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Effectiveness and Efficiency of Executive Functions: The Influence of Trait Anxiety, Situational Stress, Mental Effort, and Working Memory Capacity.

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Effectiveness and Efficiency of Executive Functions: The Influence of Trait Anxiety, Situational Stress, Mental Effort, and Working Memory Capacity

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Abstract

The current dissertation investigated the influence of trait anxiety on the effectiveness and efficiency of select executive functions. Anxiety is an aversive emotional experience, comprised of both cognitive (e.g., worrisome thoughts) and somatic (e.g., racing heartbeat) symptomatology. Anxiety is also classified as being either trait- (i.e., chronic, enduring) or state-based (i.e., acute, transient). Executive functions are separable processes involved in the coordination and maintenance of goal-oriented behaviour. These processes operate in novel situations and are ubiquitous to daily functioning and achievement. Despite anxiety being one of the most common mental health concerns in Australia, as well as being associated with impairments in executive functioning, little research has extended beyond a select series of simple executive functions. The current work aimed to evaluate the influence of trait anxiety on a series of executive functions that had not been adequately examined in prior research. Specifically, focus was given to the functions of mental rotation, forward planning, hot and cold decision-making, and sustained attention. The current work further aimed to examine the moderating influence of other sources of cognitive interference, including variations in situational stress and cognitive load. In the later stages of this research, the role of working memory capacity was also investigated. The theoretical framework of the present work was informed by the cognitive interference model, attentional control theory. The predictions of this theory were extended to examine its application amongst complex, multifaceted executive processes.

The current dissertation consisted of two research phases. Phase 1 examined the influence of trait anxiety, situational stress, and cognitive load on the performance of mental rotation (Study 1), forward planning (Study 2), cold decision-making (Study 3), and sustained attention (Study 4). Phase 2 investigated the effect of trait anxiety, situational stress, and working memory capacity in relation to performance of forward planning (Study 5), hot

decision-making (Study 6), and sustained attention (Study 7). Per the theoretical framework of the selected attentional control theory, a non-clinical sample was recruited for both phases of research. Eligible university students were recruited for the research from the campus of Bond University. Also following the framework of attentional control theory two key outcome variables were assessed across both phases: (1) performance effectiveness and (2) processing efficiency. Performance effectiveness represented the quality of performance and was indexed as task accuracy. Processing efficiency evaluated the relationship between performance effectiveness and the associated use of cognitive resources (often interpreted as reaction time [RT]). Performance efficiency in the current work was therefore estimated as a ratio of standardised performance effectiveness by standardised RT.

Hypotheses for the first phase of research a predicted three-way interaction amongst trait anxiety, situational stress, and cognitive load in influencing the select executive functions. It was specifically predicted that a combination of high trait anxiety and low cognitive load would be associated with greater effectiveness and efficiency for participants allocated to a high stress condition. Results returned partial support for these predictions, which were interpreted with respect to prior literature and theory.

Cognitive load was only found to alter performance effectiveness and processing efficiency in Study 1, which examined mental rotation. Mental rotation was assessed using a mental rotation task that adopted the seminal paradigm of Shepard and Metzler (1971). A three-way interaction between all study variables was found for mental rotation effectiveness and efficiency. At higher levels of cognitive load, high trait anxious participants who experienced a stress induction outperformed low trait anxious participants who experienced the same conditions. The influence of cognitive load only appearing in relation to mental rotation, and not any of the other Phase 1 functions, was attributed to the more simplistic procedure of the mental rotation task. That is, cognitive load exerted a noticeable change on performance only on tasks of relatively simple executive functions. By contrast, the impact was not observed for more demanded or multifaceted tasks like those examined in Study 2, 3, or 4.

In Study 2, forward planning ability was evaluated using a computerised one-touch Tower of London task. It was found trait anxiety and situational stress interactively influenced forward planning processing efficiency. When undergoing a stress manipulation, high trait anxiety participants demonstrated poorer processing efficiency (standardised accuracy/RT ratios) compared to low trait anxiety participants. Cognitive load was unrelated to processing efficiency. For performance effectiveness, situational stress alone was found to be significant, with participants in the control condition outperforming their counterparts who experienced a stress induction. Cognitive load and trait anxiety were found to be unrelated to forward planning effectiveness in this study.

Study 3 found the independent influence of trait anxiety and situational stress on the performance effectiveness of cold decision-making (i.e., logical, non-emotive decision-making). Decision-making ability was assessed using a novel task inspired by the Applying Decision Rules subtest of the Adult Decision-Making Competence battery (Bruine de Bruin, Parker, & Fischhoff, 2007). Analyses found high trait anxiety participants demonstrated greater performance effectiveness during the decision-making task compared to low trait anxiety participants. Further, participants assigned to the control condition performed with greater performance effectiveness compared to those who underwent a stress manipulation. Cognitive load had no significant contribution to performance effectiveness. No significant influence of trait anxiety, situational stress, or cognitive load were observed for processing efficiency.

Study 4 examined sustained attention ability; however no significant results were observed. Sustained attention was evaluated using a 7-minute rapid visual information processing task. Analyses suggested trait anxiety, situational stress, and cognitive load had no significant influence on the performance effectiveness or processing efficiency of sustained attention. On review, potential limitations of the chosen task and outcome measures that could have contributed to the null result were discussed. These limits were amended for the second phase of research.

In the second phase of research, the influence of trait anxiety, situational stress, and working memory capacity on the functions of forward planning, hot decision-making, and sustained attention was examined. Studies were theoretically framed within attentional control theory. Akin to the first phase of research, a non-clinical sample of eligible university students was recruited from Bond University. Hypotheses for the second phase of research were informed by attentional control theory. It was anticipated that three-way interactions between trait anxiety, situational stress, and working memory capacity would influence both performance effectiveness and processing efficiency outcome measures. Specifically, a combination of high trait anxiety and high working memory capacity would be related to better effectiveness and efficiency outcomes for participants allocated to a high stress condition. Results of the research found partial support for these predictions. All findings were ultimately reviewed in relation to attentional control theory and previous literature.

Study 5 assessed forward planning ability using a *N*-puzzle task. Analyses found trait anxiety, situational stress, and working memory capacity interactively influenced forward planning processing efficiency. In situations of induced stress, and when observing participants with high working memory capacity, those with high trait anxiety demonstrated improved processing efficiency compared to low trait anxiety participants. No significant effects were found for the performance effectiveness outcome.

Study 6 investigated hot decision-making (i.e., quick, emotive decision-making) using a modified Iowa gambling task. Variations in trait anxiety, situational stress, and working memory capacity were found to be unrelated to hot decision-making effectiveness or efficiency. Results were interpreted with respect to prior literature and theory. Discussion of results suggested incompatibility of task measures or ineffective stress manipulations might have contributed to inconsistency with previous research.

Study 7 examined sustained attention using the Test of Variables of Attention. With this task, performance effectiveness and processing efficiency calculations integrated the use of the sensitivity index *d'*. Trait anxiety, situational stress, and working memory capacity were found to interactively influence performance effectiveness and processing efficiency of sustained attention. For participants with a high working memory capacity who underwent the situational stress manipulation, those who self-reported high trait anxiety demonstrated improved performance effectiveness (i.e., target sensitivity; *d'*) and process efficiency compared to low trait anxiety participants in the same circumstances.

Ultimately, the summarised conclusions of the current research included (1) trait anxiety and situational stress impaired performance on tasks of executive functions that were complex and multifaceted, (2) trait anxiety and situational stress interacted to determine planning performance (3) trait anxiety and situational stress influenced logical, non-emotive decision-making over heuristic, risk-based decision-making (4) trait anxiety and situational stress interacted to determine target sensitivity during sustained attention, (5) cognitive load did not reliably alter the influence of trait anxiety and situational stress on complex executive functions, and (6) working memory capacity buffered the impairments of trait anxiety and situational stress on complex executive functions, as well as provided facilitating effects under certain circumstances. Findings of the current research contributed to a scarce area of literature and established a foundation for new work to be built upon. In the final discussion, results were compared to prior literature and interpreted within the framework of attentional control theory. The work was generally complementary to the extension of attentional control

theory over a range of complex executive functions. Limitations of the project were highlighted, including restricted participant recruitment (resulting in a primarily university-based sample), gender imbalance, and emphasis on cognitive anxiety symptomatology to the exclusion of somatic symptomatology. Directions for future research were suggested with consideration of these limits. Practical implications of the work were also discussed.

Declaration of Originality

This thesis is submitted to Bond University in fulfilment of the requirements of the degree of Doctor of Philosophy (PhD). 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 another institution, except where the due acknowledgment is made. All 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.

Name: Katarina B. Needham

Signature:

Date: 27 November 2019

Research Output

Conference Proceedings

Needham, K. B., Edwards, E. J., Edwards, M. S., & Lyvers, M. (2017, September). *Trait anxiety and situational stress interact to predict planning efficiency on the Tower of London task*. Paper presented at the 34th Annual British Psychological Society Cognitive Section Conference. Newcastle, United Kingdom.

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Chapter One: Introduction to Dissertation Topic

Executive function is a broad referent used for a series of cognitive functions responsible for the coordination and maintenance of goal-oriented mental and behavioural processes (Goldstein, Naglieri, Princiotta, & Otero, 2014; Royall et al., 2002). Individual executive functions are characterised by their supervisory abilities (e.g., moderation of stimuli input and behavioural output; Gilbert & Burgess, 2008). These functions operate in novel situations where established stimulus-response chains are absent or corrective action is required, such as when improving task performance or rectifying errors (Barkley, 2013). Example executive functions include planning, decision-making, mental flexibility, attentional sustainment, sequencing, updating, shifting, and inhibition, among others (see Chan, Shum, Toulopoulou, & Chen, 2008; Jurado & Rosselli, 2007). While early theories represented executive functioning as a unitary process, current research more commonly characterises executive functioning as both diverse and unified (e.g., Miyake et al., 2000). That is, individual executive functions are recognised as separable processes that share an underlying functional similarity (i.e., goal-oriented coordination; Banich, 2009; Kinsella, Storey, & Crawford, 1998). To facilitate the higher-order cognition required for daily functioning, multiple executive functions are required to work concurrently. Disruption to executive functioning can contribute to various deficiencies in such domains as academic performance, social interaction, and self-care (Anderson, Bechara, Damasio, Tranel, & Damasio, 1999; Best, Miller, & Naglieri, 2011; Pessoa, 2009).

Changes in external and internal sources of distraction have been observed to have differential effects on executive functions. Internal sources of distraction may arise from emotional instability; a common variant of this is individual differences in trait anxiety. Anxiety has been reported as unique in its association to executive functions, with other forms of aversive emotion (e.g., anger, depression) failing to replicate similar patterns of disruption (Shields, Moons, Tewell, & Yonelinas, 2016). Other sources of disruption may originate from external sources, such as situational stressors and changes in task difficulty. The investigation of disruptors to executive functions has been limited by several factors, including inconsistent definitions and restricted emphasis placed on a select few functions to the detriment of others. The current literature detailing the link between anxiety and executive functioning could benefit from expansion.

The current dissertation was designed to examine the relationship between trait anxiety and a select series of executive functions. The chosen executive functions[1] extended beyond the simpler functions that have predominated prior literature. The dissertation also examined the influence of other sources of cognitive interference on executive functioning, specifically situational stress and cognitive load. The current research was based in the theoretical framework of attentional control theory. As such, the current work used the key outcome measures detailed in the theory: performance effectiveness and processing efficiency. The general constructs examined in this dissertation, an outline of the chosen attentional control theory, and an explanation of the key outcome measures used throughout the research are summarised in the current chapter.

Executive Functions

Some work characterises executive function as a monolithic, unitary construct, often illustrated as a singular control system responsible for the allocation of attentional resources (e.g., Baddeley, 1986; Norman & Shallice, 1986). Proponents of the unitary theory have suggested executive functions to be emergent products of a broader psychological construct, similar to that of general intelligence's *g* (Banich, 2009; Salthouse & Davis, 2006). Such

[1] The executive functions that are focused on in the current dissertation are mental rotation, forward planning, cold and hot decision-making, and sustained attention. Each of the chosen functions are reviewed in detail throughout Chapter Two: Review of Selected Executive Functions.

approaches contend a unidimensional model simplifies executive function and offers greater construct validity than multidimensional structures (e.g., de Frias, Dixon, & Strauss, 2006; Duncan, Emslie, Williams, Johnson, & Freer, 1996). Some variations of the unitary theory will label this common underlying construct as executive attention (Blair, 2006; Duncan et al., 1996; Engle, 2002; McCabe, Roediger III, McDaniel, Balota, & Hambrick, 2010).

In contention with the unitary theory, a greater number of multidimensional models have been proposed. These models suggest executive functioning is divisible into clearly separable functions, each with unique characteristics and definitions. Some literature suggests there is little to no overlap between functions (Blair, Zelazo, & Greenberg, 2005; Pennington & Ozonoff, 1996; Zillmer & Spiers, 2001). Other works argue towards a middle ground in which executive functions are diverse but are also unified by a shared overlap in functionality (Banich, 2009; Friedman et al., 2008; Miyake et al., 2000). The multidimensional approach appears the most popular framework to conceptualise executive functioning. In a review of 106 studies of executive function, Baggetta and Alexander (2016) identified 79% of the screened research utilised multidimensional models. Investigation of executive functions continues despite no consensus on the boundaries of the construct’s diversity.

Trait Anxiety and Executive Functioning

Anxiety is an aversive emotional experience, consisting of both cognitive and somatic symptomatology. Cognitive symptoms may consist of excessive worry, intrusive thoughts, and feelings of distress, while somatic symptoms might include experiences of muscle tension, racing heartbeat, and other bodily disruptions (Ree, French, MacLeod, & Locke, 2008). Anxiety can be further separated into state and trait variants. State anxiety is a temporary condition, often induced by current situational stressors (Eysenck, Derakshan, Santos, & Calvo, 2007; Robinson, Vytal, Cornwell, & Grillon, 2013; Spielberger & Reheiser, 2009). In contrast, trait anxiety refers to stable, individual differences in the propensity to experience anxiety. Heightened trait anxiety can predispose individuals to experience greater negative emotionality, increase vulnerability to changes in state anxiety, and perceive stressful situations as more threatening/dangerous (Robinson, Vytal, et al., 2013; Spielberger & Reheiser, 2009).

Prior empirical studies have established a relationship between increased trait anxiety and detriments in tasks of executive function. Even in non-clinical samples, greater reports of trait anxiety have been associated with poorer performance on tasks of executive functions. This trend suggests even sub-clinical elevations in trait anxiety can be disadvantageous to higher-order cognition. An example of this is the work of Ansari, Derakshan, and Richards (2008), who recruited undergraduate university students without prior clinical diagnoses of anxiety. Their work evaluated the influence of trait anxiety on a task of set-shifting ability. Task shifting, also referred to as attentional switching or mental flexibility, is commonly cited as a separable executive function (Diamond, 2013; Friedman, Miyake, Robinson, & Hewitt, 2011; Miyake & Friedman, 2012). Utilising a mixed antisaccade task, Ansari et al. reported that compared to low trait anxious participants, those who reported high trait anxiety exhibited poorer switch costs (i.e., slower response times when changing from one task version to another). High trait anxious individuals were unable to exert the degree of top-down/volitional control necessary to meet the complex task demands. This finding was observed in the absence of threatening stimuli, suggesting threatening environmental factors are not a necessary component for cognitive interference in high trait anxious individuals. This trend has been found in other publications that have assessed shifting ability (e.g., Caselli, Reiman, Hentz, Osborne, & Alexander, 2004; Orem, Petrac, & Bedwell, 2008; Wilson, Nusbaum, Whitney, & Hinson, 2018).

