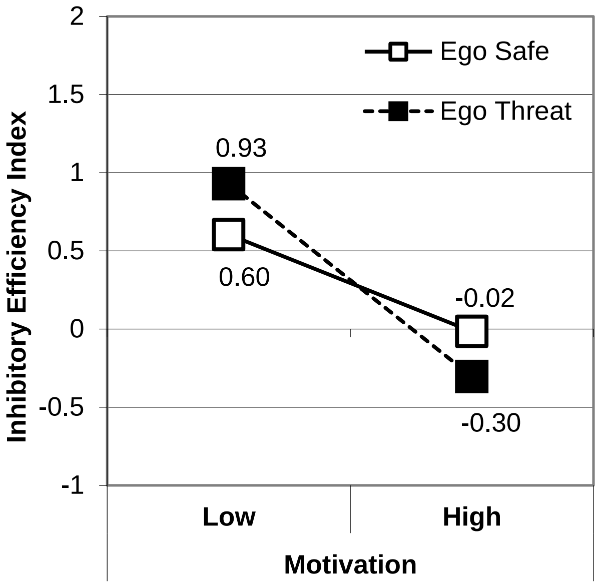

Figure 10. Relationship between cognitive trait anxiety, motivation, and inhibitory efficiency index. (*Note*: Negative scores represent poorer inhibitory efficiency for threat relative to neutral words, whereas positive scores represent better inhibitory efficiency for threat compared to neutral words).

Discussion of Anxiety and Inhibitory Threat Differentiation

Study 2.2 investigated whether cognitive trait anxiety, situational stress, and motivation would interact to predict the effectiveness and efficiency with which inhibitory responses to threat relative to neutral stimuli were made. A modified version of the Go-No-Go task that included both threat-related and neutral words was employed, and the hypotheses were derived from ACT. For inhibitory effectiveness it was predicted that cognitive trait anxiety, stress and motivation would not interact to predict the effectiveness (accuracy) of inhibitory responses on threat relative to control words trials (as measured by the threat inhibitory effectiveness index). For inhibitory efficiency, a trait anxiety x situational stress x motivation interaction was predicted such that higher trait anxiety would be associated with poorer threat inhibition, and that this relationship would be restricted to those who reported lower motivation in the ego threat condition (as measured on the threat inhibitory efficiency index). Contrary to the hypotheses, the data revealed conceptually similar response patterns for the inhibitory effectiveness and efficiency measures. Situational stress and motivation interacted to predict differential inhibitory effectiveness and efficiency, and these results were not moderated by cognitive trait anxiety.

The data suggested that higher motivation was associated with poorer inhibitory effectiveness on threat relative to neutral word trials in both the ego threat and ego safe conditions. Despite the fact the motivation x situational stress interaction was significant, the tests of the simple slopes were not reliable, making interpretation of these data difficult. The efficiency data were somewhat less complex. The efficiency of response inhibition on threat- relative to neutral word trials was poorer for individuals under higher situational stress who reported higher motivation. Motivation did not predict differential threat efficiency for individuals in the ego safe condition.

Procedural and task differences across studies make reconciliation of previous data with those reported here somewhat difficult. For example, Edwards et al. (2006) reported data indicating that trait anxiety and situational stress interacted to predict threat inhibitory efficiency. Using a modified version of the emotional Stroop task, their results suggested that higher trait anxiety was related to poorer inhibitory efficiency on threat relative to neutral words trials, and that this effect was restricted to conditions in which situational stress was high (manipulated using threat of electric shock). The present data, however, suggested that threat inhibitory efficiency was more closely related to higher situational stress and lower motivation, rather than trait anxiety. The results from Study 2.2

also contradict the data reported by Derakshan, Ansari et al. (2009) who employed the antisaccade task as their measure of inhibitory control. Their results suggested that those higher in trait anxiety had longer RTs on threat-related than neutral trials (threat differentiation efficiency) relative to those lower in trait anxiety. In that study differences in error rates on the threat and neutral word trials between high and low anxious individuals (threat differentiation effectiveness) were not significant.

A number of methodological differences may explain discrepancies in the data patterns between the present study and those reported by Edwards et al. (2006) and Derakshan, Ansai et al. (2009). For example, these studies employed different tasks (Stroop vs. antisaccade vs. Go-No-Go), manipulations of situational stress (shock threat vs. absent vs. ego threat), measures of trait anxiety (trait anxiety scale from the STAI vs. Trait-Cognitive Scale from the STICSA), and indices of inhibitory threat processing (RT alone vs. ratio of effectiveness divided by RT). Perhaps most importantly, these previous investigations did not include a measure of motivation in their modelling.

Study 1.3 investigated the relationship between cognitive trait anxiety, situational stress, and mental effort on inhibitory control using the Go-No-Go task and neutral words as stimuli. In that experiment, mental effort was a significant moderator of the relationship between trait anxiety and situational stress on both the effectiveness and efficiency measures. Higher trait anxiety was associated with lower inhibitory effectiveness for those who reported higher effort in the low stress condition. Higher trait anxiety was also predictive of lower inhibitory efficiency for those who reported higher effort, irrespective of situational stress. It is important to note that in the current study poorer threat response inhibition was restricted to those individuals who reported higher motivation in the high stress condition. Taken together, the data across both studies confirm that higher effort (Study 1.3) and motivation (present study) were each associated with poorer inhibitory efficiency, and that higher motivation is associated with reduced effectiveness and efficiency on threat relative to neutral trials. These results are somewhat problematic for the assumptions of ACT that predict effort and motivation should buffer against the effects of trait anxiety and stress on cognitive tasks. Although these factors protect against poorer performance on phonological (Study 1.1) and other executive tasks such as updating (Study 2.1.2) and shifting (Edwards, Edwards et al., 2015; Study 1.4), they have tended to have the reverse effect on the inhibitory processes as measured by the tasks employed in the present thesis.

The exact reasons why higher effort and motivation were associated with poorer inhibitory performance is unclear, particularly given that motivation was a prospective measure (current study) and effort was reported following the task (Study 1.3). As suggested by Kurzban et al. (2013), higher effort might be associated with lower performance on repetitive tasks that involve attending to two or more criteria at once. If the Kurzban et al. account is accepted as an explanation for the inverse relationship between effort and performance observed in Study 1.3, the present data also suggest that this relationship might extend to the association between prospective motivation and inhibitory performance. Alternatively, the effects of motivational effort might be understood in terms of response demand conflict, such that higher effort is associated with an increase in arousal initiated by the requirement to respond as quickly as possible. If this were the case, higher effort would predict poorer performance as observed here.

The finding that motivation plays a key role in the link between anxiety, inhibition and attentional bias for threat should prompt further research to use methodological designs capable of elucidating the influence of other factors that vary with trait anxiety and with inhibitory processing of threat. For example, studies have demonstrated that working memory capacity is related to attentional control (see McCabe, Roediger III, McDaniel, Balota & Hambrick, 2010) and capacity has also been shown to be associated with anxiety and performance on cognitive tasks such as antisaccade (e.g., Unsworth, Schrock, & Engle, 2004), achievement (e.g., Owens, Stevenson, Hadwin & Norgate, 2012) and dual-task paradigms (e.g., Edwards, Moore et al., 2015; Johnson & Gronlund, 2009). Similarly, a recent study has shown that cognitive load is associated with performance and varies disproportionately for anxious relative to non-anxious individuals (e.g., Berggren, Richards, Taylor & Derakshan, 2013). Future research may benefit from exploring the effect of these factors using the Go-No-Go paradigm.

The present study provided a robust test of the associations between trait anxiety, situational stress and motivation on threat inhibitory control. Unlike previous investigations that have implicated trait anxiety as an important predictor of threat inhibition (e.g., Derakshan, Ansari et al., 2009; Edwards et al., 2006), the data reported here indicated that the effectiveness and efficiency with which an inhibitory response is made on threat relative to neutral trials is more closely related to situational stress and motivation. Although the data implicate these factors as important variables in the relationship between anxiety and cognitive control, they do not vary in the manner specified by ACT. Future conceptual replications of these results across other inhibition tasks, and measures of motivation and stress, will necessitate appropriate modifications to future iterations of ACT, at least in terms of inhibitory control.

Study 2.3: Anxiety and Shifting Threat Differentiation

Study 2.3 investigated the inter-relationships between cognitive trait anxiety, situational stress, motivation and shifting threat differentiation, using a WCST task that included both neutral and threat-related words. In accord with Study 2.2, cognitive trait anxiety was measured using the cognitive dimension of the STICSA (Ree et al., 2000), situational stress was manipulated using ego-threat instructions, and motivation was operationalised as scores on the HWK (Klein et al., 2001). In order to examine shifting threat differentiation (shifting performance on threat words relative to neutral words), shifting effectiveness and efficiency indices were created. These measures are described below.

Hypotheses

Unlike the inhibition function, ACT does not make precise predictions regarding the relationship between anxiety and the shifting function in the presence of threat. The hypotheses for Study 2.3, therefore, follow the general assumptions of ACT, such that performance deficits should more likely be observed on efficiency than effectiveness, and that anxiety impairs attentional control in the presence of threat. After controlling for depression, it was predicted that there would be no relationship between cognitive trait anxiety, situational stress and shifting effectiveness, however the inter-relationships between trait anxiety, situational stress, and motivation would predict poorer shifting efficiency (i.e., poorer processing of threat words relative to neutral words). Specifically, higher trait anxiety was expected to predict poorer shifting efficiency on threat relative to neutral trials, and this relationship would be restricted to those in the ego threat condition and who reported lower motivation.

Measurement of Shifting Threat Differentiation

Shifting effectiveness index. To contrast shifting effectiveness on threat words with neutral words using the WCST, a threat differential index was created. As in Study 1.4, performance effectiveness was indexed as the percentage of responses that were not perseverative errors (i.e., a measure of ability to shift; see Chapter 4). Shifting effectiveness scores were calculated for threat and neutral words separately, and the differential threat shifting effectiveness index was determined by deducting the measure of performance effectiveness for neutral words from performance effectiveness for threat words. As such, negative scores represent less effective shifting on threat relative to neutral words, whereas positive scores reflect more effective shifting on threat compared to neutral words. The following equation was used to calculate the threat differential index for shifting effectiveness:

$$\textit{Shifting Effectiveness Index} = \textit{Shifting Effectiveness}_{threat} - \textit{Shifting Effectiveness}_{neutral}$$

NOTE:

Shifting Effectiveness $_{threat}$ = shifting effectiveness on threat words (see Study 1.4)

Shifting Effectiveness $_{neutral}$ = shifting effectiveness on neutral words (see Study 1.4)

Shifting efficiency index. To compare shifting efficiency for threat words with neutral words in the WCST task, a differential threat shifting efficiency index was created. In accordance with Study 1.4, shifting efficiency was calculated as the inverse of an inability to shift, such that the ratio of the number of perseverative errors to mean RT on perseverative error trials was deducted from 1 (see Chapter 4, Study 1.4). The differential threat shifting efficiency index was calculated by deducting the measures of processing efficiency for neutral words from processing efficiency for threat words. Thus, negative scores represent less efficient shifting on threat relative to neutral words, whereas positive scores reflect more efficient shifting on threat compared to neutral word trials. The shifting efficiency threat differential index was calculated using the following equation:

$$\textit{Shifting Efficiency Index} = \textit{Shifting Efficiency}_{threat} - \textit{Shifting Efficiency}_{neutral}$$

NOTE:

$\textit{Shifting Efficiency}_{threat}$ = Processing Efficiency on threat words (see Study 1.4)

$\textit{Shifting Efficiency}_{neutral}$ = Processing Efficiency on neutral words (see Study 1.4)

Participants

The sample from Study 2.1 and Study 2.2 was used. Participants comprised 90 undergraduate psychology students aged between 17 and 56 years (*M* = 27.67 years; *SD* = 11.81; 74 were female).

Validity of SRQ as an Index of Situational Stress

In accord with Study 2.1 and Study 2.2, the SRQ was confirmed as an appropriate index of situational stress (i.e., positive correlation between SRQ scores at baseline and STICSA State Cognitive scale; see Study 2.1 & 2.2).

Manipulation Check

To determine the efficacy of ego-threat instructions as a reliable procedure for elevating situational stress, SRQ scores were used as the dependent variable in a 2 x 2 repeated measures ANOVA with Time (baseline vs. post-manipulation) and Group (ego threat vs. ego safe) as the factors. The main effect of Group was non-significant, however the main effect of Time, $F(1, 89) = 52.18$, $MSE = 18.52$, *p* < .001, η^2 = .37, and the Time x Group interaction, *F*(1, 89) = 4.99, *p* = .028, η^2 = .05, were significant. Follow up *t*-tests revealed that at baseline, there was no difference in composite SRQ scores between the ego threat (*M* = 12.89, *SD* = 6.80) and ego safe (*M* = 12.04, *SD* = 5.50) groups, *t* < 1, however following the ego threat instructions individuals in the ego threat condition (*M* = 18.91, *SD* = 7.84) had significantly higher SRQ scores than those in the ego safe condition (*M* = 15.24, *SD* = 6.62, *t*(1, 88) = 2.40, *p* = .019). The data confirmed the instructions to be an appropriate procedure for inducing situational stress.

Results

Data Diagnostics and Assumption Checking

Data cleaning and outlier screening procedures were the same as in Study 2.1 and 2.2. No univariate or multivariate outliers were identified, thus the full data set is reported (N = 90).

Descriptive Statistics

The means, standard deviations, zero-order and inter-correlations of depression, cognitive trait anxiety, motivation, shifting effectiveness threat differential index and shifting efficiency threat differential index are shown in Table 38. As shown, there was a significant positive inter-correlation between depression and cognitive trait anxiety, with higher depression related to higher cognitive trait anxiety. There were no significant zero-order correlations in the shifting data.

Main Analyses

Separate moderated regression analyses were performed to determine whether cognitive trait anxiety, situational stress, motivation and their interactions predicted scores on the differential threat shifting effectiveness index and differential threat shifting efficiency index. For both analyses, depression was included as a covariate at Step 1, the main effects (cognitive trait anxiety, situational stress, and motivation) were added at Step 2, the two-way interaction terms were included at Step 3, and at Step 4, the three-way interaction term (cognitive trait anxiety x situational stress, x motivation) was entered. Mean centred scores were used to calculate multiplicative interaction terms.

Table 38.

Means, Standard Deviations, Zero-order and Inter-correlations of Depression, Cognitive Trait Anxiety, Motivation, Shifting Effectiveness Index and Shifting Efficiency Index on the WCST.

	M	*SD*	Depression	Cognitive Trait Anxiety	Motivation
Depression	7.51	7.27			
Cognitive Trait Anxiety	18.10	5.47	.68***		
Motivation	20.66	3.41	.01	.16	
Shifting Effectiveness Index	-.75	6.72	-.05	.05	.14
Shifting Efficiency Index	-.56	2.78	-.06	.03	.17

NOTE: $p < .001$***

Shifting Effectiveness Index

The unstandardised coefficients, beta weights and 95% confidence intervals for all variables are displayed in Table 39. Depression was entered at Step 1, and accounted for < 1% of the variance in differential threat shifting effectiveness, $R = .05$, $F < 1$. The main effects were added at Step 2, and accounted for 3% of the variance in the criterion, $R = .17$; the increment in explainable variance, $\Delta R^2 = .03$, $\Delta F < 1$, and the model, $F < 1$, were not significant. At Step 3, the contribution of the two-way interaction terms meant the

Table 39.
Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Shifting Effectiveness Index

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	-.41	1.03		-2.44	1.63
	Depression	-.05	.10	-.05	-.24	.15
Step 2	(Constant)	.18	1.25		-2.30	2.66
	Depression	-.12	.14	-.13	-.40	.15
	Cognitive Trait Anxiety	.15	.19	.12	-.22	.52
	Situational Stress	-.13	.73	-.02	-1.58	1.33
	Motivation	.24	.22	.12	-.20	.67
Step 3	(Constant)	-.19	1.20		-2.58	2.19
	Depression	-.07	.13	-.08	-.33	.19
	Cognitive Trait Anxiety	.11	.18	.09	-.25	.47
	Situational Stress	-.32	.70	-.05	-1.71	1.08
	Motivation	.02	.22	.01	-.42	.46
	Cognitive Trait Anxiety X Situational Stress	-.44	.14	-.35*	-.71	-.16
	Situational Stress X Motivation	-.06	.21	-.03	-.48	.35
	Cognitive Trait Anxiety X Motivation	-.10	.05	-.24*	-.20	-.00
Step 4	(Constant)	-.24	1.2		-2.63	2.16
	Depression	-.07	.13	-.08	-.33	.19
	Cognitive Trait Anxiety	.08	.19	.06	-.29	.06
	Situational Stress	-.23	.71	-.03	-1.65	1.19
	Motivation	.02	.22	.01	-.42	.46
	Cognitive Trait Anxiety X Situational Stress	-.41	.14	-.33	-.69	-.13
	Situational Stress X Motivation	-.12	.22	-.06	-.56	.32
	Cognitive Trait Anxiety X Motivation	-.10	.05	-.24	-.20	-.00
	Cognitive Trait Anxiety X Situational Stress X Motivation	-.04	.05	-.09	-.13	.06

$p < .05$*

model accounted for 15% of the variance in the criterion, *R* = .39, and the change in R^2 was significant, ΔR^2 = .15, ΔF (3, 82) = 3.00, *p* = .012, and the model was significant, *F*(7, 89) = 2.18, *p* = .048. In terms of the unique contributions, the cognitive trait anxiety x situational stress (unique variance 10%), *t* = 3.16, *p* = .002, and cognitive trait anxiety x motivation (unique variance 4%), *t* = 2.06, *p* = .043, interactions were significant. The situational stress x motivation interaction was not significant, *t* < 1. The patterns of the significant interactions are discussed below. At Step 4, the three-way interaction term did not significantly increase R^2, *R* = .39, ΔR^2 = .01, *F* < 1, and the overall model which accounted for 16% of the variance in threat effectiveness differentiation was not significant, *F* (8, 89) = 1.87, *p* = .077.

IRSE (Meier, 2008) was used to decompose the two-way interactions and perform tests of simple slopes. Figure 11 shows the pattern of the two-way interaction between cognitive trait anxiety and situational stress, plotted at ± 1 *SD* from the mean score of cognitive trait anxiety at each level of situational stress (ego safe vs. ego threat). As can be seen in the figure, lower cognitive trait anxiety was associated with significantly better shifting effectiveness for threat compared to neutral words under ego threat relative to the ego safe condition, β = .30, *t* = 2.74, *p* = .007, whereas higher cognitive trait anxiety was predictive of significantly poorer shifting effectiveness for threat relative to neutral words under ego threat relative to the ego safe condition, β = -.37, *t* = 3.12, *p* = .003.

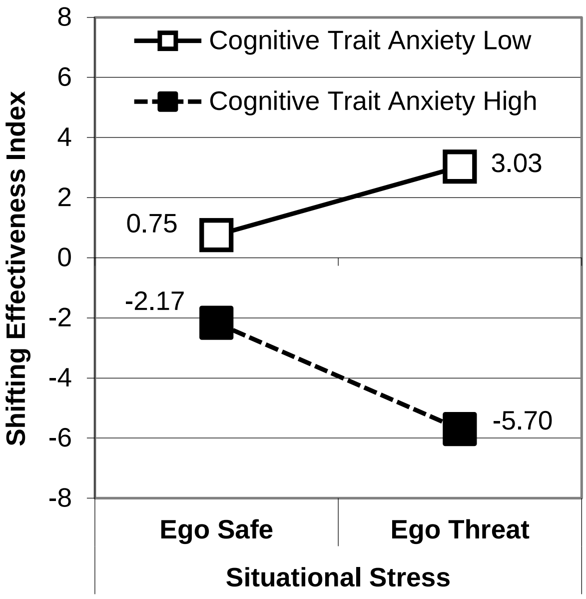

Figure 11. Relationship between cognitive trait anxiety, situational stress, and shifting effectiveness index. (*Note*: Negative scores represent poorer shifting effectiveness on threat relative to neutral words, whereas positive scores represent better shifting effectiveness on threat compared to neutral words).

The pattern of the two-way interaction between cognitive trait anxiety and motivation, plotted at ± 1 *SD* from the mean score of each variable, is displayed in Figure 12. As shown, there was a tendency for higher cognitive trait anxiety to predict poorer shifting effectiveness for threat at higher relative to lower motivation, however this effect did not reach significance, $\beta = -.27$, $t = 1.33$, $p = .187$. Lower cognitive trait anxiety was associated with better shifting effectiveness for threat at higher motivation, and this effect was marginally significant, $\beta = .30$, $t = 1.98$, $p = .050$.