Similar findings are also reported in work that has focused on other executive functions. Another example is that of Pacheco-Unguetti, Acosta, Callejas, and Lupianez

(2010), who investigate the association between trait anxiety and inhibitory control. Inhibitory control refers to the ability to resist interference from task-irrelevant stimuli, often noted as a key function in multidimensional models of executive function (Diamond, 2013; Miyake et al., 2000; Miyake & Friedman, 2012). The research conducted by Pacheco-Unguetti and colleagues (2010) involved participants being required to complete an attention network test-interaction (ANT-I) task. The task assessed individual differences in orienting, alerting, and executive control responses. Participants were required to discriminate between directional cues in the form of left- and right-facing target arrows. Target arrows were flanked by distractor arrows which were either congruent (pointing in the same direction as the target) or incongruent (pointing in the opposite direction of the target). Examples of stimuli used in the study are presented in Figure 1.

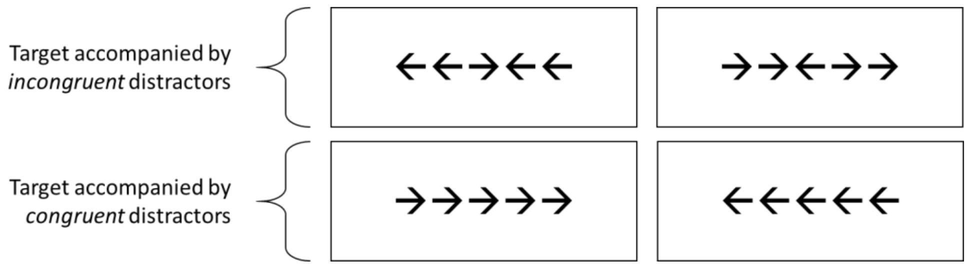

Figure 1. Example stimuli employed by Pacheo-Unguetti et al. (2010) to assess executive control.

While all participants were slower to respond to incongruent trials, the findings demonstrated high trait anxious participants showed greater interference effects by comparison (i.e., RT differences between congruent and incongruent trials). This suggested individuals high in trait anxiety possessed impoverished inhibition abilities and were unable to ignore distracting task-irrelevant information, even when the distractor stimuli were of a non-emotional nature. Multiple studies have replicated this finding (e.g., Ansari & Derakshan, 2011; Bishop, 2009; Darvishzadeh, Aguilar-Vafaie, & Moradi, 2012; Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009). While competing evidence has been put forward to suggest greater trait anxiety is related to increased inhibitory control (e.g., Basten, Stelzel, & Fiebach, 2011; Righi, Mecacci, & Viggiano, 2009; Savostyanov et al., 2009), support for this approach is more limited. Much of the research also interprets neurological activation as indices of inhibitory control in the absence of complementary behavioural data.

Although literature supports an association between trait anxiety and executive function, the interpretation and comparison of research are restricted by limitations in the operational definition of executive function. Despite being cited together, there are often key differences between studies that claim to investigate the same executive function. In the case of shifting ability, the range of tasks employed across the literature is broad. Shifting tasks may include mixed-trial prosaccade and antisaccade tasks (Ansari et al., 2008), the comprehensive trail-making task (Orem et al., 2008), and the Wisconsin card-sorting task (WCST; Grant & Berg, 1948). This selection of tasks varies in how shifting ability is assessed and may tap alternative forms of the construct. While the WCST may represent a form of complex judgement shifting, the trail-making task assesses a separable, simpler style of stimulus shifting (Kleinsorge & Heuer, 1999; Kleinsorge, 2004; Von Bastian & Druey, 2017). Indeed, in a recent review of shifting tasks, Von Bastian and Druey (2017) suggested the trail-making task to be a poor measure of shifting as an executive function and instead represents a measure of lower-order visual-spatial attention. Nuances between tasks are rarely noted in literature, nor explicitly linked to operational definitions of functions. This is a concern when assessing executive functions, as many classic tasks were designed to diagnose broad, frontal lobe impairment rather than detriments of isolated functions (Chan et al., 2008). Such tasks were devised at a time[2] when executive functioning was broadly attributed

[2] The time-period alluded to ranges from the 1940s through to the 1980s. This range is based on publication records of popular neuropsychological tests used in executive function literature. One of the earliest neuropsychological tests devised to assess executive functioning was the Wisconsin Card Sorting Task, first

to the frontal lobe (Alvarez & Emory, 2006). Since then, understanding of the human brain has expanded substantially. In particular, executive functions are no longer neuroanatomically restricted to the pre-frontal cortex (Alvarez & Emory, 2006; Lezak, Howieson, Loring, & Fischer, 2004). Indeed, executive functions by definition are an amalgamation of the multiple lower-order, non-frontal processes they rely upon and coordinate (Alvarez & Emory, 2006). Direct task-to-task comparisons therefore remain difficult due to differences in required auxiliary processes. For example, despite including a set-shifting aspect, the comprehensive trail-making task also assesses psychomotor speed, visual search strategy, sequencing ability, and inhibitory ability (Bauman Johnson, Maricle, Miller, Allen, & Mayfield, 2010). In contrast, the WCST and pro-/anti-saccade paradigms are devoid of sequencing and search strategy components. Further, differences in outcome measures can widen the gap between task comparison. While the comprehensive trail-making task and WCST both often use perseverative errors to infer impaired shifting ability, mixed pro-/anti-saccade tasks may use RT data to estimate process deficiencies.

A further issue lies in the breadth of executive functions evaluated in recent literature. In a systematic review of 106 articles examining executive functions, Baggetta and Alexander (2016) identified the most commonly cited model of executive function to be that of Miyake et al. (2000). This work highlighted the separability of three executive functions, inclusive of inhibition, shifting, and updating[3,4]. Indeed, Baggetta and Alexander's review

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referenced in 1948 by E. A. Berg. Another popular measures, the trail making test, was referenced as a measure of cognitive dysfunction in 1955 and 1958 by R. M. Reitan. A more recent example, the Tower of London was referenced as a measure of executive function and planning ability by T. Shallice in 1982.

[3] Inhibition is the ability to resist processing of task-irrelevant information. Shifting (or mental flexibility) refers to the ability to switch attentional resources between two or more task-relevant sources to maximise performance. Updating is involved in the continual coding and reappraisal of information in working memory.

[4] Some literature also refers to updating as "working memory". For the current dissertation, updating is considered the executive function involved in the active maintenance of memory content. In contrast, working memory is considered to refer to the passive, limited-capacity cognitive system (Baddeley, 2001). As such, the term updating is used throughout to refer to the separable executive function.

also noted this trio of functions to be the most frequently investigated throughout literature. The work put forward by Miyake and colleagues allowed subsequent literature to cite clear definitions of the three functions. In Miyake et al.'s (2000) original article, the authors sought to examine the separability of inhibition, shifting, and updating. Selection of these functions was attributed to (1) the functions being simple in comparison to other functions (e.g., planning) allowing for more precise operational definitions, (2) several tasks being readily available to tap the trio, and (3) the functions had often been implicated in the explanation of complex executive functions (e.g., planning). One hundred thirty-seven university students performed a series of tasks. Each function was assessed with three related tasks, with five additional tasks of "general" executive function also completed. See Table 1 (overleaf) for a summary.

Table 1

Summary of Tasks Used in Miyake et al. (2000) To Assess Inhibition, Shifting, Updating, and General Executive Function

Construct	Task	Reference
Inhibition	Antisaccade task	Roberts, Hager, & Heron (1994)
	Stop-signal task	Logan (1994)
	Stroop task	Stroop (1935)
Shifting	Plus-minus task	Jersild (1927), Spector & Biederman (1976)
	Number-letter task	Rogers & Monsell (1995)
	Local-global task	Navon (1977)
Updating	Keep track task	Yntema (1963)
	Tone monitoring task	Larson, Merritt, & Williams (1988)
	Letter memory task	Morris & Jones (1990)
"General" executive function	Wisconsin card sorting task	Grant & Berg (1948)
	Tower of Hanoi	Humes, Welsh, Retzlaff, & Cookson (1997)
	Random number generation	Ginsburg & Karpiuk (1994)
	Operation span task	Turner & Engle (1989)
	Dual-task; required completion of maze tracing speed task and concurrent word generation	Ekstrom, French, Harman, & Dermen (1976)

Use of confirmatory factor analysis determined their proposed three-factor model fit the data better than either a one-factor model or a series of reduced models. The three-factor model is illustrated in Figure 2. Evaluation of the 95% confidence intervals of correlations amongst the latent variables of inhibition, shifting, and updating suggested no pair of variables were the same construct. Once established as separable, a series of structural equation models (SEMs) determined which of the variables would best explain performance on the general executive function tasks. For the WCST, the one-path model from shifting provided the best fit. For the Tower of Hanoi, the one-path model from inhibition was best. For the random number generation task, a one-path model from inhibition and one-path model from updating best explained performance on its two subtests. For the operation span task, a one path model from updating found the best fit. Finally, for dual-task, none of the variables predicted performance.

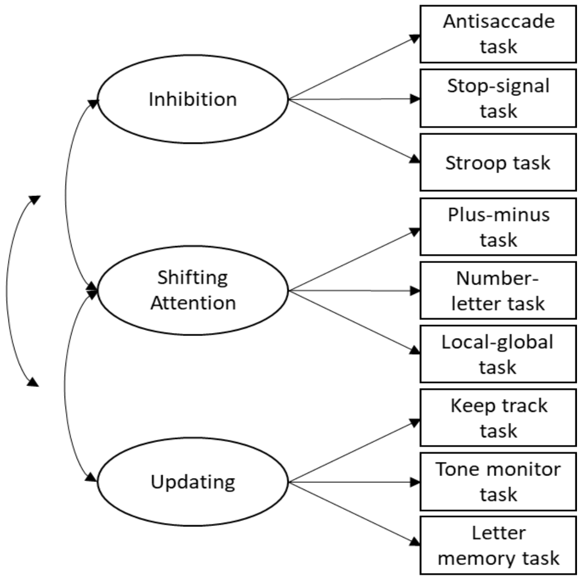

Figure 2. Model proposed in Miyake et al. (2000). The three executive functions of inhibition, shifting, and updating are noted to be related but separable.

Miyake et al. made great contributions to understanding the diversity of executive functions. However, their work (particularly their SEM findings) has been misconstrued as verifying the existence of "core" executive functions. An example of this misrepresentation can be seen in the initial publishing of attentional control theory (Eysenck et al., 2007) which claims:

> "… [Miyake et al.] used latent-variable analysis to *identify the basic control functions of the central executive*, basing their selection of tasks on lower level functions that had previously been proposed for the central executive by various theorists…"

Miyake et al. made no claim to have identified the basic control functions of the central executive. Their work instead supported some executive functions are separable yet related. Further, their work claimed some functions are more likely to contribute to complex tasks of executive function than others (e.g., shifting ability is the best predictor of WCST performance; inhibition ability predicts Tower of Hanoi performance). The identification of prominent predictor variables does not negate the influence of other processes which create patterns of processing unique to various executive functions. If the Tower of Hanoi is indeed a measure of forward planning ability then inhibition will undoubtedly play a role in successful navigation of the task, but this contribution is only partial. Inhibition, shifting, and updating are likely to predict performance on complex tasks not because they are "core functions" but because executive functions rely on coordination of multiple, concurrent functions.

Miyake et al. did not claim their three functions to be exhaustive, nor akin to fundamental units of cognition. They also noted inhibition, shifting, and updating could be further refined into multiple subprocesses. Repeated reference to the original Miyake et al. article published almost two decades ago also undermines the authors' continued development in modelling executive functioning. In more recent work by Friedman et al. (2011) the inhibition function was removed from their original model and replaced with a broader "common executive function" factor. As illustrated in Figure 3, this new variable has been found to account for performance on most executive function tasks. The reliance on inhibition, shifting, and updating as foundational units of executive functioning is arbitrary, unwarranted, and limits examination of additional executive functions. Other executive functions cannot be neglected.

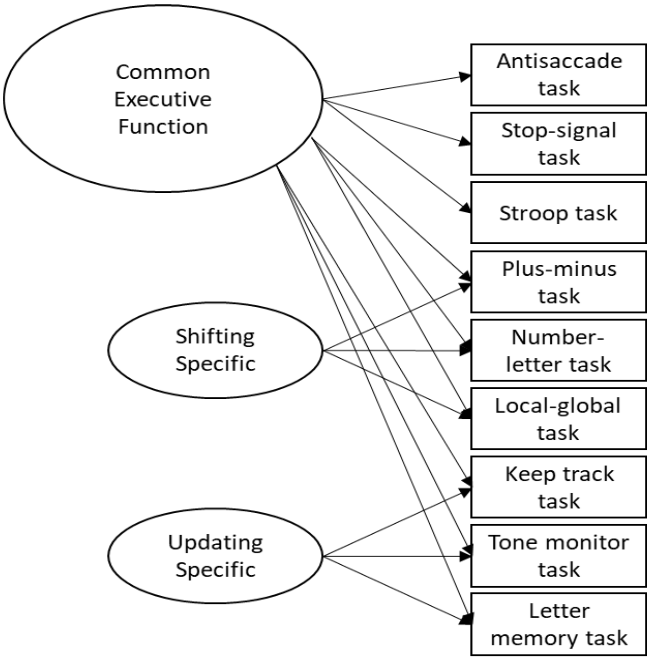

Figure 3. Model subsequently found in Friedman et al. (2011). Multiple executive function tasks were found to load on a common executive function factor supplemented by two nested factors of shifting and updating. The previously identified inhibition factor was subsumed under the new common executive function factor.

Overreliance on the Miyake et al. (2000) model is also present in literature of anxiety and executive functions. Research of the past five years demonstrates a heavy reliance on the model. While other functions have been investigated, it is not to the same extent. Efficacy of executive functions is more likely to appear in literature associated with changes in neurobiological (e.g., traumatic brain injury) or neurodevelopmental (e.g., ADHD) domains. This approach values neurophysiological disruptions to executive function. As such, further evaluation of additional executive functions in relation to individual differences in emotional, such as trait anxiety, interference is needed.

Additional Moderators of Executive Function Disruption

The influence of trait anxiety on executive functions can be further moderated by sources of interference in the external environment. A common interference is acute situational stress, which has been reported to impair multiple executive functions (Starcke, Wiesen, Trotzke, & Brand, 2016). Stress can be conceptualised as an imbalance of requirements and resources. The experience of stress occurs when the demands placed upon an individual are perceived to exceed their current capacity or capabilities (Dickerson & Kemeny, 2004).

Some propose that stress impairs executive functions by introducing additional demand for cognitive resources (Mather & Sutherland, 2011; Plessow, Fischer, Kirschbaum, & Goschke, 2011). This approach assumes cognitive resources (e.g., attention, capacity of working memory) to be finite. In response to stress, individuals reallocate these finite resources to attend to the perceived stressor. This leaves few resources available for task performance. Indeed, working memory capacity and shifting capabilities have been found to reduce under inductions of stress (Moran, 2016; Wilson, 2012). An alternative approach suggests stress impairs executive functions by reorganising attentional processing, rather than consuming resources. Stress is predicted to shift cognition from favouring voluntary, top-down processes to automatic bottom-up processes (Corbetta & Shulman, 2002; Moran, 2016; Wilson, 2012). As executive functions are all top-down control processes, their functionality is sidelined in favour of innate threat-detection processing. Regardless of the explanation, the effect of stress is expected to be particularly potent for high trait anxious individuals, who experience greater vulnerability to changes in stress (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983).