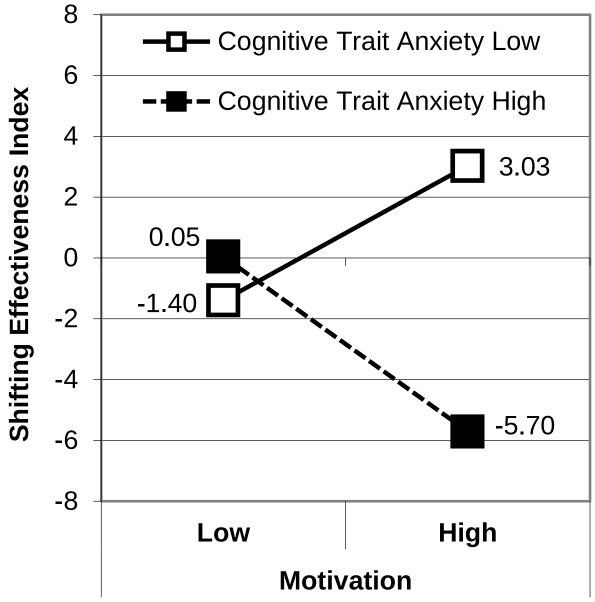

Figure 12. Relationship between cognitive trait anxiety, motivation, and shifting effectiveness index. (*Note*: Negative scores represent poorer shifting effectiveness on threat relative to neutral words, whereas positive scores represent better shifting effectiveness on threat compared to neutral words).

Shifting Efficiency Index

Table 40 displays the unstandardised coefficients, beta weights and 95% confidence intervals at each step. At Step 1, depression accounted for < 1% of the variance in the shifting efficiency index, $R = .06$, $F < 1$. The main effects were added at Step 2, and the change in R^2 accounted for 4% of the variance in the criterion, $R = .19$, however the increment, $\Delta R^2 = .03$, $\Delta F < 1$, and model, $F < 1$ were not significant. At Step 3, the two-way interaction terms did not increase R^2, $R = .27$, $\Delta R^2 = .73$, ΔF (3, 82) = 1.04, $p = .379$; the model accounted for 7% of the variance in efficiency, which was not significant, $F < 1$. At Step 4, the three-way interaction term was entered, however the change in R^2, $R = .29$, $\Delta R^2 = .01$, ΔF (1, 81) = 1.06, $p = .305$, and the overall model which accounted for 9% of the variance in threat shifting efficiency were not significant, $F < 1$.

Table 40

Unstandardised Coefficients, Beta Weights and 95% Confidence Intervals for all Variables at each step for Shifting Efficiency Index

		Unstandardised Coefficients		Standardised Coefficient	95% Confidence Intervals for B	
		B	Std. Error	Beta	Lower Bound	Upper Bound
Step 1	(Constant)	-.39	.42		-1.23	.45
	Depression	-.02	.04	-.06	-.10	.06
Step 2	(Constant)	-.19	.51		-1.21	.84
	Depression	-.05	.06	-.13	-.16	.06
	Cognitive Trait Anxiety	.05	.08	.11	-.10	.21
	Situational Stress	.12	.30	.04	-.48	.71
	Motivation	.12	.09	.14	-.06	.30
Step 3	(Constant)	-.27	.52		-1.30	.76
	Depression	-.04	.06	-.11	-.16	.07
	Cognitive Trait Anxiety	.03	.08	.07	-.12	.19
	Situational Stress	.10	.30	.04	-.50	.70
	Motivation	.09	.30	.04	-.10	.78
	Cognitive Trait Anxiety X Situational Stress	-.10	.06	-.19	.22	.02
	Situational Stress X Motivation	-.03	.09	-.04	-.21	.15
	Cognitive Trait Anxiety X Motivation	-.01	.02	-.04	-.05	.04
Step 4	(Constant)	-.30	.52		-1.33	.74
	Depression	-.04	.06	-.12	-.16	.07
	Cognitive Trait Anxiety	.02	.08	.03	-.14	.18
	Situational Stress	.15	.31	.06	-.46	.76
	Motivation	.08	.10	.10	-.11	.27
	Cognitive Trait Anxiety X Situational Stress	-.08	.06	-.16	-.21	.04
	Situational Stress X Motivation	-.07	.10	-.08	-.25	.12
	Cognitive Trait Anxiety X Motivation	-.01	.02	-.04	-.05	.04
	Cognitive Trait Anxiety X Situational Stress X Motivation	-.02	.02	-.13	-.06	.02

$p < .05$*

Discussion of Anxiety and Shifting Threat Differentiation

To test the prediction that anxiety impairs the shifting function in the presence of threat-related stimuli, a novel version of the WCST that included threat-related and neutral stimuli was employed in Study 2.3. The present study examined the associations between cognitive trait anxiety, situational stress, and motivation on differential threat shifting effectiveness and efficiency. In accord with ACT, it was predicted that trait anxiety, situational stress and motivation would not interact to predict effectiveness, but that they would combine to predict differential threat efficiency. Specifically, higher trait anxiety was expected to predict poorer shifting efficiency on threat relative to neutral trials, such that this relationship would be restricted to those in the ego threat condition who reported lower motivation.

The data revealed two significant interactions for shifting effectiveness on threat-related trials relative to neutral trials. First, the results revealed that cognitive trait anxiety and situational stress combined to predict scores on the shifting effectiveness index, such that at high situational stress, lower cognitive trait anxiety was associated with more effective shifting on threat relative to neutral words, whereas higher cognitive trait anxiety predicted poorer shifting effectiveness for threat. Second, the data also revealed that cognitive trait anxiety and motivation interacted to predict differential threat shifting effectiveness, such that at higher motivation, lower cognitive trait anxiety was associated with higher shifting effectiveness for threat. Although there was a trend for higher cognitive anxiety to be associated with poorer shifting effectiveness for threat relative to neutral words at higher motivation, the relationship was not significant. The current study indicated that the inter-relationships between cognitive trait anxiety, situational stress and motivation did not predict differential threat shifting efficiency.

The shifting efficiency data reported in Study 1.4 and the present experiment confirmed that higher trait anxiety and situational stress combine to predict poorer shifting performance. The data from Study 1.4 are consistent with those reported by Ansari et al. (2008) who used a mixed anti- and pro- saccade paradigm (see also Chapter 2) to demonstrate that anxiety impaired shifting efficiency in the absence of threat. In later work from the same laboratory, Derakshan, Ansari et al (2009) found similar results using the anti-saccade task, which included threat-related stimuli, and reported their findings in terms of inhibitory threat processing. Taken together, there is now a growing body of evidence to suggest that anxiety impairs the shifting function (e.g., Study 1.4; Ansari et al.; Edwards, Moore et al., 2015), and that higher anxiety (Derakshan, Ansari et al) and stress further attenuate shifting effectiveness on threat-related relative to neutral trials (current study).

The present study also provided the first empirical test of whether motivation further moderates the relationship between trait anxiety and situational stress on differential threat inhibitory effectiveness and efficiency. The data yielded a significant cognitive trait anxiety x motivation interaction that suggested shifting effectiveness for threat words relative to neutral words was improved for low trait anxious individuals who reported higher motivation, however the opposite pattern was observed for those higher in trait anxiety. As no previous studies have investigated the relationship between anxiety, motivation and shifting, reconciling the current data with existing work was not possible. Nonetheless, the results are conceptually consistent with those reported by Calvo

(1985) and Eysenck (1985) also suggested that motivation enhances performance of low- but not high-trait anxious individuals. Together, the data confirm that the relationship between anxiety and cognitive performance (Calvo, 1985; Eysenck, 1985), including shifting effectiveness (current study), is buffered by prospective motivation.

Following ACT, it was hypothesised that trait anxiety, situational stress and motivation would interact to predict scores on the inhibitory efficiency index. Specifically, higher trait anxiety was predicted to be associated with poorer shifting efficiency on threat relative to neutral trials, and that this relationship would be restricted to those who reported lower motivation in the ego threat condition. Contrary to predictions, scores on the inhibitory efficiency index were independent of the interactive relationships between anxiety, stress and motivation. These data are in contrast to those reported in Study 1.4. In that experiment, poorer shifting efficiency was associated with higher anxiety and lower effort, and restricted to those in the ego threat condition. There are two important procedural differences between these studies that might explain the contrasting results. First, it is plausible that inter-relationships between anxiety, stress, and effort (Study 1.4), rather than anxiety, stress and motivation (current study), are required to illuminate shifting efficiency deficits. Second, the present study compared differential inhibitory responses between threat and neutral stimuli, whereas Study 1.4 employed neutral stimuli only. This considerable methodological change suggests that lower inhibitory efficiency might be associated with higher anxiety and stress and lower effort for neutral stimuli, but that this pattern is not augmented on threat relative to neutral trials. It is also possible that some combination of both procedural changes might explain the differing results between studies.

Of note, there is a potential problem with the use of the WCST as a pure measure of shifting. In order to switch to a new category or set, the participant is required to withhold a response to an old category or set before switching to a new one, and as such, the task is not necessarily 'process pure'. Despite this limitation, there are similar problems associated with other measures of shifting efficiency. For example, the requirement in the anti-saccade task for participants to look towards or away from a given target also requires a mix of inhibition and shifting processes. In order to look away from the given target, the subject has to inhibit looking towards the target. Although the data reported in Study 1.4 and the present study are interpreted with respect to the inhibitory processes, it is important to recognise that other cognitive processes are likely to be operating concurrently.

The present study provided the first systematic test of the associations between cognitive trait anxiety, situational stress and motivation on shifting performance in the presence of threat-related stimuli using a modified WCST. The data suggested that cognitive trait anxiety and situational stress combined to produce performance deficits for effectively shifting from threat words relative to neutral words. These findings support the notion that high trait anxious individuals experience difficulties disengaging from threat-related words relative to neutral words, which provides support for ACT. The data also indicated that higher motivation was related to better shifting effectiveness for threat compared to neutral words but only at lower trait anxiety. The present work adds of the body of literature examining attentional biases in anxiety, and confirms the role of motivation in moderating this relationship. Further work however is warranted to replicate and extend the findings reported here for the shifting function in the presence of threat.

Chapter Summary

The studies reported in Chapter 6 investigated the inter-relationships between cognitive trait anxiety, situational stress and reported motivation in predicting performance on updating, inhibition and shifting tasks, when the inhibition and shifting tasks contain both neutral and threat-related stimuli. In Study 2.1, a modified version of the reading span task from Study 1.2 was employed, such that shorter sentences were included to reduce task complexity and potential for floor compression effects (see Study 1.2.2). The data from Study 2.1 revealed that the unique factors of mental effort and situational stress predicted updating effectiveness, such that higher effort was associated with higher effectiveness, and higher stress was related to poorer effectiveness. However, there were no inter-relations between cognitive trait anxiety, situational stress, effort and efficiency. Study 2.1.2 investigated whether the cognitive trait anxiety x situational stress model was moderated by motivation. The results suggested that situational stress predicted updating effectiveness, and cognitive trait anxiety and motivation combined to predict updating efficiency, such that at higher motivation, higher trait anxiety was associated with higher updating efficiency, whereas at lower motivation, higher cognitive trait anxiety was related to poorer efficiency.

Study 2.2 and 2.3 included threat-related and neutral words to reveal that threat-related and neutral stimuli are differentially processed on tasks of inhibition and shifting. For Study 2.2 the data suggested that situational stress and motivation combine to predict inhibitory efficiency, but not effectiveness, for threat-related words relative to neutral words. Specifically, higher motivation was related to poorer efficiency for threat under high stress compared to low stress.

The results of Study 2.3 yielded two inter-relationships for shifting effectiveness on threat words relative to neutral words. A cognitive trait anxiety x situational stress interaction revealed that under high situational stress, higher cognitive trait anxiety was associated with poorer shifting effectiveness for threat, whereas lower cognitive trait anxiety was related to better shifting effectiveness for threat words relative to neutral words. Further, at higher motivation, lower cognitive trait anxiety was related to better shifting effectiveness for threat, whereas there was a tendency for higher cognitive trait anxiety to be associated with poorer threat shifting effectiveness (although this effect was marginally significant). A summary of findings, as well as limitations and directions for future research, is discussed in Chapter 7.

CHAPTER 7: GENERAL DISCUSSION

The studies in the current program of research investigated the relationship between anxiety and stress on the effectiveness and efficiency of phonological, updating, inhibition and shifting processes. In Experimental Series 1, somatic and cognitive trait anxiety, situational stress, and the role of mental effort in moderating these relationships, were investigated. In Experimental Series 2, threat and neutral stimuli were included to determine whether responses to items of differential valence were equivalent, and the role of motivation in moderating responses was included in the data modelling.

In Chapter 1, the models of Yerkes and Dodson (1908), Eysenck (1979), Sarason (1984), Humphreys and Revelle (1984), Eysenck and Calvo (1992), and Eysenck et al. (2007) were outlined and compared, as these earlier theoretical positions laid the historical framework for the development of ACT. Particular emphasis was placed on describing the assumptions of ACT which formed the theoretical basis for the hypotheses in each experiment, and the interpretational basis for the data.

In Chapter 2 the evidence for the associations between anxiety and cognitive performance was reviewed and critically evaluated. Results of empirical work were evaluated in terms of the assumptions of ACT. The review identified a number of methodological shortcomings in the current literature that posed interpretation difficulties for the existing data. The procedural challenges were summarized as follows: (1) the separate and combined contributions of trait anxiety and situational stress on cognitive processes were not well delineated, (2) the contributions of cognitive and somatic trait anxiety on cognitive processes were not well understood, (3) the inclusion of appropriate situational stress (somatic and cognitive) induction procedures have not consistently been applied, (4) appropriate measures of effectiveness and efficiency (that are consistent with the definitions of ACT) had not been developed, (5) few studies had controlled for the comorbidity between depression and anxiety, (6) systematic investigations into the buffering roles of effort and motivation on the anxiety-performance relationship had not been undertaken, and (7) there were a limited number of investigations into inhibitory and shifting performance on tasks that include both neutral and threat-related stimuli.

To overcome interpretational difficulties associated with these methodological problems, the research reported in the present thesis was conducted as two two-part series of experiments. Experimental Series 1 (see Chapter 3 & 4) contained four studies that examined the relationship between trait anxiety (somatic and cognitive), situational stress (somatic and cognitive), and mental effort on phonological, updating, inhibitory, and shifting performance (effectiveness and efficiency). Experimental Series 2 (see Chapter 5 & 6) contained three studies that investigated the associations between cognitive trait anxiety, situational stress, and motivation on updating, inhibitory and shifting performance (effectiveness and efficiency). The two attentional tasks (inhibition and shifting) in this series examined anxiety-related attentional biases for threat, such that the tasks contained both neutral and threat-related stimuli.

For each experiment, the data were analysed using hierarchical moderated regression analyses. This procedure allowed examination of the separate and combined contributions of the factors in predicting the criterion, after controlling for variance in the criterion explained by depression. Detailed interpretations of the data with respect to the specific cognitive function and previous empirical and theoretical bases were provided in the corresponding Discussion sections for each study, and results were reconciled with appropriate empirical literature and the assumptions of ACT. To avoid repetition of detail, the following summary describes the general patterns of results with respect to the assumptions of ACT (see Chapter 1). The limitations associated with this program of research are noted, and recommendations for future work are discussed.

Empirical Support for Attentional Control Theory

The present program of research included seven empirical experiments designed to test the assumptions of ACT. The findings are summarised below in terms of each assumption.

Anxiety is Determined Interactively by Trait Anxiety and Situational Stress

The data from four experiments (Study 1.1.2, Study 1.3.2, Study 1.4.2, & Study 2.3) revealed empirical support for the assumption that trait anxiety and situational stress interact to predict performance on phonological, inhibitory and shifting tasks. Under some conditions this relationship is further buffered by mental effort and motivation. It is important to note that trait anxiety and situational stress did not interact to predict updating performance in either of the two studies conducted in the current thesis (see Study 1.2 & Study 2.1). Situational stress did however play a significant and unique role in predicting updating performance as indexed on the reading span task.

Anxiety and Effort

According to ACT, anxious individuals recruit additional cognitive resources, typically in the form of extra mental effort, to overcome performance shortfalls. Support for the assumption was revealed in the bivariate analyses between the measures of somatic and cognitive trait anxiety and effort on the phonological (Study 1.1) and updating tasks (Study 1.2), and between somatic trait anxiety and effort on the inhibition (Study 1.3.1) and shifting tasks (Study 1.4.1). There was also evidence to show that mental effort was positively related to phonological (on both the simple and complex task; Study 1.1) and updating effectiveness (Study 2.1). Effort, however, negatively predicted inhibitory effectiveness and was not associated with shifting effectiveness. The present data also confirmed that mental effort moderated the association between trait anxiety and situational stress on cognitive performance. Support for this assumption was revealed on tasks that indexed the phonological loop and inhibition and shifting functions of the central executive (Study 1.1.2; Study 1.3.2; Study 1.4.2). The results of these studies showed that different patterns of performance were observed at lower versus higher invested effort.

Effectiveness and Efficiency

ACT suggests that performance can be measured in terms of effectiveness (quality of performance) and efficiency (effectiveness relative to RT). Evidence for this assumption was reported above (in five studies) with differing patterns of results between phonological (Study 1.1.1, & Study 1.1.2), updating (Study 2.1.2), inhibition (in the presence of threat-related and neutral words only; Study 2.2) and shifting (Study 1.4) effectiveness and efficiency. However, the results showed a similar pattern of performance for inhibitory effectiveness and efficiency in the presence of neutral words only (Study 1.3.2). More details are provided below.

Anxiety Impairs Efficiency more than Effectiveness

The data from four experiements demonstrated support for the assumption that anxiety impairs efficiency to a greater extent than effectiveness (Study 1.1.2, Study 1.4, Study 2.1.2, & Study 2.2). Specifically, cognitive trait anxiety impaired efficiency more than effectiveness on simple (forward word span) and complex (backward word span) phonological tasks, on an updating task (reading span task), on a shifting task (WCST) which included neutral stimuli, and on an inhibition task (Go-No-Go) which included threat-related and neutral stimuli. On the inhibition task that inlcuded only neutral stimuli, the data indicated that anxiety impairs both effectiveness and efficiency (see Study 1.3). When threat-related stimuli were included on the shifting task (Study 2.3), the pattern was reversed, such that anxiety impaired effectiveness but not efficiency. On the basis of these data it appears that whether efficiency and effectiveness deficits are revealed might depend on which cognitive function is being engaged, and whether or not threat-related material is being processed.

Effects of Anxiety on Performance are Greater as Task Demands Increase

The assumption that effects of anxiety on performance are greater as task demands increase was tested in Study 1.1 by employing both simple (forward word span) and complex (backward word span) tasks. The results, however, did not support the notion that anxiety-linked deficits are greater as task demands increase. For example, Study 1.1.1 demonstrated that somatic trait anxiety and somatic situational stress combined to predict phonological efficency on a complex relative to a simple task, however their interrelations enhanced efficiency on the backward word span task for high trait anxious individuals in a low stress condition. Further, Study 1.1.2 demonstrated that cognitive trait anxiety and cognitive situational stress (moderated by mental effort) interacted to predict phonological efficency in a conceptually similar way for both simple and complex tasks, albeit the relationship suggested that higher trait anxiety was associated with poorer phonological efficiency at low reported mental effort. Future studies are needed to replicate the present findings with different low- and high-complexity phonological tasks, in addition to investigating variations in cognitive load on updating, inhibition and shifting functions, given that these empirical questions were beyond the scope of the current thesis.

Anxiety Impairs the Functioning of the Central Executive

According to Miyake et al. (2000) the central executive has a least three separate functions, updating, inhibition and shifting. The data from the present program of research support the assumption that trait anxiety and situational stress are related to performance deficits on updating (Study 2.1), inhibition (Study 1.3 & Study 2.2), and shifting tasks (Study 1.4 & Study 2.3). Differences in the patterns of performance effectiveness and efficiency varied across the functions and are discussed in more detail below.