Most experimental work has focused on temporarily inducing acute stress (Wilson, 2012). Experimental induction of stress has often involved the introduction of some environmental manipulation. A classic manipulation that is physiological in nature is introducing threat-of-shock (Moran, 2016). A threat-of-shock manipulation requires individuals to receive randomly timed electrical shocks, delivered through an electrode often attached to the arm. Other forms of stress manipulation involve greater emphasis on emotional manipulation (Moran, 2016). A classic form of affect-based stress manipulation is the use of ego-threat instructions. In work using ego-threat, participants receive false information to threaten their self-image or self-worth. Often participants believe their intelligence is being evaluated or are continually informed they are performing poorly (regardless of actual performance). Other variations of ego-threat may involve some form of social-evaluation such as being required to perform difficult mathematics to a researcher or being asked to perform a short speech. The most effective forms of stress manipulation involve inductions that, for the individual, are uncontrollable and unpredictable (Dickerson & Kemeny, 2004).

The effect of stress on executive functions is mixed. Some research suggests there is no association between stress and executive functions (Pabst, Schoofs, Pawlikowski, Brand, & Wolf, 2013), while other work reports stress produced a facilitating influence for executive functions (Beste, Yildiz, Meissner, & Wolf, 2013; Bolton & Robinson, 2017). However, the greater amount of research suggests the effects of stress are detrimental (Robinson, Letkiewicz, Overstreet, Ernst, & Grillon, 2011; Robinson, Vytal, et al., 2013; Shackman et al., 2006; Starcke et al., 2016). Differences in how stress influences executive functions may be reliant on the specific executive function under investigation.

Another source of disruption to executive functions is cognitive load. Cognitive load, also referred to as workload or mental effort in some work, determines the quantity of cognitive resources necessary to perform a task (Paas, Van Merriënboer, & Adam, 1994; Redifer, Bae, & Debusk-Lane, 2019). Rather than imbalance attentional processing, increased cognitive load is expected to deplete available cognitive resources (Redifer et al., 2019). In optimal circumstances where distraction is minimal, the influence of increasing workload might be negligible. However, when combined with internal and/or external interference, greater cognitive load can leave few resources available to attend to both the task and sources of interference. Cognitive load is often greater for complex and novel tasks. This is pertinent to the area of executive functions, given that executive functions are required to operate in situations where automatic processes are unreliable and are often complex by nature. The pattern of cognitive load's influence on trait anxiety and executive function has been mixed. Some works suggest greater load exacerbates the detriments of trait anxiety as there are less cognitive resources available for compensation (Shackman et al., 2006). However, other works have reported greater cognitive load improves performance of executive functions in the presence of trait anxiety (Vytal, Cornwell, Arkin, & Grillon, 2012; Vytal, Cornwell, Letkiewicz, Arkin, & Grillon, 2013). Detriments are instead observed at levels of low- and medium-load. These studies claim the greater load requirements reduce mind-wandering and opportunities for distraction. Further work is needed to investigate how these contrasting trends appear across different executive functions.

Anxiety and Executive Functions, Theoretical Perspectives

Theories of anxiety and cognition often attempt to define the conditions at which anxiety becomes debilitating for on-task performance. Proponents of cognitive interference theories suggest performance detriments become noticeable when the cognitive resources (e.g., attention, mental capacity) necessary for a task are no longer available. While these resources might be depleted through fatigue, they might also be consumed by competing task-irrelevant processes, such as anxious preoccupation.

Of these cognitive interference models, the current dissertation selected attentional control theory (Eysenck et al., 2007) as its theoretical framework. A summary of the theory and its predictions are discussed in the following section. Prior to this, the earlier theoretical perspectives of cognitive interference theory (Sarason, 1988) and processing efficiency theory (Eysenck & Calvo, 1992) are also briefly outlined to provide background to attentional control theory's development.

Cognitive Interference Theory

Cognitive interference theory (Sarason, 1988) emphasises the cognitive symptomatology of anxiety. The theory highlights the role of self-preoccupation, the tendency to orient attention towards cues reminiscent of the topic of preoccupation[5]. Self-preoccupation is expected to impair attention to environmental cues and processes of encoding information. In cases of increased anxiety, self-preoccupation manifests as heightened concern over personal inadequacies and shortcomings. As such, attention is diverted away from task-relevant processing in favour of threat identification. Highly anxious individuals are expected to fixate on the identification of perceived threats to their sense of self amongst the immediate environment. The theory also suggests faults during the encoding and transformation of information predispose anxious individuals to experience greater levels of worrisome thoughts. This heightened worry consumes any remaining attentional resources, contributing to further detriments of task performance. The theory predicts these detriments are more pronounced in situations where greater demands are placed on the allocation of attention. Example situations may include evaluative scenarios (e.g., testing situations) or increased task complexity.

Cognitive interference theory is ultimately a resource-sharing model. The theory iterates attention is finite, and as such attention must be optimally distributed across multiple processes to facilitate goal-directed behaviour. Changes to the allocation strategy directly impact on the efficacy of behavioural responses. During increased anxiety, these changes are

[5] Cognitive interference theory notes self-preoccupation is not restricted to the domain of anxiety (e.g., task-oriented individuals are expected to display heightened attention to cues relevant to job-completion; paranoid individuals are expected to be especially attentive to cues reminiscent of their delusions).

brought about by worry and self-preoccupation consuming attention. Attention is further depleted when additional demands are present in the environment. That is, the effect of anxiety should be worse when participants expect they are being evaluated and/or the demands of a task are complex. Though Sarason (1988) notes it is possible to overcome cognitive impairments by learned coping strategies[6], the theory assumes high anxious individuals inherently lack these abilities.

Sarason's (1988) theory has been subsequently critiqued as vague, more akin to a summary of then-recent research. Cognitive interference theory does not identify the exact processes affected by anxiety (Derakshan & Eysenck, 2009; Eysenck, 1992). Instead, the theory focuses on broader concepts like general information processing. The theory was also noted to place undue emphasis on the maladaptive nature of anxiety (Derakshan & Eysenck, 2009; Eysenck, 1992). Specifically, the theory did not account for conditions where heightened anxiety may not lead to performance detriments. Subsequent work has built on these limitations.

Processing Efficiency Theory

Processing efficiency theory (Eysenck & Calvo, 1992) was proposed as a model that addressed the limitations of cognitive interference theory. Central to its predictions, processing efficiency theory distinguishes between two outcome measures of cognitive performance, namely *performance effectiveness* and *processing efficiency*. Performance effectiveness refers to the overall quality of task performance and is often indexed using accuracy-based measures. Processing efficiency estimates the relationship between performance effectiveness and the required cognitive resources. Traditionally, processing efficiency has been estimated using reaction time (RT). Optimal processing efficiency is

[6] Sarason does not provide specifics of these apparent coping strategies, only that high anxious individuals do not possess them.

achieved when individuals can attain higher performance effectiveness in combination with lower resource consumption (i.e., greater accuracy and faster RTs).

Processing efficiency theory predicts anxiety will impair processing efficiency to a greater extent than performance effectiveness. Specifically, the theory suggests impairment is due to the worrisome thoughts generated by anxiety. Increased worry is expected to limit the available storage and processing capacity of working memory, consuming cognitive resources that might otherwise be allocated to concurrent task performance. Processing efficiency theory also predicts increased worry can activate a compensatory response, in which greater effort is expended to overcome perceived task impairments. This additional effort is borne out in slower and more deliberate RT to maintain optimal accuracy, hence detriments in processing efficiency over performance effectiveness.

Processing efficiency theory was based within Baddeley and Hitch's (1974) original three-part model of working memory, as illustrated in Figure 4. Working memory is involved in the temporary storage and manipulation of information. The tripartite model separates working memory into three components inclusive of the phonological loop associated with storage/processing of verbal information, the visuospatial sketchpad associated with storage/processing of visual and spatial information, and the modality-free central executive responsible for the coordination of attentional resources. Although a fourth component known as the episodic buffer was later added to the model (Baddeley, 2001; see Figure 5), it does not feature in the predictions of processing efficiency theory. Baddeley and Hitch's (1974) model was used in identifying the cognitive components disrupted by anxiety, unlike the vague predictions of Sarason's (1988) model. Processing efficiency theory predicted anxiety would disrupt only the functions of the central executive and phonological loop. Attending to worrisome thoughts was expected to impair the central executive's ability to allocate resources to task-relevant goals, while the verbal nature of worry was anticipated to consume storage of the phonological loop. Worry was not expected to be visual in nature and was therefore predicted to leave the visuospatial sketchpad unaffected.

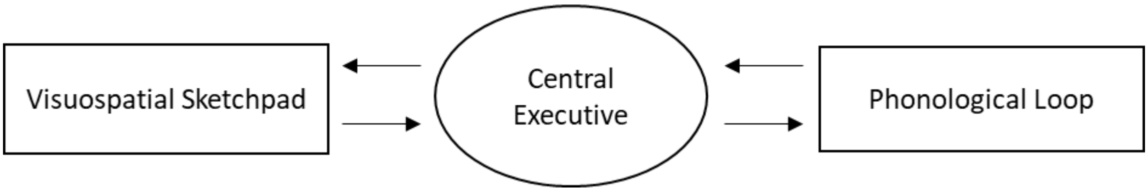

Figure 4. Original model of working memory proposed by Baddeley and Hitch (1974).

Processing efficiency theory received empirical support (Eysenck et al., 2007 for review), though was critiqued for providing few details as to how anxiety disrupted the central executive. This critique was driven by changing views of the central executive, viewing it less as a unitary structure and more as a multimodal system comprised of several discrete processes. This limitation was addressed in the most recent iteration of the model, attentional control theory (Eysenck et al., 2007).

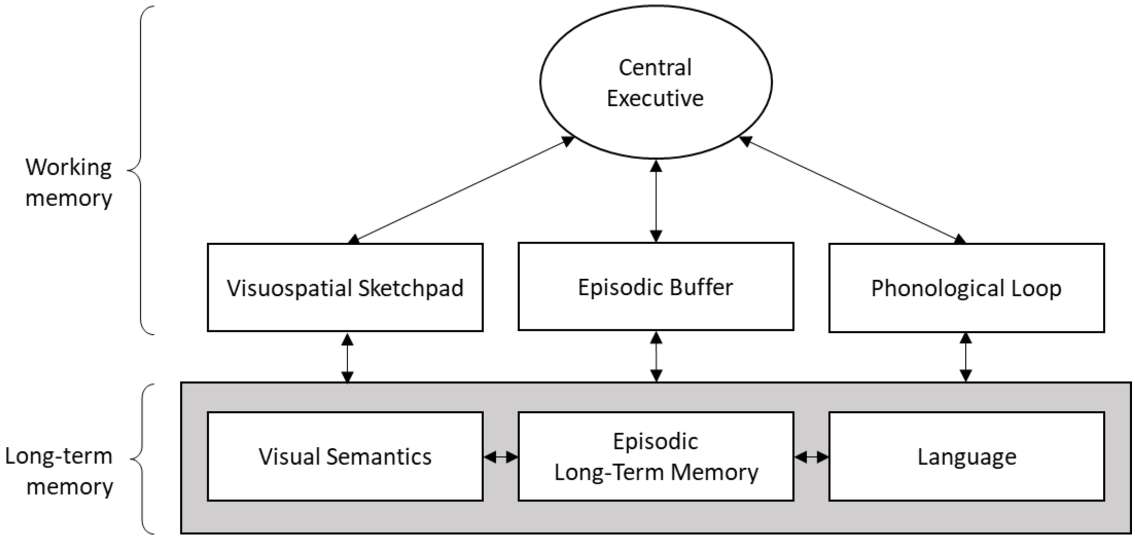

Figure 5. Updated model of working memory proposed by Baddeley (2001). The revised model incorporates links between working memory and long-term memory through both subsystems (phonological loop, visuospatial sketchpad) and the new episodic buffer. Neither the episodic buffer nor long-term memory links feature in processing efficiency theory or the subsequent attentional control theory.

Attentional Control Theory

Attentional control theory (Eysenck et al., 2007; Derakshan & Eysenck, 2009) was developed to address the limitations of processing efficiency theory by identifying the specific functions within the central executive that were supposedly disrupted by anxiety. Attentional control theory places emphasis on individual differences, focusing on trait anxiety and how it interacts with variations in situational stress. The theory is applicable to a non-clinical population. Like its predecessor, attentional control theory continues to distinguish between the outcomes of performance effectiveness and processing efficiency. Anxiety is predicted to predominantly impair processing efficiency, as individuals experiencing anxiety are expected to recruit additional effortful resources to offset decrements in performance effectiveness (Derakshan & Eysenck, 2009). That is, anxious individuals will utilise significantly more cognitive resources on a task to achieve accuracy that is comparable to their less anxious peers.

Attentional control theory states that an understanding of attentional control underscores the broader relationship between anxiety and complex-task performance. The theory states attention is split amongst two attentional systems, one of which is top-down and goal-driven, while the other is bottom-up and stimulus-driven. Heightened anxiety disrupts the balance of these systems, causing a reallocation of resources to favour the stimulus-driven system and prioritise the detection of threats, both external (e.g., scanning of the environment) and internal (e.g., worrisome thoughts; Corbetta & Shulman, 2002). As the stimulus-driven system consumes resources to attend to threat-relevant stimuli, fewer resources are made available for the goal-driven system, thus impairing concurrent task-relevant processes. Attentional control theory suggests it is this feedback process which underlies anxiety’s disruption of performance.

Further to its predictions of resource allocation, attentional control theory refined its use of the tripartite working memory model (Baddeley & Hitch, 1974). The theory views discrete executive functions to be inherently derived from working memory's central executive. The theory integrated the research of Miyake and colleagues (2000; Miyake & Friedman, 2012), who identified inhibition, shifting, and updating as functions underlying tasks of complex executive function. Attentional control theory suggested these were the lower-level control functions of the central executive (Eysenck et al., 2007). The theory predicted anxiety severely impairs the inhibition and shifting functions of the central executive, with the updating function becoming impaired in conditions of heightened situational stress. Predictions pertaining to the phonological loop and visuospatial sketchpad are less developed. Though there is limited mention of the slave systems, the original predictions of processing efficiency theory are carried over (Eysenck et al., 2007). Anxiety is predicted to moderately impair performance on tasks dependent on the phonological loop, but have no effect on tasks reliant on the visuospatial sketchpad. The theory continues to omit the episodic buffer.

Overall, attentional control theory predicts anxiety impairs performance by creating a preference for stimulus-driven processing over goal-driven processing. The theory expects trait anxiety and situational stress combine to impair processing efficiency to a greater extent than performance effectiveness. Specifically, impairments are expected in tasks reliant on inhibition, shifting, and updating processes. Later revisions to attentional control theory note that these impairments might be buffered by the use of additional effort (Derakshan & Eysenck, 2009).

Current Project

There is a need to better understand how sources of cognitive interference can impede executive functions. Emotional disruptions such as anxiety or situational stress can harm the efficacy of executive functions, but limited research has been conducted on functions beyond those proposed by Miyake et al. (2000; inhibition, shifting, and updating). The current research aimed to evaluate the influence of cognitive interference, both internal and external, on the efficacy of executive functions. Sources of interference included trait anxiety, situational stress, and cognitive load. The research utilised a non-clinical population. The research initially focused on four executive functions commonly referred to amongst literature: mental rotation, forward planning ability, decision-making ability, and sustained attention (also referred to as vigilance or internal monitoring).