Anxiety Impairs the Functioning of the Phonological Loop

Study 1.1 tested systematically whether trait anxiety (somatic or cognitive), situational stress (somatic or cognitive), mental effort and their interactions were related to phonological effectiveness and efficiency on simple and complex tasks. The data suggested that somatic anxiety was unrelated to phonological effectiveness or efficiency on a simple task. On a complex task, however, somatic trait anxiety and somatic stress combined to predict phonological efficiency, but not effectiveness, and this relationship was not buffered by mental effort. The data also suggested that cognitive anxiety was unrelated to phonological effectiveness irrespective of task complexity, however as predicted, cognitive trait anxiety, cognitive situational stress, mental effort, and their interactions combined to predict phonological efficiency. Furthermore, despite the lack of support for either a unique or moderated link between anxiety and phonological effectiveness, the data did confirm that individuals who invested greater mental effort performed with greater effectiveness, and those higher in trait anxiety invested greater mental effort. These data have important implications for ACT and shed new light on the relationship between anxiety and the functioning of the phonological loop component of the working memory system (cf., Baddeley, 1986).

Anxiety Impairs the Updating Function (Under Stressful Conditions)

The present thesis tested the assumption that anxiety impairs updating performance (indexed here on the reading span task) under high situational stress (manipulated using ego threat instructions). Although Study 1.2 did not reveal results to support this prediction, the task employed may have been too difficult and a floor effect in the data may have occurred. To overcome this possibility, task demands were lessened by shortening the sentences and reducing the memory load associated with the task. Study 2.1, however, afforded only partial support for this assumption. Two separate studies tested whether effort or motivation moderated the link between anxiety and updating performance (see Study 2.1). The data from Study 2.1.1 demonstrated that situational stress and mental effort made unique contributions to updating performance effectiveness, such that high stress predicted poorer updating effectiveness, and higher effort predicted better effectiveness. These relationships, however, were independent of trait anxiety and were not observed for updating efficiency. The data from Study 2.1.2 yielded a trend for situational stress to be related to updating effectiveness (in accord with Study 2.1.1), such that high stress predicted poorer effectiveness. However, this relationship was again unrelated to trait anxiety. An important finding from Study 2.1.2 was that irrespective of situational stress, cognitive trait anxiety and motivation were jointly associated with updating efficiency, such that at higher reported motivation, higher cognitive trait anxiety predicted higher updating efficiency, whereas at lower motivation higher cognitive trait anxiety predicted poorer efficiency.

Anxiety Impairs the Inhibition Function

Study 1.3 examined anxiety-linked inhibitory control deficits using a Go-No-Go task with neutral stimuli, and provided support for idea that anxiety impairs inhibitory control, as predicted by ACT. The data from Study 1.3.1 revealed that somatic anxiety was not associated with inhibitory control, however the results of Study 1.3.2 demonstrated that cognitive trait anxiety, cognitive situational stress and mental effort interacted to predict inhibitory effectiveness and efficiency. Specially, higher trait anxiety was related to poorer inhibitory effectiveness at low stress and higher effort, whereas higher trait anxiety was associated with poorer inhibitory efficiency at higher effort, irrespective of stress manipulation. Evidence that anxiety impaired the inhibition function in the presence of threat-related stimuli was also found, however to avoid repetition, these data are discussed below.

Anxiety Impairs the Shifting Function

Study 1.4 investigated the assumption that anxiety is associated with shifting impairments. Study 1.4.1 indicated that somatic anxiety was unrelated to shifting effectiveness or efficiency, whereas the data from Study 1.4.2 provided clear empirical support for ACT. The results of Study 1.4.2 demonstrated that cognitive trait anxiety, cognitive situational stress and mental effort predict shifting efficiency deficits, but these factors are unrelated to shifting effectiveness (uniquely or in combination) on the WCST. The data from Study 1.4.2 indicated that at higher reported mental effort, higher trait anxiety was associated with low shifting efficiency irrespective of stress, whereas at lower effort, higher trait anxiety predicted lower efficiency at high stress only. The shifting function was also examined in the presence of threat-related stimuli and these results are discussed below.

Anxiety Impairs Attentional Control in the Presence of Threat

Study 2.2 and Study 2.3 investigated the relationship between anxiety and attentional control using inhibition and shifting tasks containing threat-related and neutral stimuli (see Study 2.2 and Study 2.3, respectively). Mixed support was found for the assumptions of ACT. The data from Study 2.2 indicated that situational stress and motivation combined to predict inhibitory efficiency (but not effectiveness) of threat-related words compared to neutral words. However the pattern of this relationship was only partially consistent with ACT. Higher situational stress was related to poorer inhibitory efficiency for threat at higher but not lower motivation. Further, the data from Study 2.3 yielded two interactive relationships that varied on shifting effectiveness for threat-related words relative to neutral words, yet there was no relationship between anxiety and efficiency of threat differentiation. In accord with ACT, cognitive trait anxiety and situational stress interacted to predict shifting effectiveness, such that higher cognitive trait anxiety was associated with poorer shifting effectiveness for threat-related relative to neutral words, whereas lower cognitive trait anxiety was related to better shifting effectiveness for threat differentiation. Cognitive trait anxiety also interacted with motivation to predict poorer shifting effectiveness, and these results are discussed below. Taken together, the data from Study 2.2 and Study 2.3 provide support for the suggestion that anxiety impairs attentional control, and in particular the degree to which the threat-related material is differentially processed (cf. Cisler & Koster, 2010). In this regard the data reported here broadly support ACT. Subtle differences between the findings reported in the present thesis and those described in previous work are likely explained by subtle variations in task requirements.

Anxiety and Motivation

The experiments reported in Series 2 of this program of research are among the first to explore whether motivation further moderates the anxiety-stress relationship on updating, inhibition and shifting performance (see ACT; Eysenck & Derakshan, 2011). Motivation was defined as the degree to which an individual is committed to achieving a goal on a cognitive task. It was operationalised using a self-report questionnaire which was administered prior to performing the task (i.e., HWK; Klein et al., 2001). ACT suggests that if a task is sufficiently demanding and has clear goals, highly anxious individuals will increase their motivation and consequently enhance their performance. On the reading span task (Study 2.1), higher cognitive trait anxiety and higher motivation predicted better reading span efficiency, but not effectiveness. For high trait anxious individuals, however, motivation had the opposite effect on the attentional processes of inhibition and shifting. Specifically, those high in trait anxiety, who reported higher motivation, demonstrated poorer efficency on the inhibition task (Go-No-Go) in Study 2.2, and poorer effectiveness on the shifting task (WCST) in Study 2.3. It is important to note, though, that the tasks employed in Study 2.2 and Study 2.3 contrasted responses between threat-related and neutral trials. If motivation is viewed as an intentional strategy, then perhaps recruitment of extra motivation is beyond the purview of protecting against shortfalls of differential responses to threat. In light of the well established notion that threat-processing biases operate counter to intention (i.e., automatically; see Cisler & Koster, 2010), consciously motivated strategies would seem unlikely to be effective.

Practical Implications

The present thesis was designed to assess the utility of ACT in explaining the relationship between cognitive performance (phonological, updating, inhibitory and shifting processes) and state and trait measures of anxiety. Furthermore, the program of research examined whether these relationships were moderated by motivational effort. ACT provides a set of assumptions specific to non-clinical anxiety. Future work should determine whether the patterns of data found here for non-clinically anxious individuals hold for clinically anxious patients. Importantly, any dissociations in the patterns of results between clinically and non-clinically anxious subjects might represent an important marker of clinical breakdown and provide therapists with behavioural deficits to target during treatment.

Limitations and Directions for Future Research

Despite the procedural strengths of the present thesis, there are some considerations and/or limitations that require mention. The present program of research controlled for the relationship between anxiety and depression, and depression and the criterion. Specifically, the results reported in Chapters 4 and 6 explain variance in the criterion above that explained by the variance in depression. Nonetheless, it is likely that other personal attribute variables might also co-vary with anxiety, effort, and/or motivation, and also with cognitive performance. Importantly, the use of random assignment to the situational stress conditions (e.g., ego safe vs. ego threat) ensured that person variables were randomised between these groups.

ACT represents a theory developed for individual differences in anxiety within non-clinical populations, and accordingly the studies reported here employed undergraduate student samples with varying levels of anxiety as a personality dimension. It remains to be seen whether the patterns of data reported in the present thesis generalise to clinical populations, such as those with a diagnosis of social anxiety, generalised anxiety disorder, post-traumatic stress disorder or other subcategories of anxiety disorders. Numerous studies have presented data demonstrating the relationship between clinically diagnosed anxiety and cognitive performance (e.g., Dalgleish et al., 2003; Harvey, Bryant, & Rapee, 1996; Mathews & MacLeod, 2005). As such, differences between results reported here and those of studies employing clinically anxious individuals could reflect important markers of clinical breakdown. Understanding the precise mechanisms that underpin the cognitive performance of clinically anxious individuals can assist with tailoring treatments to the specific cognitive strategies being utilised.

Summary and Conclusions

A large body of anxiety research has sought to clarify whether anxiety is related to impaired or enhanced cognitive performance. The present thesis provides a number of critical observations to shed light on this relationship, and most importantly critically appraises one of the most recent theoretical approaches in this area, namely ACT. The present results indicated that higher cognitive trait anxiety was related to impaired performance (1) efficiency (but not effectiveness) on simple and complex phonological tasks, at lower effort and under high stress;

(2) efficiency on an updating task, at lower motivation; (3) efficiency on an inhibition task, at higher effort, irrespective of stress; (4) efficiency (but not effectiveness) on a shifting task, at higher effort, irrespective of stress, and at lower effort, and high but not low stress ; and (5) effectiveness of threat relative to neutral words on a shifting task, at higher motivation. On the other hand, the present data demonstrated that higher cognitive trait anxiety was only related to enhanced performance efficiency on an updating task at higher motivation, and this relationship was irrespective of stress condition. In accord with ACT, these results permit two clear conclusions. Specifically, elevated anxiety is more strongly associated with impaired than enhanced performance, and performance impairments are more likely to manifest as efficiency costs than effectiveness deficits. There was some evidence to support the notion that anxious individuals devote increased effort and/or motivation to the accomplishment of the specified task goals.