Chapter Two: Review of Selected Executive Functions

The purpose of the current dissertation was to examine the association between anxiety and executive functioning. Specifically, the current body of research focused on individual differences in trait anxiety. The additional moderating effects of situational stress and cognitive load were also be examined. Regarding executive functioning, several discrete executive functions were isolated for examination as per the multidimensional models of executive function (Baggetta & Alexander, 2016; Banich, 2009; Friedman et al., 2008). The selection of executive functions chosen went beyond the three functions proposed by the Miyake et al. (2000) model. Given the large number of processes that may be identified as executive functions, this research was not able to provide an exhaustive analysis. However, investigation of a select number of functions still provides insight that may be extended in later work. Selection of functions for the current research was informed by literature prevalence and the availability of psychometrically sound tasks to assess each function. As per the parameters of the research discussed in Chapter One, the tasks were required to use neutral, non-emotive stimuli[7] and allow for the manipulation of task load. Given these considerations, the first phase of research evaluated four functions; mental rotation, forward planning, decision-making, and sustained attention. The current chapter provides further information about each construct and a brief summary of past literature concerning their association with anxiety. Moderating influences of situational stressors and/or cognitive load are noted where applicable.

Mental Rotation and Anxiety

Mental rotation is a visuospatial ability requiring the capability to search the visual field, identify the form and position of perceived imagery, and mentally manipulate this

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[7] As the current work seeks to evaluate the influence of emotive traits and states on executive functions, any additional emotional content embedded in the task itself could introduce a confound into the findings.

imagery (Thompson, Nuerk, Moeller, & Kadosh, 2013). Specifically, mental rotation is the capacity to form a mental image of two- or three-dimensional objects and mentally manipulate this imagery around rotational axes, such as those depicted in Figure 6 (Kaltner & Jansen, 2016; Voyer & Jansen, 2017). Mental rotation is often subsumed under the broader category of spatial ability and has been found crucial for matters of navigation (e.g., estimation of trajectory), examination of the immediate environment, and academic performance, particularly in the domain of mathematics (Hawes, Moss, Caswell, Seo, & Ansari, 2019; Verde et al., 2013; Pellegrino, Alderton, & Shute, 1984). In further classifying mental rotation as a spatial ability some advocate mental rotation represents a form of spatial representation, a category of spatial abilities involving the creation of non-verbal illustration, both symbolic (e.g., graphical representations) and pictorial (e.g., replicated images or diagrams; Höffler, 2010). Other literature proposes mental rotation is more akin to spatial relations, which requires the mental transformation of an imagined object and subsequent comparison to a reference (Höffler, 2010). Further still, additional work identifies mental rotation as its own, standalone subtype of spatial ability (Linn & Petersen, 1985). Regardless of conceptual categorisation, the task variations and processes used to examine mental rotation ability are well-established.

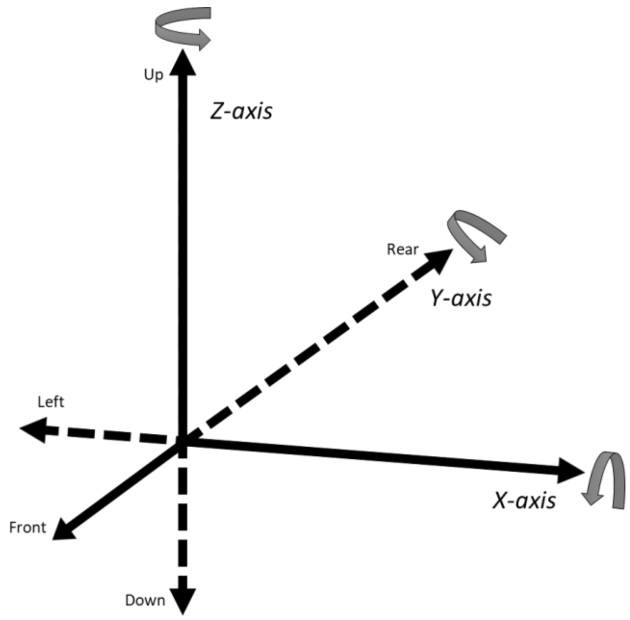

Figure 6. Axes of rotation implemented in mental rotation tasks. Alternative labels may denote x-axis as lateral, y-axis as longitudinal, and z-axis as vertical.

Mental rotation was originally examined in Shepard and Metzler's (1971) seminal article. Participants were tasked with comparing pairs of abstract three-dimensional images (see Figure 7 for example stimuli). The comparative images were presented in different spatial orientations, with the angle of rotation varying between 0° and 180°. Participants identified if the two images were the same (i.e., the images could be rotated into congruence) or different (i.e., images additionally varied by reflection and could never be rotated into congruence). Shepard and Metzler observed that participants' RTs varied as a linear function of the degree of rotation. The greater the rotational discrepancy between the two images, the longer participants took to respond. This finding has been extensively replicated across a variety of stimuli (e.g., alphanumeric, three-dimensional abstract, two-dimensional abstract, illustrations) and populations (Jolicœur, Regehr, Smith, & Smith, 1985; Koriat & Norman, 1985; Tarr & Pinker, 1989). The consistent trend suggests mental representations of objects, and their subsequent manipulation, adhere to similar spatial attributes as physical objects. In this way, mental rotation ability might serve the purpose of simulating the physical world to extract new information (Borst, Kievit, Thompson, & Kosslyn, 2011; Thompson, Kosslyn, Hoffman, & Van Der Kooij, 2008). Mental rotation has been found to be unaffected by participant expectations or tacit knowledge (Borst et al., 2011), suggesting the linear relationship between RT and rotation disparity is indeed a product of the nature of representation and process.

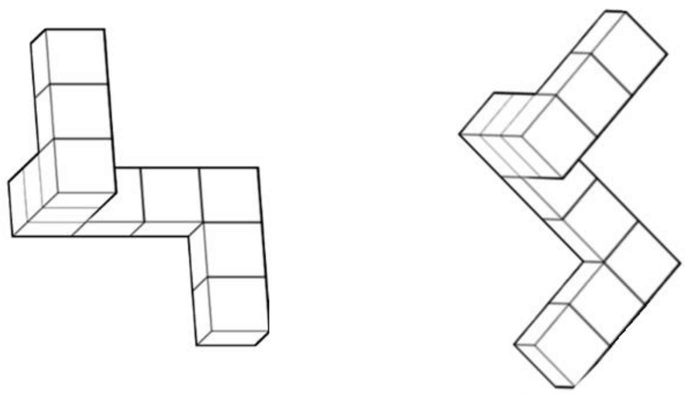

Figure 7. Example of three-dimensional abstract imagery similar to the stimuli used by Shepard and Metzler (1971).

As an executive function, mental rotation requires the coordination of several subprocesses including coordination of feature evaluation (either piece-by-piece or holistic; Khooshabeh, Hegarty, & Shipley, 2013), shifting attention between simultaneous spatial representations, and the inhibition of anticipatory judgements (Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001; Thompson et al., 2013). Tasks designed to assess mental rotation are exceptionally homogenous. All mental rotation tasks share the same fundamental premise. Participants are required to compare two visual stimuli, one reference image and one comparative image varying by some rotational discrepancy. Participants indicate if the images are identical or mismatched. For mismatched stimuli, the comparative image is a mirrored version of the reference. Mismatching of any feature other than mirroring has been found to remove the mental rotation effect (Borst et al., 2011). Beyond this procedure, mental rotation tasks can vary by the type of stimuli used (e.g., alphanumeric, abstract images, realistic illustrations), the direction of rotation required (e.g., vertical, longitudinal, lateral), and the form of trial sequences (Borst et al., 2011; Neubauer, Bergner, & Schatz, 2010; Shepard & Metzler, 1988). While any of these variations can change the speed of mental rotation (e.g., complex images taking longer to rotate than simple letters), such changes ultimately do not alter the underlying trend[8] (Borst et al., 2011; Voyer, Voyer, & Saint-Aubin, 2017). Because of this, the use of any currently available mental rotation task will be satisfactory to assess the mental rotation function. However, use of other visuospatial-related tasks cannot substitute for this assessment. Though mental rotation does comprise of a visuospatial element, tasks associated with broader visuospatial processing are likely to sample different abilities.

While it has been proposed anxiety is unrelated to mental rotation ability (Oshiyama et al., 2018), this view is less prominent. The competing suggestion that anxiety does influence mental rotation has been more readily observed in literature. Theoretically, this is inconsistent with the predictions of attentional control theory which assumes functions reliant on the visuospatial sketchpad are spared by the influence of anxiety (Eysenck et al., 2007). However, this prediction is likely an artefact of the theory's predecessor, processing efficiency theory (Eysenck & Calvo, 1992), which itself was heavily influenced by Sarason's (1988) cognitive interference theory. Conceptually these works defined anxiety as being verbal in nature (e.g., manifesting as worrisome thoughts, rumination), and as such favours the cognitive resources of the phonological loop. However, on review of attentional control theory's key assumption that anxiety predominantly disrupts the central executive, it can be argued the favoured disruption of one slave system (i.e., phonological loop, visuospatial sketchpad) over the other is irrelevant. If anxiety does disrupt the central executive, it disrupts the initial allocation of resources to either system. As such, it can be concluded that anxiety

[8] The trend being as rotational discrepancy increases, so too does response time when judging same-image pairs.

will alter task performance due to the misallocation of attentional resources by the central executive, regardless if the underlying task requires the processing of verbal or visual stimuli. Ultimately, given the visuospatial sketchpad vs. phonological loop distinction in attentional control theory, little work has been conducted to examine a potential association between anxiety and visual-based tasks within the predictions of this theory. The current work seeks to address this limitation.

Amongst literature anxiety has been found to influence the visually based function of mental rotation, though the direction of association between the constructs is disputed. One view is that the negative emotionality of anxiety is associated with improved rotation abilities under certain conditions. In research reported by Borst, Standing, and Kosslyn (2012), heightened state anxiety following exposure to fearful stimuli seemingly facilitated mental rotation ability. Mental rotation was assessed by use of three-dimensional abstract images, with possible rotation angles of 50°, 100°, or 150° around the y-axis. Participants were classified into low and high state anxiety groups based on a median split of scores on the state-subscale of the STAI (Spielberger et al., 1983). State anxiety was measured at completion of the experiment. Priming stimuli consisted of fearful and neutral facial expressions. Both high and low state anxiety groups demonstrated a positive linear trend between RTs and angular disparity, regardless of priming stimuli. Further comparison of these trends found the high state anxiety group performed mental rotation faster following exposure to fearful stimuli over neutral stimuli. There was no change in rotation speed for the low state anxiety group between fearful and neutral conditions. The authors noted these findings were unlikely to be the result of a speed/accuracy trade-off, as there was no significant difference in error rates between anxiety groups or priming conditions. However, evaluation of this trade-off might have been better conducted by use of an integrated measure of RT and accuracy (e.g., inverse efficiency score, bin score, accuracy/RT ratio; Edwards, Moore, Champion, & Edwards, 2015; Vandierendonck, 2017). Borst et al. ultimately concluded the mental rotation of highly state anxious individuals was facilitated by the acute emotionality produced through exposure to fear-related imagery. The authors chose not to divide groups further to examine differences between high and low trait anxious individuals. Without this additional comparison, it is unclear if the observed trends would have been observed in individuals reporting a chronic experience of emotional instability. This inquiry was instead evaluated by Kaltner and Jansen (2014).

In a work of replication and extension, Kaltner and Jansen built on the research of Borst et al. (2012), evaluating the influence of trait anxiety on mental rotation ability. The study's mental rotation task comprised of simple alphanumeric stimuli and complex photographic stimuli depicting full-scale individuals in varying postures. Stimuli could be rotated at angular discrepancies of 0°, 30°, 60°, 90°, 120°, 150°, or 180°. Unlike Borst et al., the Kaltner and Jansen study did not factorise trait anxiety[9] but instead entered the variable as a continuous covariate. Results demonstrated an interaction between trait anxiety and angular discrepancy for RT data. RTs were found to increase with angular discrepancy; however, RTs were significantly longer for higher trait anxious participants at the levels of 0°, 120°, 150°, or 180°. Kaltner and Jansen concluded that trait anxiety impairs mental rotation ability, particularly during trials requiring greater cognitive load. Differences to Borst et al.'s findings were suggested to be due to the evaluation of trait anxiety in place of state anxiety, in addition to analysis of anxiety as a continuous covariate rather than a categorical factor. Given the contrasting findings, further evaluation of trait anxiety's influence when moderated by acute environmental factors would be of interest. Further evaluation of the effect of cognitive load would also be relevant. Kaltner and Jansen observed trait anxiety to impair

[9] In Borst et al. (2012), state anxiety was transformed into a between-subjects variable by use of a median split procedure. Participants who reported state anxiety values above the median of the sample were allocated to the high state anxiety group, while those scoring below the median were allocated to the low state anxiety group.

mental rotation at greater degrees of rotation, where the difficulty is assumed to be greater and cognitive load is increased[10] (Jansen-Osmann & Heil, 2007; Kaltner & Jansen, 2014; Prather & Sathian, 2002). However, other work has suggested trait anxiety only impairs mental rotation when cognitive load does not exceed the available capacity (Ramirez, Gunderson, Levine, & Beilock, 2012). Ramirez et al. observed higher levels of trait anxiety to predict slower mental rotation RTs, but only in those with larger working memory capacity. The influence of trait anxiety was absent in participants with smaller capacity. The authors proposed participants with greater working memory capacity attempted to compensate for their anxiety by use of less efficient task strategies, which they aligned with the predictions of attentional control theory (Eysenck et al., 2007; Ramirez et al., 2012).

Generally, there is evidence to suggest an association between mental rotation ability and anxiety. Prior work has investigated the separable influence of trait and state variations of anxiety, however, no work to date has examined the interactive effect of these constructs. As such, it is unclear how (or if) trait anxiety's influence on mental rotation ability is altered by the addition of external stressors. Cognitive interference theories like processing efficiency theory and attentional control theory would suggest situational stress should exacerbate the performance detriments associated with trait anxiety (Derakshan & Eysenck, 2009; Eysenck et al., 2007). The current research examined the influence of trait anxiety on mental rotation effectiveness (i.e., accuracy) and efficiency (i.e., accuracy and RT relationship), as moderated by external and internal sources of distraction. The research examined the interactive effect of situational stress as a source of external interference, and the influence of task difficulty as a source of internal interference (via increasing task demands/mental effort requirements). These sources of interference are highlighted as key contributors to variation in task

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[10] This suggestion relies findings that report a positive linear trend between error rates and angular discrepancy. That is, as the angle of mental rotation increases so too does error rates (Jansen-Osmann & Heil, 2007; Kaltner & Jansen, 2014; Prather & Sathian, 2002).

performance amongst cognitive interference theories (i.e., attentional control theory; Eysenck et al.). A summary of the general methodology adopted for the research is presented in Chapter Three.