Together, these combined results have significant implications for ACT. The finding of differential effects of trait anxiety, situational stress, effort, and motivation on the various tasks used in the current work (i.e., word span, reading span, Go-No-Go, WCST) raises the question of how the performances of these tasks are resourced within the cognitive system. ACT suggests that anxious individuals use strategies such as recruitment of extra effort or motivation to protect against performance shortfalls. It is possible, nonetheless, that each process (phonological, updating, inhibition and shifting) is resourced differently. For example, for performance of phonological tasks, trait anxiety and situational stress may delete resources but invested mental effort seems to buffer this relationship. However, for performance on an updating task, trait anxiety might tax the available resources but motivation appears to moderate this relationship. The aforementioned interpretation is, however, beyond the scope of the present thesis and requires empirical investigation. It is hoped that the present data provides the impetus for such work.

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Appendix A

BOND UNIVERSITY

Faculty of Society and Design

PhD Research Project

Individual Differences in Processing of Emotional Information

RO-559A

Experimenter: Elizabeth (Liz) Edwards

Supervisor: Dr Mike Lyvers

Information for Participants in the Cognitive Psychology Laboratory

The research carried out in the Cognitive Psychology Laboratory includes a number of new and continuing research projects. Our studies are concerned with understanding more about the nature of human cognition and a variety of related phenomenon. The success of our research is vitally dependent upon the assistance of volunteers like yourself, and we are extremely grateful for your participation.

Today I am volunteering to participate in a research study that will involve the completion of some questionnaires and a number of tasks that assess cognitive abilities. In addition, it may also include a procedure that could temporarily elevate my stress levels. I also understand that any data I provide will be held as totally confidential and that I am free to withdraw from the experiment without prejudice at any time.

This study has been cleared by the Bond University Human Research Ethics Committee (BUHREC) in accordance with the National Health and Medical Research Council's guidelines. You are free to discuss your participation in this study with project staff on 5595 2673.

________________________	________________________
Student's Signature	Print Student's Name
________________________	________________________
Student Number	Date

Appendix B

Word Span Task (Forward and Backward)
(modified from Wechsler, 1997)

Trial		Stimuli
P	1	desk,keys
	2	bath,doors,rack
1	1	step,wall
	2	rack,hook
2	1	hook,keys,chair
	2	desk,rack,wall
3	1	rack,step,desk,wall
	2	wall,keys,hook,bath
4	1	doors,step,bath,hook,desk
	2	wall,step,keys,chair,bath
5	1	step,bath,desk,rack,doors,wall
	2	bath,keys,desk,hook,rack,step
6	1	keys,hook,desk,bath,doors,rack,chair
	2	wall,keys,step,rack,bath,doors,desk
7	1	bath,desk,wall,hook,rack,doors,keys,chair
	2	desk,bath,doors,chair,rack,hook,keys,step
8	1	desk,keys,chair,hook,wall,keys,chair,bath,hook
	2	keys,wall,chair,hook,desk,rack,step,doors,bath

Appendix C

Reading Span Task
(Daneman & Carpenter, 1980; Masson & Miller, 1983; see Series 1)

Trial		Sentence
P1	1	She had been so engrossed in her little lecture that she had almost forgotten her listener.
	2	One man had to bail steadily while another struggled to apply patches to the pontoon.
	Q	She had been engrossed in her little lecture.
	A	TRUE
P2	1	At two hundred fifty miles per hour he felt that he was nearing his level-flight maximum speed.
	2	He gently lifted the various pans and baskets, placing them just so in the sleigh.
	3	The restaurant was a richly appointed, wood-panelled room with thick carpets and glistening silver.
	Q	The restaurant was ugly and had tarnished silver.
	A	FALSE
2.1	1	Due to his many capabilities, his position as director was promoted quickly.
	2	It is possible of course, that life did not arise on earth at all.
	Q	He was fired because he was lazy.
	A	FALSE
2.2	1	After all, he had not gone far, and some of his walking had been circular.
	2	The old lady was thoroughly persuaded that she was not long to continue this novel.
	Q	The lady with the novel was old.
	A	TRUE
2.3	1	Jane's relatives had decided that her gentleman friend was one of high status.
	2	Without any hesitation, he plunged into the difficult mathematics assignment blindly.
	Q	Jane did not have relatives or friends.
	A	FALSE
2.4	1	The entire town arrived to see the appearance of the controversial political candidate.
	2	After passing all the exams, the class celebrated for an entire week without resting.
	Q	Everyone had come to see the candidate.
	A	TRUE
2.5	1	According to the results of the survey, Robert Redford is the most liked Hollywood star.
	2	The weather was unpredictable that summer so no one made plans too far in advance.
	Q	The weather that summer was stable and predictable.
	A	FALSE
3.1	1	The regenerating effects of the floods were not fully realized until months later.
	2	In a moment of complete spontaneity, she developed a thesis for her paper.
	3	At the conclusion of the musician’s performance, the crowd applauded.
	Q	The regenerating effects of the floods were noticed.
	A	TRUE
3.2	1	They attended the theatre habitually except for circumstances beyond their control.
	2	The lumbermen worked long hours in order to obtain the necessary amount of wood.
	3	The old lady talked to her new neighbour on her weekly walks from church.
	Q	The men worked to obtain the wood.
	A	TRUE
3.3	1	There are days when the city where I live wakes in the morning with a strange look.
	2	We boys wanted to warn them, but we backed down when it came to the pinch.
	3	With shocked amazement and complete fascination Marion looked at the pictures.
	Q	Marion did not look at the pictures.
	A	FALSE
3.4	1	What would come after this day would be inconceivably different, would be real life.
	2	He stood there at the edge of the crowd while they were singing, and he looked bitter.
	3	John became annoyed with Karen's bad habits of biting her nails and chewing gum.
	Q	Real life would come after this day.
	A	TRUE

3.5	1	Circumstantial evidence indicated that there was a proposal to select him.
	2	To determine the effects of the medication, the doctor hospitalized his patient.
	3	Her mother nagged incessantly about her lack of concern for the fashion of the children.
	Q	The patient did not get any medication.
	A	FALSE
4.1	1	I found the keynote speaker incredibly smart, intelligent and well read.
	2	In order to postpone the business trip, he cancelled his engagements for the week.
	3	The incorrigible child was taught about the importance of respect for his elders.
	4	The brilliant trial attorney dazzled the jury with his astute knowledge of the case.
	Q	They thought the key note speaker did well.
	A	TRUE
4.2	1	I imagine that you have a shrewd suspicion of the object of my earlier visit.
	2	I turned my memories over at random like pictures in a photograph album.
	3	I'm not certain what went wrong but I think it was my short and loud laugh.
	4	Filled with these happy thoughts, I forcefully opened the heavy wooden door.
	Q	They turned the memories over at random.
	A	TRUE
4.3	1	Sometimes I get so tired of trying to convince him that I love him and shall forever.
	2	When in trouble, children naturally hope for a miraculous intervention by a superhuman.
	3	It was your belief in the significance of my studies that kept me going.
	4	The girl hesitated for a moment to taste the onions because her husband hated the smell.
	Q	They thought that the studies were insignificant.
	A	TRUE
4.4	1	The smokers were asked to refrain from their habit until the end of the production.
	2	The young business executive was determined to develop his housing projects within the year.
	3	Despite the unusually cold weather, the campers continued the canoe trip.
	4	All students that passed the test were exempt from any further seminars that semester.
	Q	The students were not given the tests.
	A	FALSE
4.5	1	The entire construction crew decided to lengthen their work day in order to have lunch.
	2	In comparison to his earlier works, the musician had developed a unique enthralling style.
	3	The boisterous laughter of the children was disturbing to the aged in the building.
	4	The sound of an approaching train woke him, and he started to his feet.
	Q	The crew decided not to have lunch.
	A	FALSE
5.1	1	A small oil lamp burned on the floor and two men crouched against the wall, watching them.
	2	The products of digital electronics will play an important role in your future.
	3	One problem with this explanation is that there appears to be no defence against cheating.
	4	Sometimes the scapegoat is an outsider who has been taken into the community.
	5	I should not be able to make anyone understand how exciting it all was.
	Q	Digital electronics will be important in the future.
	A	TRUE
5.2	1	In a flash of fatigue and fantasy, he saw a man sitting beside a campfire.
	2	The lieutenant sat beside the man with the walkie-talkie and stared at the muddy ground.
	3	I will not shock my readers with a description of the cool-blooded acting that followed.
	4	The courses are designed as much for professional engineers as for amateur enthusiasts.
	5	The taxi turned up Michigan Avenue, where they had a clear view of the lake.
	Q	The acting that followed was cool-blooded.
	A	TRUE
5.3	1	The words of human love have been used by the saints to describe their vision of God.
	2	It was shortly after this that an unusual pressure of business called me into town.
	3	He pursued this theme, still pretending to seek for information to quiet his own doubts.
	4	I was so surprised at this unaccountable apparition, that I was speechless for a while.
	5	When at last his eyes opened, there was no gleam of triumph, no shade of anger.
	Q	They were not surprised by the apparition.
	A	FALSE

5.4	1	He leaned on the wall of the building and the two policemen watched him from a distance.
	2	These splendid glittering eyes were turned upon me from the mirror with a haughty stare.
	3	He sometimes considered applying but the thought was too oppressive to remain in his mind.
	4	And now that a man had decided, some unimaginably different state of affairs must come to be.
	5	When I got to the big tobacco field I saw that it had not suffered much.
	Q	The big tobacco field did not suffer much.
	A	TRUE
5.5	1	Here, as well as elsewhere, the empirical patterns are important and abundantly documented.
	2	The intervals of silence grew progressively longer; the delays became very maddening.
	3	Two or three substantial pieces of wood smouldered on the hearth, for the night was cold.
	4	I imagined that he had been thinking things over while the secretary was with us.
	5	There was still more than an hour before breakfast, and the house was silent and asleep.
	Q	The empirical patterns are not important or documented.
	A	FALSE
6.1	1	The announcement of it would resound throughout the world, penetrate to the remotest land.
	2	To do so in directions that are adaptive for mankind would be a realistic objective.
	3	Slicing it out carefully with his knife, he folded it without creasing the face.
	4	He laughed heartily and looked as though he was quite amused at me for my joke.
	5	He tolerated another intrusion and thought himself a paragon of patience for doing so.
	6	The reader may suppose I had other motives, besides the desire to escape the law.
	Q	The directions would be adaptive for mankind.
	A	TRUE
6.2	1	He listened carefully because he had the weird impression that he knew the voices.
	2	The basic characteristic of the heroes in the preceding stories is their sensitivity.
	3	His imagination had so abstracted him that his name was called twice before he answered.
	4	He had an odd elongated skull which sat on his shoulders like a pear on a dish.
	5	He stuffed his denim jacket into his pants and fastened the stiff, new snaps securely.
	6	On the desk where she wrote her letters was a clutter of objects coated in dust.
	Q	He was so abstracted by his imagination.
	A	TRUE
6.3	1	He had encouraged her when she was at school and supported her when she was a student.
	2	The rain and howling wind kept beating against the rattling window panes.
	3	He covered his heart with both hands to keep anyone from hearing the noise it made.
	4	The stories all deal with a middle-aged protagonist who attempts to withdraw from society.
	5	Without tension there could be no balance either in nature or in mechanical design.
	6	I wish their existed someone to whom I could say that I felt very sorry.
	Q	The stories had all contained a middle-aged protagonist.
	A	TRUE

Appendix D

Go-No-Go Task Stimulus Words (see Series 1)

Neutral Words
desk (4209)
suite (1322)
beds (2038)
blanket (1063)
taps (434)
wall (11180)
cups (1173)
chair (6969)
stair (339)
iron (4375)
fence (1502)
sugar (3365)
hook (1303)
bath (3318)
doors (4383)
eaves (183)

Appendix E

Wisconsin Card Sorting Task
(modified from Heaton et al., 1993; see Series 1)

Target Cards

Stimulus Cards

21	22	23	24
garage garage	sheets sheets sheets	garage garage	carpet carpet carpet
25	26	27	28
garage garage garage garage	carpet carpet	sheets sheets sheets	coffee coffee coffee coffee
29	30	31	32
garage garage	sheets	coffee coffee coffee coffee	garage
33	34	35	36
coffee coffee coffee	sheets sheets sheets sheets	garage	carpet carpet carpet carpet
37	38	39	40
coffee coffee	garage garage garage	coffee	sheets sheets sheets sheets
41	42	43	44
carpet	garage garage garage	coffee coffee coffee coffee	carpet carpet
45	46	47	48
garage garage garage	sheets sheets	coffee	carpet carpet carpet

49
sheets
sheets

50
garage garage
garage garage

51
carpet

52
garage garage
garage

53
coffee
coffee

54
carpet carpet
carpet carpet

55
sheets

56
coffee coffee
coffee

57
sheets
sheets

58
carpet

59
sheets sheets
sheets

60
coffee
coffee

61
garage garage
garage garage

62
sheets sheets
sheets

63
carpet
carpet

64
sheets

Appendix F

Depression Anxiety Stress Scale
(DASS; Lovibond & Lovibond, 1995)

Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement applied to you **over the past week**. There are no right or wrong answers. Do not spend too much time on any statement.

		Did not apply to me at all	Applied to me to some degree, or some of the time	Applied to me to a considerable degree, or a good part of time	Applied to me very much, or most of the time
		0	1	2	3
1	I found it hard to wind down	0	1	2	3
2	I was aware of dryness of my mouth	0	1	2	3
3	I couldn't seem to experience any positive feeling at all	0	1	2	3
4	I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)	0	1	2	3
5	I found it difficult to work up the initiative to do things	0	1	2	3
6	I tended to over-react to situations	0	1	2	3
7	I experienced trembling (eg, in the hands)	0	1	2	3
8	I felt that I was using a lot of nervous energy	0	1	2	3
9	I was worried about situations in which I might panic and make a fool of myself	0	1	2	3
10	I felt that I had nothing to look forward to	0	1	2	3
11	I found myself getting agitated	0	1	2	3
12	I found it difficult to relax	0	1	2	3
13	I felt down-hearted and blue	0	1	2	3
14	I was intolerant of anything that kept me from getting on with what I was doing	0	1	2	3
15	I felt I was close to panic	0	1	2	3
16	I was unable to become enthusiastic about anything	0	1	2	3
17	I felt I wasn't worth much as a person	0	1	2	3
18	I felt that I was rather touchy	0	1	2	3
19	I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat)	0	1	2	3
20	I felt scared without any good reason	0	1	2	3
21	I felt that life was meaningless	0	1	2	3

Appendix G

State-Trait Inventory for Cognitive and Somatic Anxiety – State Scale
(STICSA-S; Ree et al., 2000)

Below is a list of statements which can be used to describe how people feel. Beside each statement are four numbers which indicate the degree with which each statement is self-descriptive of you mood at this moment (e.g., 1=Not at All, 4=Very Much So). Please read each statement carefully and circle the number which best indicates how you feel right now, at the very moment, even if this is not how you usually feel.

		Not at All	A Little	Moderately	Very Much So
		1	2	3	4
At present...					
1	My heart beats fast	1	2	3	4
2	My muscles are tense	1	2	3	4
3	I feel agonised over my problems	1	2	3	4
4	I think that others won't approve of me	1	2	3	4
5	I feel like I'm missing out on things because I can't make up my mind soon enough	1	2	3	4
6	I feel dizzy	1	2	3	4
7	My muscles feel weak	1	2	3	4
8	I feel trembly and shaky	1	2	3	4
9	I picture some future misfortune	1	2	3	4
10	I can't get some thought out of my mind	1	2	3	4
11	I have trouble remembering things	1	2	3	4
12	My face feels hot	1	2	3	4
13	I think that the worst will happen	1	2	3	4
14	My arms and legs feel stiff	1	2	3	4
15	My throat feels dry	1	2	3	4
16	I keep busy to avoid uncomfortable thoughts	1	2	3	4
17	I cannot concentrate without irrelevant thoughts intruding	1	2	3	4
18	My breathing if fast and shallow	1	2	3	4
19	I worry that I cannot control my thoughts as well as I would like to	1	2	3	4
20	I have butterflies in my stomach	1	2	3	4
21	My palms feel clammy	1	2	3	4

State-Trait Inventory for Cognitive and Somatic Anxiety – Trait Scale
(STICSA-T; Ree et al., 2000)

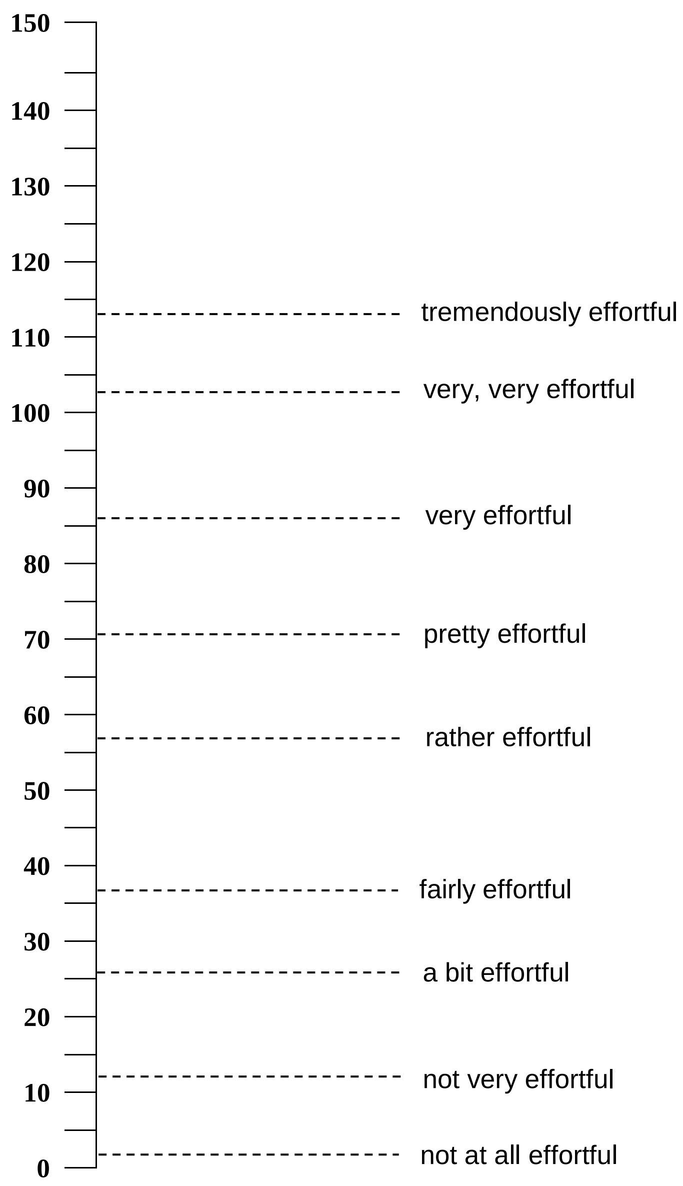
Below is a list of statements which can be used to describe how people feel. Beside each statement are four numbers which indicate the degree with which each statement is self-descriptive of you mood at this moment (e.g., 1=Not at All, 4=Very Much So). Please read each statement carefully and circle the number which best indicates **how often, in general, the statement is true for you.**

		Almost Never	Occasionally	Often	Almost Always
		1	2	3	4
	In general...				
1	My heart beats fast	1	2	3	4
2	My muscles are tense	1	2	3	4
3	I feel agonised over my problems	1	2	3	4
4	I think that others won't approve of me	1	2	3	4
5	I feel like I'm missing out on things because I can't make up my mind soon enough	1	2	3	4
6	I feel dizzy	1	2	3	4
7	My muscles feel weak	1	2	3	4
8	I feel trembly and shaky	1	2	3	4
9	I picture some future misfortune	1	2	3	4
10	I can't get some thought out of my mind	1	2	3	4
11	I have trouble remembering things	1	2	3	4
12	My face feels hot	1	2	3	4
13	I think that the worst will happen	1	2	3	4
14	My arms and legs feel stiff	1	2	3	4
15	My throat feels dry	1	2	3	4
16	I keep busy to avoid uncomfortable thoughts	1	2	3	4
17	I cannot concentrate without irrelevant thoughts intruding	1	2	3	4
18	My breathing if fast and shallow	1	2	3	4
19	I worry that I cannot control my thoughts as well as I would like to	1	2	3	4
20	I have butterflies in my stomach	1	2	3	4
21	My palms feel clammy	1	2	3	4

Appendix H

Rating Scale for Mental Effort
(RSME; Zilstra, 1993)

Draw a line through the vertical scale to indicate how much mental effort you had to invest to execute the previous task (i.e., how effortful was it for you to perform the previous task).