Planning Ability and Anxiety

Planning ability is comprised of the identification and selection of optimal actions sequences to achieve a desired goal state (Kaller, Unterrainer, & Stahl, 2012). While at times referred to synonymously as problem-solving, the ability to plan is one subfunction of the ability to evaluate and solve daily problems (Phillips, Kliegal, & Martin, 2006). Planning ability can be viewed as being comprised of several coordinated stages. These stages include the comparison of start and goal states, identification of intermediary requirements, generation and comparison of potential plan sequences, inhibition of suboptimal sequences, and execution of the final plan including recognition of the attained goal state (Carlin et al., 2000; Owen, 1997; Unterrainer et al., 2004). Amongst executive function literature, planning ability is cited as a key exemplar (Alvarez & Emory, 2006; Chan et al., 2008; Diamond, 2013; Grafman & Litvan, 1999; Snyder, 2013). The consistency by which planning is identified as an example is significant, given the general ambiguity towards a definitive list of executive functions (see Chapter 1). Though at times referred to synonymously as problem-solving, the current work defines planning as a separable and only partial component of overall problem-solving ability (Eichmann, Goldhammer, Greiff, Pucite, & Naumann, 2019; García, Boom, Kroesbergen, Núñez, & Rodríguez, 2019).

The assessment of planning ability relies on tasks that require participants to transition between an incongruent start and goal state. Several example tasks are summarised in Table 2 (located on page 33). Beyond the requirement that participants attain a goal state, the process by which participants navigate through the various tasks is markedly different (see Table 2). Of these variants, the most widely used neuropsychological test to assess planning ability is the Tower of London (see Shallice, 1982; Kaller et al., 2012; Berg & Byrd, 2002; Phillips, Wynn, Mcpherson, & Gilhooly, 2001). Given the task's prevalence in planning literature, its logic is briefly discussed here. In the original task, participants are presented with a pegboard consisting of three rods and three coloured beads (see Figure 8). Participants are required to use their planning ability to transform the starting configuration of beads into a new goal configuration. Completion of the task is often restricted by a minimum move-set (e.g., participants must achieve the goal pattern in no more than three moves of the beads) and task-specific rules (e.g., participants cannot move a bead that is beneath another bead; participants cannot stack more beads than a peg allows). While the original test consisted of a physical pegboard, new alternatives exist for computerised administration.

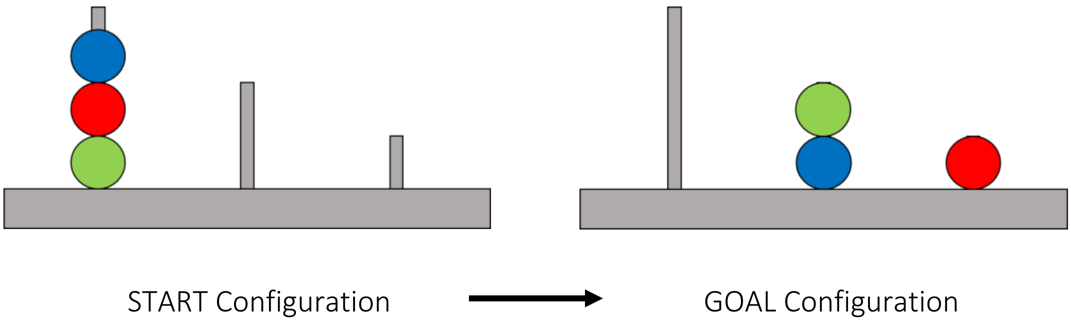


Figure 8. Example Tower of London setup per Shallice (1982) parameters. Change from START to GOAL configuration represents a 3-move solution.

Several variations of the Tower of London have been constructed, most of which are isomorphs (i.e., tasks that do not alter the original setup of Shallice's task). The remaining tasks are true variations, changing the underlying construction of the task by varying the number of beads and/or pegs. By altering the ratio of open spaces to beads, these tasks change the number of possible plans a participant can construct by increasing the number of alternative routes. Generally, the greater the ratio of open spaces to beads, the greater the potential planning alternatives (and, by extension, the complexity of the task). A summary of Tower of London variants is illustrated in Table 3 (located page 34).

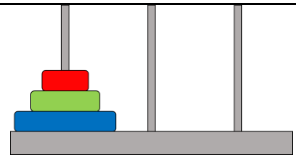
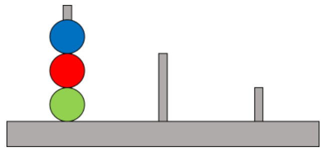
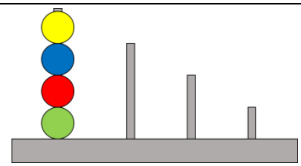
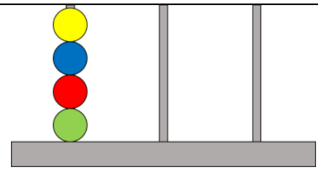
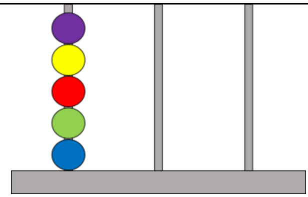
Table 2

Example Cognitive Tasks Identified as Assessments of Planning Ability

Task Name	Author	Description
Tower of London	Shallice (1982)	Participants must rearrange beads/discs placed on a pegboard to match a goal configuration in a minimum number of moves. Completion of the task is restricted by rules stipulating legal moves. Difficulty of the task varies by the number of beads, number and size of pegs, and minimum number of moves available.
Trail Making Task	Partington and Leiter (1949)	Participants are required to connect a series of 25 dots as quickly and as accurately as possible. Part A of the task includes only numbers (e.g., 1, 2, 3…). Part B requires participants to switch between numbers and letters (e.g., 1, A, 2, B…).
Rey Osterrieth Complex Figure	Meyers and Meyers (1995)	Task requires participants to replicate a complex line drawing. First phase of the task requires freehand copying, second phase requires reproduction from memory.
Plan a Day Task	Holt et al. (2011)	Participants are required to plan a list of work activities (e.g., picking up mail, checking inventory). Consideration must be given to constraints regarding location and duration of activities to be carried out in a set timeframe. Difficult of the task varies by the number of tasks to be scheduled and constraints.
Modified Six Elements Test	Wilson, Alderman, Burgess, Emslie, and Evans (1996)	Participants are instructed to complete a series of six subtasks within a limited timeframe. Completion of all tasks is impossible; therefore, emphasis is placed on maximising output. Participants must conform to unpredicted task-switching rules.

Table 3

Summary of Tower of London Variations used to Assess Planning Ability

Task Name	Author	Description	Example Layout
Tower of Hanoi	Claus (1883)	Participants must transfer hierarchy of disks from far-left peg to far-right peg. Larger disks may not be placed on smaller discs.	
Tower of London* *Isomorphs include: • Tower of London^{DX} (Culbertson & Zillmer, 1998) • Tower of London – Revised (Schnirman et al., 1998) • Stockings of Cambridge (Cambridge Cognition, 2019)	Shallice (1982)	Participants must rearrange three beads from start position to goal position. Pegs are scaled to restrict stacking. Ratio of open spaces to beads is 1:1.	
Four-Rod Tower of London	Kafer and Hunter (1997)	Participants must rearrange four beads from start position to goal position. An additional peg is added. Pegs are scaled to restrict stacking. Ratio of open spaces to beads is 3:2.	
Four Bead Tower of London	Ward and Allport (1997)	Participants must rearrange four beads from start position to goal position. Pegs are of equal length. Ratio of open spaces to beads is 2:1.	
Five Bead Tower of London	Ward and Allport (1997)	Participants must rearrange five beads from start position to goal position. Pegs are of equal length. Ratio of open spaces to beads is 2:1.	

Note. Isomorphs are Tower of London variants which do not alter the layout or requirements of the Shallice (1982) task. Some differences between the tasks may still exist in the number of problems generated for completion.

Planning tasks adapted from the Tower of London represent a step-based paradigm that requires sequential planning. Planning ability may be assessed at the start of these tasks prior to any actual manipulation of the starting configuration. This phase of the task can also be referred to as an evaluation of forward planning (i.e., the ability to mentally rehearse and plan a sequence of actions). The mental process of planning can be represented graphically by the use of a problem space. The problem space refers to the diagrammatic summary of all possible, viable plans to reach a goal state. That is, the problem space represents a "road map" of planning processes (Berg & Byrd, 2002). Understanding a task or activity's problem space allows for plotting of the optimal path(s) to achieve a solution. The problem space also allows for identification of incorrect moves that could disrupt a plan. Changes to the minimum number of required moves, the number of open spaces, or the number of subgoals[11] can all increase the complexity of the problem space (Phillips et al., 2001; Ward & Allport, 1997). An example of the problem space embedded within a Tower of London (or variant) planning task is illustrated in Figure 9.

[11] Subgoals refer to intermediary moves; that is, moves that do not place an obstacle in its final goal position but are essential for the final solution (e.g., during the Tower of London task, temporarily moving a bead to the incorrect peg in order to access the bead beneath it).

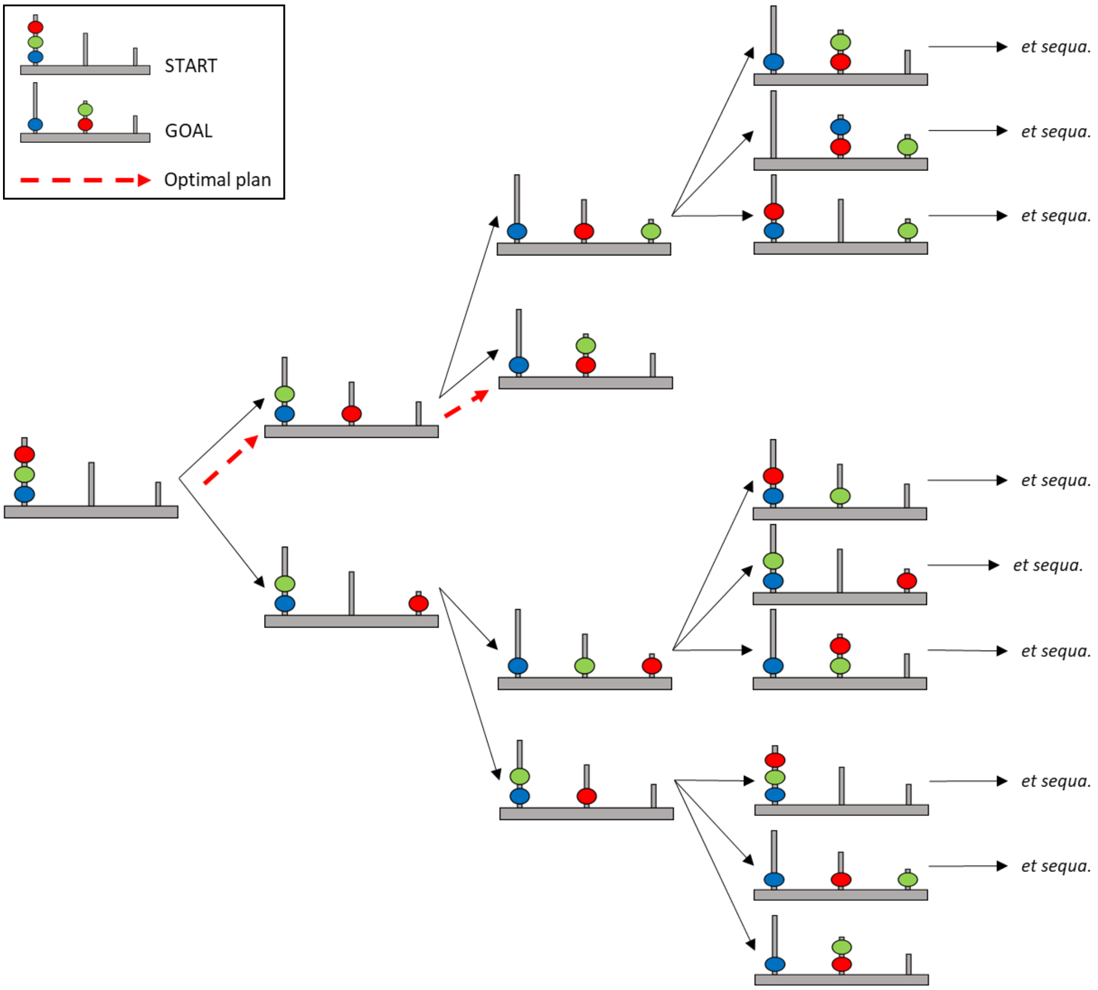


Figure 9. Example problem space for a Tower of London 2-move problem, illustrating branching possibilities from every potential move. The optimal plan that demonstrates the sequence of actions that result in the goal state using the minimum number of moves is highlighted.

Available literature evaluating an association between changes in anxiety and planning ability is sparse. More often, the examination of deficits in planning ability has been related to physical trauma (e.g., traumatic brain injury). This may be in part to planning ability's traditional association with frontal brain regions when the function was still subsumed under unitary models of executive function (Alvarez & Emory, 2006; Berg & Byrd, 2002). Few works explicitly identify anxiety as a variable of interest, despite recent works investigating planning in the context of other psychological disorders (e.g., schizophrenia; Holt, Wolf, Funke, Weisbrod, & Kaiser, 2013; Schuepbach, Weber, Kawohl, & Hell, 2007).

Of the anxiety-related work that is available, outcomes are mixed. One view is that anxiety is unrelated to planning ability. Robinson, Vytal, et al. (2013), in their review of literature surrounding anxiety and cognition, suggest that anxiety does not influence planning ability. The authors detail their own previously unpublished work, in which twenty-two non-clinical participants completed a computerised Tower of London task. Participants were shown images of two pegboards (starting configuration vs. goal configuration) each consisting of three coloured beads. The task required participants to plan the number of moves to configure the starting pattern into the goal pattern. Rather than manipulating the beads themselves, participants selected the number of moves from on-screen options (i.e., one-touch responding). Solutions ranged in difficulty from 2-move to 5-move problems. Both accuracy and RT were recorded. Robinson, Vytal, et al. evaluated changes in state anxiety, manipulated within-subjects by threat-of-shock. The planning task was completed under alternating, counterbalanced shock-threat and shock-safe conditions. Results demonstrated that while participants showed lower accuracy and slower RTs as task difficulty increased, there were no interactive effects with either self-reported state anxiety or threat-of-shock blocks. While Robinson, Vytal, et al. suggest the findings are illustrative of planning ability operating independently of emotional states, they did not consider the influence of trait anxiety. As trait anxiety and state anxiety are highly correlated (typically $r \geq .70$; Spielberger et al., 1983), such individual differences may further moderate the response to situational stressors. Research intending to gain a greater depth of understanding into how anxiety influences planning should consider this interaction.

Beyond their own work, Robinson, Vytal, et al.'s review also noted the work of Van Tol and colleagues (2011). Van Tol et al. (2011) investigated differences in planning ability using a computerised Tower of London task. Task difficulty ranged from 1-move to 5-move problems. RT and accuracy were recorded, with accuracy indexed as total correct trials. Participants comprised of individuals diagnosed with major depressive disorder (MDD), various anxiety-related disorders (inclusive of generalised anxiety disorder, social anxiety disorder, and panic disorder), and non-clinical controls. Only participants diagnosed with severe MDD showed significant slowing of RTs on the planning task. Comparatively, task accuracy and RTs of the anxiety-disorder and control groups were considered to be within a normal range. Van Tol et al. suggested these findings provided evidence of executive dysfunction being unrelated to anxiety. Of note though, Van Tol et al.'s anxiety group was comprised of mixed diagnoses, creating a somewhat heterogeneous compilation. The development and aetiology of anxiety disorders are not wholly interchangeable (American Psychiatric Association, 2013), as such the findings attributed to the anxiety-disorder group may be misinformed.

Unlike Van Tol and colleagues' (2011) work, several studies have reported planning ability to be impaired in individuals diagnosed with obsessive-compulsive disorder, an anxiety-related diagnosis (American Psychiatric Association, 2013; Mataix-Cols et al., 1999; Purcell, Maruff, Kyrios, & Pantelis, 1998). Recent work has also found planning ability to be impaired amongst a subclinical population. In a study conducted by Unterrainer et al. (2018), planning ability was observed in a large sample of 4240 adults aged 40 to 80 years by the use of a computerised Tower of London. Task difficulty ranged from 4-move to 6-move problems. Information for both trait anxiety and depression levels was measured by self-report. The results found irrespective of age that higher levels of subclinical anxiety were predictive of poorer accuracy on the Tower of London (i.e., fewer problems correctly solved in the minimum number of moves). RT data were not reported. When both anxiety and depression were entered into a single predictive model, only anxiety acted as a significant predictor. The authors proposed the planning deficits they observed were a product of cognitive interference, likely generated by anxiety-related worriedness/nervousness. Overall, Unterrainer and colleagues viewed their results to be complementary to the work of Van Tol et al. rather than contrasting. Specifically, the authors proposed that the influence of anxiety on planning performance may manifest distinctly between subclinical and clinical populations. However, given that Unterrainer et al. did not measure RT of participants, the studies could not be compared on assessments of planning efficiency, only effectiveness.

Most of the work used to assess anxiety and planning ability represents the latter construct as a step-based process. As such, these works rely on variations of the Tower of London task which conceptualises planning as the successful navigation of sequence-based problems. The current work used the same approach in its aim to extend on prior empirical findings of trait anxiety and planning ability's association. The relationship was further examined under varying conditions of situational stress and cognitive load. These latter constructs were selected based on the current work's theoretical framework, attentional control theory (the same framework alluded to in Unterrainer et al.'s [2018] work). To gain a more detailed examination of planning ability, both effectiveness (accuracy) and efficiency (accuracy and RT) values were recorded using a computerised Tower of London variant. Further details of the general methodology adopted in the current research is provided in Chapter Three.

Decision-Making and Anxiety

Within executive function literature, decision-making involves the evaluation of a finite series of options against task-relevant criteria (Buelow & Blaine, 2015; Del Missier, Mantyla, & Bruine De Bruin, 2010). Depending on the context in which the decision must be made, such criteria could involve the use of rulesets, calculation of risk/benefit ratios, or the application of personal values (De Martino, Kumaran, Seymour, & Dolan, 2006; Hastie &

Dawes, 2001; Hinson, Jameson, & Whitney, 2003). Dual-process theories suggest decision-making is supported by a combination of heuristic and analytical processes (Evans, 2003; 2007; Kahneman, 2003; Reyna, 2004; Sloman, 1996). Heuristic decision-making is intuitive and instinctual, though its key characteristics vary across interpretations. Works reliant on classic dual-process theories of decision-making might refer to System 1 thinking, emphasising the spontaneity and emotionality of the process (Evans, 2003; Kahneman, 2011; Stanovich & West, 2000). Other research, inclusive of executive function literature, refers to the process as hot decision-making and highlights the role of uncertainty and ambiguity (Chan et al., 2008). Despite differences in labelling conventions, these variations represent a similar form of decision-making that is ultimately quick and reliant on the use of immediate feedback and learned associations (Del Missier, Mäntylä, & Bruine de Bruin, 2010; Evans, 2003). By contrast, analytical decision-making is slower and deliberate (Buelow & Blaine, 2015; Evans, 2003). Other sources again use different naming conventions and highlight distinct features. Dual-process theories may refer to this decision-making as System 2 and emphasise the process being controlled and effortful (Kahneman, 2011). In executive function literature, the process is more likely to be labelled as cold decision-making, reliant on logic, explicit rules, and reduced emotionality (Chan et al., 2008). Some approaches suggest the heuristic and analytical forms of decision-making are sequential, with the faster heuristic process preceding the slower analytical process (Kahneman & Frederick, 2005). Amongst executive function literature, the two forms of decision-making are more commonly represented as separable and operating in distinct circumstances (Chan et al., 2008; Geurts, Van Der Oord, & Crone, 2006; Pripfl, Neuman, Köhler, & Lamm, 2013; Zimmerman, Ownsworth, O’Donovan, Roberts, & Gullo, 2016).

Hot[12] decision-making tasks are used to evaluate the executive function when the outcome of choice selection is intentionally left ambiguous. The decisions to be made often centre around risk assessment, requiring the task-relevant criteria for choice selection be comprised of risk vs. benefit analyses. This risk vs. benefit assessment continuously updates, informed by immediate win/loss feedback provided to participants. Many of the current hot decision-making tasks are built around a gambling paradigm to replicate real-world scenarios (Bechara, 2008). A selection of example tasks used as measures of hot decision-making is provided in Table 4. A commonality between these tasks is their use of risk evaluation as the decision-making criterion to be applied. Rather than categorising individuals by net gain or net loss, often decision-making ability is operationalised by the difference in choice of risk-approach strategies and risk-avoidant strategies. The larger the discrepancy, the more an individual is seen to favour either form of approach. As such, outcome measures of hot decision-making tasks are often framed in terms of risk-approach and risk-avoidant strategies, rather than traditional measures of accuracy. Further, most hot decision-making tasks implement feedback into the task protocol. Often this feedback is immediate to evoke intuitive, gut-based responses. Feedback often uses salient stimuli such as expressive colours (e.g., green vs. red) and auditory cues (e.g., coin rattle vs. buzzer).

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[12] The term "hot" is used to distinguish heuristic decision-making. This terminology is more common amongst executive function literature (Poon, 2018; Zelazo & Carlson, 2012; Zelazo & Cunningham, 2007) and is used throughout the dissertation from this point forward. Likewise, the term "cold" is adopted for analytic decision-making.

Table 4

Example Cognitive Tasks Identified as Assessments of Hot Decision-Making

Task Name	Author	Description	Decision criteria
Iowa Gambling Task	Bechara, Damasio, Damasio, and Anderson (1994)	Participants are presented four decks of cards. Selecting from each deck, participants win or lose a cumulative monetary reward.	Two decks are advantageous (low risk/low reward). Continued sampling creates a net gain. Two decks are disadvantageous (high risk/high reward). Continued sampling creates a net loss.
Game of Dice	Brand et al. (2002)	Participants place bets on virtual dice. Participants select up to four numbers the dice may roll. Participants gain a cumulative monetary reward for the outcome.	Rolling selected numbers results in gain, while unselected numbers result in loss. Selection of more numbers increases win probability but reduces potential reward (low risk/low reward). Selection of fewer numbers increases loss probability but increases potential reward (high risk/high reward).
Balloon Analogue Risk Task	Lejuez et al. (2002)	Participants are tasked with pumping a computerised balloon. For each pump, participants gain a cumulative reward. After each pump participants can collect their winnings (starting a new trial) or continue with inflation.	Bursting point of the balloon varies randomly. Participants may lose their reward at any point between first and last trial. Longer trials (i.e., greater number of pumps) increases risk and reward concurrently. If balloon bursts prior to collection of winnings, all rewards are lost.
Columbia Card Task	Figner, Mackinlay, Wilkening, and Weber (2009)	Participants are presented 32 cards and asked to turn the cards over in any order. Each card accumulates points. Participants continue until they wish to stop or until a loss card is turned.	Risk varies by the number and value of loss cards embedded amongst the deck. Reward varies by value of gain cards.

Research examining the influence of trait anxiety on hot decision-making has produced mixed results. The dominant view amongst research suggests individuals who report higher levels of trait anxiety favour risk-avoidant decisions. For example, a study by Maner et al. (2007) evaluated the association between trait anxiety and hot decision-making using a sample of university students. Maner et al. separately evaluated the influence of social-based anxiety (Study 1) and broader trait anxiety (Study 2). The study controlled for the influence of negative affect, noting this construct was shared between anxiety and the co-morbid experience of depression. By statistically controlling for negative affect, Maner et al. intended to examine only the unique markers of anxiety (e.g., physiological sensitivity, worrisome thoughts). Social anxiety levels were self-reported via the Fear of Negative Evaluation scale (FNE; Leary, 1983), while trait anxiety was reported using the STAI (Spielberger et al., 1983). Negative affect was measured via the Positive Affect Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988). For the outcome variable, hot decision-making was evaluated using the balloon analogue risk task (BART; see Table 4 for brief description). Decision-making was operationalised as the average number of perseverative responses to the task, representing a continuous measure of risk-avoidant preference. That is, participants who exhibited less persevering responses displayed a risk-avoidant decision preference. After controlling for the role of negative affect, results in Study 1 supported a positive relationship between social anxiety and risk-aversion. This relationship was replicated in Study 2 with trait anxiety and risk-avoidance. That is, over and above the presence of negative affect, participants reporting either higher social anxiety or higher trait anxiety were more likely to favour risk-avoidant decisions. Maner et al. noted their sample's mean values of social-anxiety and trait anxiety were below cut-off values for clinical diagnosis, suggesting even moderate levels of anxiety can differentially alter decision-making preferences. This association between anxiety and risk-avoidance in decision-making has been observed across multiple other works (Heilman, Crişan, Houser, Miclea, & Miu, 2010; Giorgetta et al., 2012; Maner & Schmidt, 2006; Mueller, Nguyen, Ray, & Borkovec, 2010).

Maner et al. (2007) further extended their work to suggest anxiety's influence on hot decision-making was unique compared to other mood states. Employing a clinical sample, decision-making was assessed again using the BART amongst participants reporting a clinical diagnosis for either an anxiety disorder, mood-disorder, or attentional disorder. Results of all clinical groups were compared to a non-clinical control group. The findings demonstrated participants reporting an anxiety diagnosis responded to the BART with significantly greater risk-aversion compared to those diagnosed with a mood disorder, attentional-disorder, and the non-clinical controls. Maner et al. proposed the results supported a decision-making bias exclusive to heightened anxiety. This suggestion has also been supported by other works comparing anxiety to other negative moods (e.g., anger, disgust, depression; Raghunathan & Pham, 1999; Shields et al., 2016)

There is variance in how literature explains the process underling anxiety's effect on risk-avoidance during hot decision-making. Some sources place emphasis on the attentional biases inherent to anxiety. Heightened anxiety has been associated with biased attention to threat-related information, in turn inciting a predisposition to view ambiguous stimuli as negative (Mathews & Macleod, 2005; Hartley & Phelps, 2012). One proposal is that the uncontrollable and unpredictable outcomes embedded within hot decision-making tasks promote this threat-related bias (Hartley & Phelps, 2012). That is, in the context of hot decision-making tasks, individuals are unable to guarantee their decision will result in a "win" due to the randomised generation of outcomes. As such, highly anxious individuals are more likely to become intolerant of ambiguous feedback cues (Broman-Fulks, Urbaniak, Bondy & Toomey, 2014; Gu, Huang, & Luo, 2010; Krain et al., 2008). Such perceptions are suggested to evoke harm-minimisation strategies, hence the adoption of risk-avoidant preference. Another view suggests anxiety alters the interpretation of the evaluative criteria rather than the outcome. Paulus and Angela (2012) propose the aversive emotions experienced in anxiety changes the value and weight of risk-based computation options. In this approach, emotion transforms the evaluative criteria necessary for a decision, such that highly anxious individuals experience profoundly different probability and value computations than non-anxious individuals exposed to the same information (Rottenstreich & Hsee, 2001). This appraisal can be further adjusted based on changes in preference and environment (Gottlieb, Weiss, & Chapman, 2007; Kusev, van Schaik, Ayton, Dent, & Chater, 2009; Paulus & Angela, 2012).

In contrast, other work has found heightened levels of trait anxiety to be associated with riskier decision-making. Miu, Heilman and Houser (2008) found participants reporting higher trait anxiety scores on the STAI (Spielberger et al., 1983) were more likely to favour the high risk/high reward options on the Iowa Gambling Task (IGT; Bechara et al., 1994; see Table 4) compared to their lower trait anxious counterparts. Likewise, Zhang, Wang, Zhu, Yu, and Chen (2015) reported similar results. Participants of Zhang et al.'s study were allocated to high, moderate, and low anxiety groups based on scores of the STAI. Overall, high trait anxiety participants demonstrated a preference for riskier decision-making, sampling the disadvantageous options (producing net loss) more often than the advantageous (producing net gain). Compared between groups, high trait anxiety participants were found to sample the high risk/high reward options more often than moderate anxiety participants. However, the high trait anxiety group sampled the high risk/high reward options less often than the low trait anxiety group. Research observing a preference for riskier decision-making has suggested the tendency is due to anxiety causing distraction from task-relevant processing. This may be due to confusion of relevant and irrelevant cues, or reduced capacity for processing of evaluation criteria due to consumption of cognitive resources by anxiety-related worrisome thoughts, rumination, and so on (de Visser et al., 2010; Miu et al., 2008). Another view is that anxiety impairs the ability to adequately learn contingencies, precluding anxious individuals from the advantageous nature of low risk options (Preston, Buchanan, Stansfield, Bechara, 2007; Sailer et al., 2008).

While hot decision-making tasks emphasise inductive reasoning, cold decision-making tasks should rely on deductive reasoning. The number of cognitive tasks that explicitly claim to assess cold decision-making is markedly fewer than compared to hot decision-making (Buelow & Blaine, 2015; Markiewicz & Kubinska, 2015). Further, most cold decision-making tasks are replicants of hot decision-making tasks, retaining use of risk/benefit evaluation criteria, and are altered only in the removal of immediate feedback from the task procedure (Brandts & Charness, 2000; Figner et al., 2009). An example of this is the Columbia Card Task which may be administered as either a hot or cold variant (Figner et al., 2009). In both versions of the task, participants are provided with an array of 32 cards consisting of gain and loss options. Risk is varied by the number of loss cards, while benefit is varied by the value of gain cards. In the hot variant, participants turn cards over one at a time to reveal the outcome of their choice. They continue to select cards until they either stop or reach a loss card. In the cold version of the task, participants only indicate how many cards they would prefer to turn over. No cards are revealed, and no feedback is given. This alteration (i.e., removal of feedback) is proposed to encourage respondents to rely only on the non-emotive task instructions when making their decision (Buelow & Blaine, 2015; Figner et al., 2009). Some see this approach as appropriate, ultimately stating that a rational and knowledgeable assessment of risk is indeed “cold” if kept distinct from emotive feedback interference (Séguin, Arseneault, & Tremblay, 2007). Other measures of cold decision-making can be observed by use of paper-and-pencil batteries. A recent example is the Adult Decision-Making Competence Battery (A-DMC; Bruine de Bruin, Parker, & Fischhoff, 2007). The A-DMC's Applying Decision Rules section consists of evaluative items to assess analytical decision processes, requiring participants to identify a correct outcome from distractors by applying a sequential series of rules (Bruine de Bruin et al., 2007). Alternatively, some works simply construct novel, cold decision-making tasks that are environmentally dependent on their area of interest (e.g., aviation safety; Causse et al., 2013).