Appendix I

State Rating Questionnaire

For each of the following dimensions circle the option that best describes **how you feel, right now, at this moment.**

1. Calm to Nervous

Very Calm	Quite Calm	Slightly Calm	Neither Calm Nor Nervous	Slightly Nervous	Quite Nervous	Very Nervous

2. Fearless to Fearful

Very Fearless	Quite Fearless	Slightly Fearless	Neither Fearless Nor Fearful	Slightly Fearful	Quite Fearful	Very Fearful

3. Relaxed to Anxious

Very Relaxed	Quite Relaxed	Slightly Relaxed	Neither Relaxed Nor Anxious	Slightly Anxious	Quite Anxious	Very Anxious

4. Unconcerned to Worried

Very Unconcerned	Quite Unconcerned	Slightly Unconcerned	Neither Unconcerned Nor Worried	Slightly Worried	Quite Worried	Very Worried

5. Comfortable to Tense

Very Comfortable	Quite Comfortable	Slightly Comfortable	Neither Comfortable Nor Tense	Slightly Tense	Quite Tense	Very Tense

Appendix J

Reading Span Task (shortened; see Series 2)

Trial		Sentence
P1	1	She was so engrossed in the lecture, she forgot about the listener.
	2	One man bailed steadily while the other applied patches to the pontoon.
	Q	She was engrossed in her lecture.
	A	TRUE
P2	1	He thought two hundred miles per hour was his maximum speed.
	2	He carefully lifted the gift boxes and placed them on Santa's sleigh.
	3	The five star restaurant had leather chairs, fine china and beautiful silver.
	Q	He threw the boxes on Santa's sleigh
	A	FALSE
2.1	1	Due to his vast experience and many capabilities, he was promoted quickly.
	2	It is possible that no one survived the plane crash at all.
	Q	He was fired because he was lazy.
	A	FALSE
2.2	1	Jane's family had decided that her new work friend had high status.
	2	Without thinking of the consequences, he proceeded to announce his resignation blindly.
	Q	Jane did not have any family or friends.
	A	FALSE
2.3	1	Jane's family had decided that her new work friend had high status.
	2	Without thinking of the consequences, he proceeded to announce his resignation blindly.
	Q	Jane did not have any family or friends.
	A	FALSE
2.4	1	People came from all around to see the newly elected political candidate.
	2	After finishing her studies she celebrated for an entire week without resting.
	Q	Many people came to see the candidate.
	A	TRUE
2.5	1	According to the survey, Zac Efron is the most liked Hollywood star.
	2	The weather was unpredictable, so it was difficult to plan in advance.
	Q	The weather was predictable.
	A	FALSE
3.1	1	The effects of the flood were not fully realised until months later.
	2	With sudden inspiration, she thought of a brilliant idea for her paper.
	3	At the end of the beautiful musical performance, the crowd enthusiastically applauded.
	Q	The flood had no effects.
	A	FALSE
3.2	1	They attended the church habitually except for circumstances outside of their control.
	2	The carpenters worked long hours to saw the necessary amount of wood.
	3	The old lady walked with her new neighbour to and from church.
	Q	The men sawed enough wood.
	A	TRUE
3.3	1	There are days when you wake up and have a strange look.
	2	We fought hard, but backed down when it came to the pinch.
	3	With complete fascination, Marion flicked through the book examining all the pictures.
	Q	Marion showed no interest in the book.
	A	FALSE
3.4	1	Dreaming of winning gold lotto is wonderful, but probably not real life.
	2	He stood and watched her for a while feeling sad and bitter.
	3	John was annoyed when his daughter Karen started swearing and chewing gum.
	Q	Winning lotto is not real life.
	A	TRUE

3.5	1	After the investigation there was enough evidence to identify and select him.
	2	To determine the effects of the medication, the doctor hospitalised his patient.
	3	His wife nagged incessantly about maintaining a healthy diet for their children.
	Q	The doctor hospitalised his patient.
	A	TRUE
4.1	1	I found the speaker intelligent, very easy to follow and well read.
	2	He postponed his business trip and cancelled his engagements for the week.
	3	The child was taught about the importance of respect for her elders.
	4	The attorney impressed the jury with his thorough knowledge of the case.
	Q	The speaker was hard to follow.
	A	FALSE
4.2	1	I imagine that you are suspicious of the purpose of my visit.
	2	She has pictures of my great-grandmother in an old photograph album.
	3	He was not sure what went wrong but it made him laugh.
	4	Filled with these happy thoughts, she pushed open the heavy wooden door.
	Q	She has no old family photographs.
	A	FALSE
4.3	1	I am trying to convince him that I will love him forever.
	2	The small troubled child wished for a miraculous intervention by a superhuman.
	3	It was your strong belief in my ability that kept me going.
	4	The girl hesitated to taste the onions because she hated the smell.
	Q	Your belief in me was very helpful.
	A	TRUE
4.4	1	All the performers gathered back stage at the end of the production.
	2	The young business executive was determined to improve his sales this year.
	3	Despite the unusually cold weather, the teenagers were planning a camping trip.
	4	Students that passed the exam were exempt from further classes that semester.
	Q	The students were not examined.
	A	FALSE
4.5	1	Staff agreed to longer work days in order to break for lunch.
	2	By comparison to other classical musicians, the violinist had an entertaining style.
	3	Students playing loud music disturb the old people living in the building.
	4	The children were instructed to walk very slowly and lift their feet.
	Q	The staff decided to extend their day.
	A	TRUE
5.1	1	The clowns gathered a small crowd and many children were watching them.
	2	Having a formal education will play an important role in your future.
	3	There was a problem with the examination with some evidence of cheating.
	4	Sometimes it is beneficial to bring an outsider in to the community.
	5	I should have been able to understand how exciting it all was.
	Q	Formal education is important to your future.
	A	TRUE
5.2	1	After searching the bushland they found the man sitting beside the campfire.
	2	The travelling circus crew arrived to set up at the muddy ground.
	3	I was shocked when my son described the hilarious events that followed.
	4	The photography courses are designed as much for professionals as for enthusiasts.
	5	The tour bus parked to give tourists a view of the lake.
	Q	The man was eventually found.
	A	TRUE
5.3	1	Their religious leader wrote a lenthgy description of his vision of God.
	2	Shortly after this, the unexpected pressure of business called me into town.
	3	He continued questioning, pretending to seek information to fulfil his own doubts.
	4	After the shocking announcement today, I was totally speechless for a while.
	5	When we finally spoke, there was no sign of jealousy or anger.
	Q	I was shocked by the announcement today.
	A	TRUE

5.4	1	He held his child and the woman watched him from a distance.
	2	My eyes turned upon me from the mirror with a haughty stare.
	3	He considered writing about her so she would remain in his mind.
	4	When the jury makes their decision, a conclusion will come to be.
	5	We arrived at the plantation and found it had not suffered much.
	Q	The plantation did not suffer much.
	A	TRUE
5.5	1	The investigation is vitally important and the findings must be well documented.
	2	Hour after hour the difficulties got worse and the delays became maddening.
	3	The hikers complained about the steep climb in the rain and cold.
	4	We were thinking things over while our manager was talking to us.
	5	It was an hour before breakfast and the house was still asleep.
	Q	The hikers enjoyed the climbing conditions.
	A	FALSE
6.1	1	The news had spread across the world even to the remotest land.
	2	We will activate the social policy and this will meet our objective.
	3	Wipe the lens carefully with a soft cloth to protect the face.
	4	He laughed heartily and looked as though he appreciated my clever joke.
	5	He tolerated a third interuption and showed much patience for doing so.
	6	She thought I had other motives, besides trying to escape the law.
	Q	My joke was apreciated.
	A	TRUE
6.2	1	He listened carefully because he thought that he recognised the soft voices.
	2	A common personal attribute among the central characters was their unique sensitivity.
	3	Being so distracted meant his name was called twice before he answered.
	4	She served the chocolate tart with mixed berries to decorate each dish.
	5	He pulled the strap across his waist and fastened the catch securely.
	6	The desk was cluttered with old papers and objects coated in dust.
	Q	He answered every time his name was called.
	A	FALSE
6.3	1	He encouraged her while she was at university and still a student.
	2	The rain and howling wind kept beating against the rattling window panes.
	3	He wondered if people woud hear the loud noise that it made.
	4	The couple moved to the country and attempted to withdraw from society.
	5	Without the correct tension there would be no balance in mechanical design.
	6	When I saw him, I wanted to say that I felt sorry.
	Q	The couple moved to the country.
	A	TRUE

Appendix K

Go-No-Go Task Stimulus Words (see Series 2)

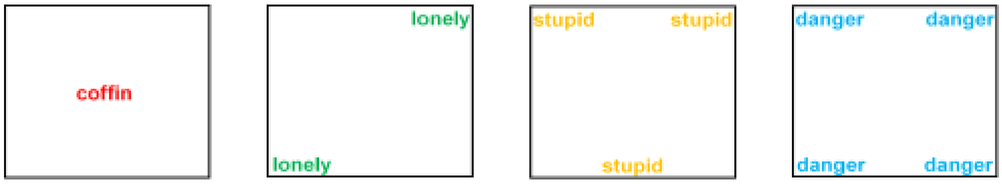
Neutral Words	Threat-Related Words
desk (4209)	hurt (4145)
suite (1322)	grief (1315)
beds (2038)	evil (2745)
blanket (1063)	lacking (1479)
taps (434)	scar (411)
wall (11180)	dead (11643)
cups (1173)	burnt (1100)
chair (6969)	pain (6928)
stair (339)	satan (375)
iron (4375)	kill (4375)
fence (1502)	burn (1559)
sugar (3365)	abuse (3389)
hook (1303)	ugly (1252)
bath (3318)	fail (3238)
doors (4383)	worry (4516)
eaves (183)	spasm (184)

NOTE: Frequencies per million x 89 are shown in parentheses

Appendix L

Wisconsin Card Sorting Task
(modified from Heaton et al., 1993; see Series 2)

Target Cards



Stimulus Cards

(Matched according to the WCST in Series 1)

Neutral Cards	Threat-Related Cards
carpet (2088)	coffin (1317)
garage (1603)	lonely (1696)
sheets (2127)	stupid (2439)
coffee (5724)	danger (5709)

NOTE: Frequencies per million x 89 are shown in parentheses