Regardless of the use of computerised tasks (e.g., Columbia Card Task) or paper-and-pencil measures (e.g., A-DMC), very little literature is available that explicitly evaluates the association of anxiety and cold decision-making. This may be due to use of overgeneralised executive function terminology (i.e., use of the unitary model described in Chapter 1), or a disconnect between the theoretical divide of hot/cold decision-making and subsequent operationalisation. To date, an academic search for research evaluating anxiety's influence on the performance of cold decision-making task returns few viable results. One study conducted by Di Rago, Panno, Lauriola, & Figner (2012) utilised the cold Columbia Card Task, found that increased self-reported anxiety was related to lower risk-taking behaviour. This work mimics trends observed in hot decision-making tasks, though it does not offer insight into how anxiety may alter the application of non-risk rulesets. Tasks that evaluate the application of non-risk rulesets (e.g., the A-DMC measures) have not been used in studies investigating anxiety or stress. The A-DMC however has been applied in the context of personality and attention deficit hyperactivity disorder (ADHD), which shares aetiological overlap with anxiety in terms of disrupted attentional processes (Michelini, Eley, Gregory, & McAdams, 2014). Specifically, cognitive interference that consumes attention resources (American Psychiatric Association, 2013; Michelini et al., 2014). Prior work by Mäntylä, Still, Gullberg, and Del Missier (2012) found participants diagnosed with ADHD performed with poorer accuracy on the Applying Decision Rules section of the A-DMC when compared to non-clinical controls. Further work has also reported greater levels of neuroticism, a personality trait often elevated in high trait anxious individuals, is predictive of less accurate decision-making on the Applying Decision Rules subtest (Dewberry, Juanchich, & Narendran ,2013). Tentatively, the inference can be made that anxiety – by its disruption of attentional processes and consumption of cognitive capacity similar to that observed in ADHD, or the heightened anxious symptomatology in high neuroticism individuals – might also impair cold decision-making. Specifically, the decision-making in a non-risky situation that requires the application of neutral rulesets. This was examined by the current research.

The choice to examine cold decision-making, as opposed to hot decision-making, was made on the consideration of task parameters. The current work sought to evaluate the influence of trait anxiety on decision-making, as moderated by situational stress and/or cognitive load. Given the emotion-based nature of two of the study's three independent variables, the inclusion of additional emotionality was unwarranted at this stage. Past research has suggested an association between anxiety and hot decision-making, but the current work was interested in if this trend could still be observed when the emotional/heuristic nature of the decision rulesets was removed. As such, use of a cold decision-making task that required the application of emotionally neutral, logic-based rulesets was preferred for the first phase of research. Examination of cold decision-making in the first phase was also complementary to the other executive functions under investigation, all of which could also be identified as cold functions (Chan et al., 2008). Given that no literature to date had examined the association between anxiety and cold decision-making, the evaluation of such a function could also contribute readily to literature. The current research made use of a novel decision-making task based on the structure of Bruine de Bruin et al.'s (2007) Applying Decision Rules subtest. Further details of the task and a summary of general methodology is provided in Chapter Three.

Sustained Attention and Anxiety

Sustained attention is the ability to allocate attentional resources towards an environmental focal point for extended periods of time and identify relevant changes that may require behavioural intervention (Moriarty, 2015). This ability, also referred to as vigilance and passive monitoring in some work (Ballard, 1996; Warm, Parasuraman, & Matthews, 2008), is crucial for individuals tasked with prolonged monitoring of automated processes, such as combat system operators (i.e., radar and sonar), commercial pilots, or long-haul drivers (Moriarty, 2015). The function is also predictive of improved academic performance (Matthews et al., 2010; Steinmayr, Ziegler, & Träuble, 2010). Sustained attention requires the differentiation of task-relevant target stimuli from task-irrelevant noise. Further, sustained attention encompasses the modulation of attentional and behavioural strategies. Participants must monitor both internal (e.g., emotions, fatigue) and external feedback (e.g., task rules, environmental changes) to facilitate goal-oriented persistence (Aupperle, Melrose, Stein, & Paulus, 2012; O’Grada & Dinan, 2007).

Sustained attention is often contrasted against alternative processes of divided and selective attention. The distinction between divided and sustained attention relies on the number of relevant information sources embedded within a task. Divided attention, also referred to as multi-tasking, involves the simultaneous processing of two or more task-relevant stimuli (Sarter, Givens, & Bruno, 2001). This might involve splitting attention between locations, senses (e.g., concurrent auditory and visual stimuli), or target features (e.g., shape and colour evaluation). That is, multiple sources of information are pertinent to task completion. In contrast, sustained attention manages the focus of one task-relevant information source; identification of target stimuli. The division between selective and sustained attention is more nuanced. Selective attention refers to processes of redirecting attention to task-relevant stimuli while ignoring task-irrelevant stimuli. Though this ability is similar to sustained attention (i.e., identifying relevant targets amongst irrelevant noise), the processes differ in the duration and changeability of stimuli (Moriarty, 2015). Selective attention is brief, used in tasks requiring the evaluation of competing information (e.g., Stroop task, Go/NoGo) in which stimuli alter frequently (Sarter et al., 2001). Sustained attention lacks the dynamic appraisal of selective attention, and is instead characterised by extended bouts of inactivity, required as individuals monitor generally unchanging stimuli (Warm et al., 2008).

Some literature presents sustained attention as a complementary process, rather than a separable function, of executive functioning (Aupperle, Allard, et al., 2012; Barkley, 1997; Sauseng, Hoppe, Klimesch, Gerloff, & Hummel, 2007; Stins et al., 2005; Weissenborn et al., 2005). While these works do not present sustained attention as a unique executive function, all acknowledge the process exemplifies key characteristics of executive functioning. For example, the allocation of cognitive resources and maintenance of goal-oriented behaviour (Aupperle et al., 2012; Sauseng et al., 2007; Weissenborn et al., 2005). Other works recognise sustained attention as a unique and separable executive function (Chan et al., 2008; Cunningham, Pliskin, Cassisi, Tsang, & Rao, 1997; García-Madruga, Gómez-Veiga, & Vila, 2016; O'Grada & Dinan, 2007; Liss et al., 2001). Given the consistent reference to the process' goal-oriented and regulatory nature, the current dissertation proposes sustained attention embodies the defining characteristics of executive functioning. As such, it is represented in the current dissertation as a separable function.

Performance of sustained attention is most often assessed using continuous performance tasks, a homogenous subgroup of cognitive tasks requiring continuous engagement with target stimuli amongst a continuous stream of distractors (Shalev, Humphreys, & Demeyere, 2018). Continuous performance tasks emphasise extended task duration and generally have long uninterrupted durations (Ballard, 1996). These tasks provide minimal rest periods between testing blocks, integrating fatigue and boredom effects into the task procedure (Shalev et al., 2018; Warm et al., 2008). Most sustained attention tasks consist of only one block of continuous trials, with some durations extending in excess of twenty minutes (see Table 5 for example tasks and approximate durations; Leark, Greenberg, Kindschi, Dupuy, & Hughes, 2007). Despite their simple appearance, continuous performance tasks have been found to be demanding of working memory capacity and require extensive cognitive resources to complete (Warm et al., 2008). Studies assessing sustained attention have employed continuous performance tasks such as the Rapid Visual Information Processing task (RVIP; Wesnes, Warburton, Matz, 1983), Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), and Test of Variables of Attention (TOVA; Greenberg, 2007; Leark et al., 2007).

Table 5

Example Cognitive Tasks Identified as Assessments of Sustained Attention

Task Name	Author	Description	Duration
Rapid Visual Information Processing	Wesnes, Warburton, and Matz (1983)	Participants are shown a continuous series of numbers ranging from 2 to 9. Numbers are presented in a pseudo-random order. Participants are required to respond when they observe a target sequence (e.g., 2-4-6, 3-5-1). The task duration is approx. seven minutes.	Approx. 7 minutes
Sustained Attention to Response Task	Robertson, Manly, Andrade, Baddeley, and Yiend (1997)	Participants are presented a continuous sequence of numbers ranging from 0 to 9. Participants must withhold a behavioural response (usually button pressing) to an infrequent target while continuing to respond to frequent non-targets (e.g., participants must respond to all numbers except the digit 3). Task duration is approx. six minutes.	Approx. 6 minutes
Test of Variables of Attention	Greenberg (2007)	Task presents a continuous series of visual stimuli, requiring participants to discriminate between target and non-target stimuli. The first task phase features frequent non-targets, while the second phase displays frequent targets. Task duration is approx. 22 minutes for adults.	Approx. 22 minutes for adults Approx. 11 minutes for children
Conners Continuous Performance Test	Conners (2014)	Task presents a continuous sequence of alphabetical stimuli. Participants are required to respond (usually button pressing) whenever the target stimuli “X” appears onscreen. Participants must inhibit responding to non-targets.	Approx. 14 minutes

Note. Task durations are based on original task procedures. Tasks may be altered by adding or removing additional test blocks, thus altering the total completion time.

Literature on the association between trait anxiety and measures of sustained attention has demonstrated mixed results. The most prominent suggestion is anxiety does impair performance on tasks requiring sustained attention (Geen, 1985; Smallwood, Fitzgerald, Miles, & Phillips, 2009; Mrazek et al., 2011; Robinson, Gath, & Unsworth, 2015; Su, Tran, Wirtz, Langteau, & Rothman, 2009). In early work conducted by Elliman, Green, Rogers and Finch (1997), sustained attention and self-reported trait anxiety were investigated. Using scores on the Hospital Anxiety and Depression Scale (Snaith & Zigmond, 1994), participants were allocated to low, moderate, or high trait anxiety groups. To evaluate sustained attention, participants completed a six-minute RVIP task (see Table 5 for summary). Participants viewed a stream of numbers and were required to respond upon identifying three consecutive odd numbers or three consecutive even numbers. Responses were analysed across one-minute intervals. Results found no significant difference between anxiety groups on measures of accuracy (indexed as the number of correct hits). However, high trait anxious participants demonstrated a significant increase in RTs as the task progressed. This trend was not observed for low or moderate anxiety groups. Elliman et al. interpreted these findings as being supportive of processing efficiency theory (Eysenck & Calvo, 1992), in that trait anxiety was associated with impairments of sustained attention efficiency (i.e., RT) but not effectiveness (i.e., accuracy).

More recent work by Forster, Nunez Elizalde, Castle, and Bishop (2015) found similar behavioural results as Elliman and colleagues. Behavioural data of task accuracy and RT were recorded during six sessions of a six-minute SART (see Table 5). The SART uses a Go/NoGo paradigm, requiring participants to continuously respond to frequent distractor stimuli while inhibiting responses to infrequent target stimuli. Trait anxiety and trait worry were also recorded by self-report measures. When examining participants' error-free task blocks, results found higher levels of trait anxiety predicted slower RTs. Forster and colleagues concluded the findings were indicative of high trait anxious individuals compromising the speed of their performance to compensate for their impoverished attentional control. The authors suggested these findings complemented attentional control theory, in that high trait anxious participants maintained their effectiveness of task performance by sacrificing processing efficiency. The findings were independent of trait worry, suggesting trait anxiety exerted a unique influence on sustained attention beyond interference by worrisome thoughts.

Some older works have reported that the influence of trait anxiety on sustained attention can be further modified as a function of situational interference. Geen (1985) evaluated the influence of anxiety and stress on sustained attention using a 36-minute computerised continuous performance task within a sample of university students. The task required participants to observe an ongoing display of static for 36 minutes. Throughout the task, nine target stimuli randomly appeared onscreen for 60ms. Participants were instructed to verbally report “hit” each time they observed a target. Low and high trait anxiety groups were created by recruiting participants who scored in the lower and upper 20th percentile of the Test Anxiety Scale (Sarason, 1978) respectively. Participants were further divided into either the control or false feedback group. The false feedback group underwent an ego-threat procedure to incite situational stress. Sustained attention effectiveness was evaluated with a *d’* measure of sensitivity, calculated as the standardised proportion of false alarms subtracted from the standardised proportion of hits. Results found a significant trait anxiety × stress interaction, such that high trait anxious participants in the situational stress condition demonstrated lower *d’* values compared to low trait anxious participants. The results suggested when experiencing stressful conditions, high trait anxiety was associated with poorer sustained attention characterised by a reduced ability to identify task-relevant targets amongst task-irrelevant noise. Geen’s work also suggests the influence of trait anxiety is moderated by external variables. However, given the vintage of the study, it would be of interest to examine whether Geen's results are replicable using other sustained attention task variants.

Alternatively, other research has reported no association between anxiety and sustained attention (Righi et al., 2009; Roche, Garavan, Foxe, & O'Mara, 2005). This view is less prominent and is likely due to differences in operationalisations. For example, Righi et al. utilised a six-minute SART to assess sustained attention, indexing performance with accuracy and RT measures. Accuracy was recorded as total hits on both target and distractor trials, while RT was measured only on correct target trials. State and trait anxiety were measured by self-report. Results found state and trait anxiety were unrelated to accuracy as well as RT. However, Righi and colleagues reported RTs for correct target trials only. In other works which used the same task of sustained attention, variations due to anxiety levels had been observed in RT for distractor trials (i.e., correct rejection of non-targets; Forster et al., 2015). Further to this, additional works have proposed anxiety enhances sustained attention (Grillon et al., 2017; Grillon, Robinson, Mathur, & Ernst, 2016; Robinson, Krimsky, & Grillon, 2013). However, these works evaluate only manipulations of state anxiety without consideration of trait-based differences. Using a 15-minute SART as a measure of sustained attention, Robinson, Krimsky, et al. (2013) examined performance under threat-of-shock. Participants who reported elevated state anxiety due to the shock manipulation also demonstrated improved accuracy on distractor trials in the form of lower errors of commissions (i.e., false alarms). No changes to RTs were observed. This finding was replicated in the authors' later work (Grillon et al., 2017; Grillon et al., 2016).

Generally, the trend of results associating anxiety and situational stress to sustained attention effectiveness or sustained attention efficiency is mixed. Operational differences in defining effectiveness and efficiency may contribute to the inconsistency of results. Most evaluations of sustained attention utilise a continuous performance paradigm requiring a distinction between target and non-target stimuli (Ballard, 1996). This approach allows assessment of four outcomes, including hit (target trial + response), miss (target trial + no response), false alarm (non-target trial + response), and correct rejection (non-target trial + no response). Prior studies have often used a proportion of hits to define sustained attention effectiveness (e.g., Elliman et al., 1997; Forster et al., 2015; Robinson, Krimsy, et al., 2013), though others place emphasis on the proportion of errors (e.g., Grillon et al., 2017; Grillon et al., 2016). While substantial work suggests an association between anxiety and sustained attention, the inconsistent operational definitions of sustained attention performance contribute to mixed findings. In the context of the current work's theoretical framework (attentional control theory; Eysenck et al., 2007), emphasis was placed on the accuracy and related RT of responding. As such, evaluation of the proportion of hits (that is, accurate responding to targets) was chosen as the initial outcome measure for investigation of performance effectiveness. The current study built upon and clarified previous results by the examination of not only trait anxiety's influence, but additional interactive variables that could explain contradictory findings. Specifically, situational stress (external interference) and cognitive load (i.e., task difficulty or mental effort; internal interference). Further detail of the general methodology and task adopted for this research is presented in Chapter 3.

Current Research

Overall, there is evidence to support trait anxiety is associated with executive functions beyond that proposed by the Miyake et al. (2000) model. Much of the reviewed research demonstrates only simple associations with mental rotation, planning, decision-making, and sustained attention. As such, whether the influence of trait anxiety on these functions varies by conditions of additional external or internal interference is yet to be determined. A further concern is that none of the evaluated works attempted to control for the covariance of depression. Correlations between anxiety and depression range from moderate to high (Clark & Watson, 1991; Mineka, Watson, & Clark, 1998), while some research suggests a direct link between depression and general executive functioning (Kizilbash, Vanderploeg, & Curtiss, 2002). As such, it is difficult to determine if results that fail to control for depression are evidence of executive functions being influenced by anxiety, depression, or both. The current research aimed to amend these limits.

The first phase of the current research examined the influence of trait anxiety on several discrete executive functions, including mental rotation, forward planning, cold decision-making, and sustained attention. The research also evaluated the addition of situational stress (external interference) and cognitive load (internal interference). Results were evaluated in the context of prior literature and the theoretical framework of attentional control theory[13]. Trait anxiety and depression were assessed using self-report measures. Situational stress was manipulated by use of cognitive stress procedure (detailed in Chapter Three). Cognitive load was varied within the difficulty levels of each executive function task (detailed in Chapter 3). The studies used accuracy-based measures to evaluate performance effectiveness as well as a processing efficiency ratio based on accuracy/RT calculations per prior work (Edwards & Edwards, 2018).

Hypotheses, First Research Phase

For the first experimental series, the following hypotheses were proposed based on literature and the framework of attentional control theory. The pattern of predictions was relevant to all observed outcomes in mental rotation, planning ability, cold decision-making,

[13] Attentional control theory predicts (1) anxiety impairs performance by through the preferencing of stimulus-driven processing (e.g., external stressors, worrisome thoughts) over goal-driven processing, (2) trait anxiety and situational stress combine to impair processing efficiency to a greater extent than performance effectiveness, and (3) impairments are expected in tasks functions derived from the central executive. Later revisions to attentional control theory have suggested anxiety-related impairments might be further moderated by variations of cognitive load and/or mental effort.

and sustained attention. Individual calculations of performance effectiveness and processing efficiency are detailed in Chapter Four.

H1: After controlling for depression, a significant three-way interaction between trait anxiety × situational stress × cognitive load is predicted for performance effectiveness. High trait anxiety and low cognitive load are predicted to be associated with greater effectiveness in the high stress condition.

H2: After controlling for depression, a significant three-way interaction between trait anxiety × situational stress × cognitive load is predicted for processing efficiency. High trait anxiety and low cognitive load are predicted to be associated with poorer efficiency in the high stress condition.

Chapter Three: General Methodology of First Phase of Research

Chapter Three details the general methodology adopted in the dissertation's first phase of research. Ultimately, four individual studies were carried out. Study 1 evaluated mental rotation, Study 2 examined planning ability, Study 3 assessed cold decision-making, and Study 4 investigated sustained attention. Research approval was granted through the Bond University Human Research Ethics Committee. All studies examined the relationship between trait anxiety and the chosen executive functions (mental rotation, planning, decision-making, sustained attention), as moderated by situational stress and mental effort. Information pertaining to the situational stress manipulation, psychological measures, and cognitive tasks is detailed here.

Participant Recruitment

Participants comprised of undergraduate university students from Bond University on the Gold Coast, Australia. Participants were recruited through the School of Psychology's research participation pool and advertising through Bond University's Student Daily Digest. Participants were reimbursed for their time with partial subject credit and all provided informed consent before study commencement. Due to varying levels of attrition between tasks and the process of data cleaning (i.e., removal of outliers), the demographic information and final participant numbers differed between each study. To avoid repetition, final numbers and demographic summaries are detailed before each relevant study in Chapter Four.

Situational Stress Manipulation

The current research was concerned with how individual differences in trait anxiety may be moderated by external environmental changes. As such, to evaluate the construct of situational stress an experimental manipulation was employed. The chosen manipulation utilised an ego-threat procedure based on false feedback. Ego-threat procedures are a broad range of stress manipulations whereby participants are exposed to unfavourable evaluations of their performance (Leary, Terry, Batts Allen, & Tate, 2009; Miketta & Friese, 2019). The intention of the ego-threat is to threaten the self-image, often by criticising performance standards or over-emphasising failures (Moran, 2016; South, Oltmanns, & Turkheimer, 2003). This procedure has been reported to induce elevations in anxiety, worry, and other negative affect (Edwards, Edwards, et al., 2015; Leary et al., 2009; Moran, 2016). Additionally, the choice to use ego-threat over other stress manipulation was partly informed by theory. The framework of the present work (i.e., attentional control theory; Eysenck et al., 2007) emphasises the role of anxiety's cognitive symptomatology. As such, ego-threat was thought to be a more appropriate stress induction over physiological alternatives (e.g., threat-of-shock).

The current study used a common variant of ego-threat in which participants were led to believe they were performing poorly on tests of intelligence (regardless of their true performance; Leary et al., 2009). Participants allocated to the ego-threat condition were informed that several of the tasks they would complete were measures of general intelligence and that their performance would be compared to others who had completed the task in earlier sessions. Following practice trials, participants were told they were performing below-average. Specifically, they were less accurate and slower than their peers. The false feedback instructions were repeated during rests between tasks. In contrast, individuals allocated to the ego-safe (i.e., control) condition were only given task-relevant information (e.g., reminding of task instructions) to improve their understanding following practice trials.

Questionnaire Materials

A series of questionnaires was used to evaluate the constructs of trait anxiety and depression. The latter was measured to be subsequently controlled for during statistical analyses as a potential covariate. Additionally, a measure of state-based cognitive stress was also included in the questionnaire package to later evaluate the efficacy of the situational stress manipulation. All measures are reproduced in Appendix A for examination.

State and Trait Inventory of Cognitive and Somatic Anxiety (STICSA; Ree, French, MacLeod, & Locke, 2008). The STICSA is a self-report measure designed to assess state and trait levels of cognitive and somatic anxiety. Each state and trait variant of the STICSA includes 21-items, with 10 related to cognitive symptomatology and 11 related to somatic symptomatology. Scores from the trait cognitive anxiety subscale were used in constructing the independent variable of the present research. Scores from the state cognitive anxiety subscale were recorded to be used during manipulation checks of the situational stress induction. The somatic anxiety subscales were not used.

***Scoring*.** Participants were required to rate the extent to which statements were self-descriptive of their mood generally, most of the time (trait measure) and at the moment of completion (state measure). Example statements relevant to the cognitive anxiety subscales included “I feel agonised over my problems” and “I think that the worst will happen”. Responses were made on a 4-point Likert scale ranging from 1 (*Almost Never*) to 4 (*Almost Always*). Scores for the cognitive subscales ranged from 10 to 40 for both trait and state variants. Higher values were representative of greater levels of state/trait anxiety symptomatology.

Reliability and validity. The STICSA has shown good levels of internal consistency for both state and trait forms of the cognitive subscales (Cronbach’s αs > .87; Grös, Antony, Simms, & McCabe, 2007). In the current study, estimates of internal consistency were also found to be good for both the trait cognitive subscale (α = .90) and state cognitive subscale (α = .88). The STICSA state subscale has demonstrated good convergent validity with the state version of the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983), while the trait subscale of the STICSA has shown convergent validity with both the trait version of the

STAI and the anxiety subscale of the DASS (Grös et al., 2007; Ree et al., 2008). Compared to other measures of anxiety, the STICSA has been reported to possess favourable discriminant validity when correlated with measures of depression such as the DASS-D or BDI-II (Beck, Steer, & Brown, 1996; Grös et al., 2007; Ree et al., 2008). Taken together, these results suggested the STICSA was acceptable for use in the current research.

Depression Anxiety Stress Scale – 21 Item Version (DASS-21; Lovibond & Lovibond, 1995). The DASS-21 is a self-report measure of psychological distress, incorporating three subscales each consisting of seven items which measure symptoms of depression, anxiety, and stress respectively. The current study used only scores of the depression subscale (DASS-D) for later use as a statistical control.

Scoring. Respondents were asked to rate the extent to which statements applied to them over the past week. For the DASS-D example statements included “I felt downhearted and blue” and “I felt that I had nothing to look forward to”. Responses were rated on a 4-point Likert scale ranging from 0 (*Did not apply to me at all*) to 3 (*Applied to me very much, or most of the time*). Ratings on the DASS-D were summed and multiplied by two to achieve a total score which can range from 0 to 42. Higher scores were indicative of higher levels of depressive symptomatology in the past week.

Reliability and validity. The DASS-D has demonstrated good to excellent internal reliability when assessed separately from the other DASS subscales, with ratings of Cronbach’s α ranging from .88-.96 (Brown, Chorpita, Korotitsch, & Barlow, 1997; Crawford & Henry, 2003; Henry & Crawford, 2005). In the current study the internal consistency of the subscale was acceptable (α = .79). The DASS-D has shown convergent validity with the Beck Depression Inventory-II (Beck et al., 1996; Wang & Gorenstein, 2013) and the depression subscale of the Hospital Anxiety and Depression Scale (Crawford & Henry, 2003; Snaith & Zigmond, 1994) via significant positive correlations. The DASS-D was also reported to demonstrate discriminant validity with the Positive Affect Negative Affect Scale (Watson, Clark, & Tellegen, 1988), showing inverse correlations with levels of positive affect (Crawford & Henry, 2003). As such, despite being an isolated subscale, the DASS-D was considered acceptable for use in the current study.

Stress Rating Questionnaire (Edwards, Edwards, & Lyvers, 2015). The Stress Rating Questionnaire is a brief self-report measure of situational stress. The Stress Rating Questionnaire was implemented in the current research to track participants' level of cognitive stress at multiple points of the testing session.

Scoring. Participants were asked to rate their feelings in the current moment according to five bipolar subscales. Subscales included dichotomies of Calm/Nervous, Fearless/Fearful, Relaxed/Anxious, Unconcerned/Worried, and Comfortable/Tense. Participants responded using a 7-point scale ranging from one extreme of the emotional pairs (e.g., 1 = *Very Calm*) to the extreme of the other (e.g., 7 = *Very Nervous*). Scores were summed across all five dimensions, with total composite scores ranging from 5 to 35. Higher scores were considered indicative of greater levels of stress.

Reliability and validity. The Stress Rating Questionnaire has been reported as a valid measure of situational stress in prior literature (Brugnera et al., 2018; Edwards, Edwards, et al., 2015). Bivariate correlations between baseline scores of the Stress Rating Questionnaire and STICSA state cognitive subscale were conducted for each study to evaluate the measures' suitability. Results of these analyses are presented within each discrete study chapter.

Cognitive Tasks

Mental Rotation, Shepard and Metzler Paradigm. To evaluate mental rotation ability, the current research utilised a computerised mental rotation task comparable to that established by Shepard and Metzler (1971). As noted in Chapter Two, any form of mental rotation task retains the same procedural properties. While changes can be made to the presentation sequence, stimuli complexity, and rotational axes, these variations do not alter the underlying mental rotation trend[14] (Borst et al., 2011; Voyer et al., 2017). The current task used concurrent-pair presentation of three-dimensional abstract cubed objects, like that of Shepard and Metzler's (1971) seminal work, rotated on the y-axis (longitudinal axis). The choice of stimuli and presentation style was also selected to minimise the effect of sex-based differences common to mental rotation tasks (Jansen-Osmann & Heil, 2007). Computerised mental rotation tasks that require the manipulation of three-dimensional objects, akin to the protocol employed in the current work, have shown to demonstrate good reliability and validity (Jansen-Osmann & Heil, 2007; Voyer et al., 2017). The task comprised of 80 trials total, separated into two blocks of 40 trials. Participants were shown a 500ms fixation cross in the centre of the screen at the start of each trial, followed by a pair of the three-dimensional cubed objects (see Figure 10 for example stimuli). In half the trials the paired objects were the same, while the remainder were mirrored (Borst et al., 2011). Participants were required to compare the right-side object to the left-side reference and determine if the objects were the same or mirrored. Participants were instructed to respond as accurately and quickly as possible. The angular discrepancy of the stimuli could appear as rotations of 0°, 45°, 90°, 135°, or 180°. Responses were entered using a response box with a two-button configuration (same vs. mirror). The object pairs remained on-screen until a response was entered or the trial timed out at 800ms.

[14] As the degree of required mental rotation increases, so too does RT.

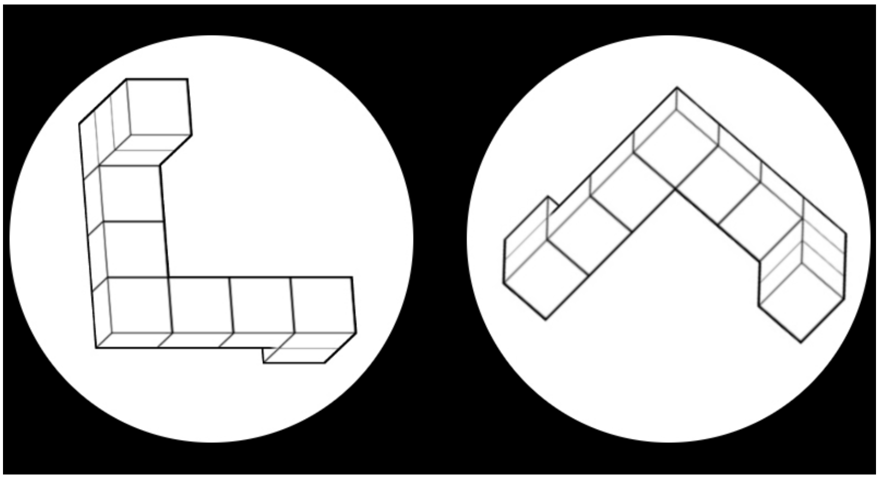


Figure 10. Example of mental rotation task stimuli depicting a same-image trial at 135° rotation.

Planning Ability, One-Touch Tower of London. The Tower of London is a neuropsychological task widely used and accepted as a measure of planning ability (Berg & Byrd, 2002; Kaller et al., 2012; Phillips et al., 2001). Planning ability was assessed in the current research by use of a computerised, one-touch Tower of London task. Rather than manually rearranging digital pegboards, the one-touch variant of the Tower of London requires participants to provide responses via a single button press. This approach minimises confounds attributed to differences in dexterity/motor control. The Tower of London is preferable for the current work as it allows for modification to the range of difficulty, in addition to the use of neutral stimuli unlikely to interact with trait anxiety or situational stress. Though some sources have reported low task reliability, particularly test-retest coefficients, this finding is expected. As an assessment of a discrete executive function, the task relies somewhat on novelty and unfamiliarity with how to solve its planning sequences (Berg & Byrd, 2002; Phillips et al., 2001). Newer variations of the Tower of London task, which typically contain a greater range of structurally-balanced trials, have been reported to exhibit improved reliability and validity compared to the Shallice's (1982) original task (Kaller et al., 2012; Köstering, Nitschke, Schumacher, Weiller, & Kaller, 2015). The current task was derived from prior literature and considers contemporary recommendations in construction of task stimuli (Kaller et al., 2012; Tunstall, O'Gorman, & Shum, 2016; Ward & Allport, 1997).

The current study used a computerised, four-bead variant (compared to the original three-bead configuration) to improve suitability for a non-neurologically impaired sample (per recommendations; Tunstall et al., 2016; Ward & Allport, 1997). The task contained eight practice trials, followed by 48 test trials divided across two blocks. At the commencement of each trial, participants were presented two images depicting virtual pegboards, positioned above (START image) and below (GOAL image) one another. The images depicted three pegs with four coloured beads arranged into various patterns. The task involved six levels of difficulty ranging from 2-move to 7-move solutions. Participants were instructed to mentally plan how many moves it would take to reconfigure the START image into the GOAL image. Participants were required to report the minimum number of necessary moves by selecting the appropriate number on a 7-key response box. An example of the test stimuli is depicted in Figure 11 (overleaf).

Participants were instructed to respond as quickly and accurately as possible. Images remained on-screen until participants responded or timed out after two minutes. There was a 500ms inter-trial interval, and a fixation cross was displayed for 800ms before the next trial. The images were balanced for starting position (tower vs. flat) and direction of bead movement for solving (right vs. left) per recommendations of literature (Berg & Byrd, 2002; Berg, Byrd, McNamara, & Case, 2010).

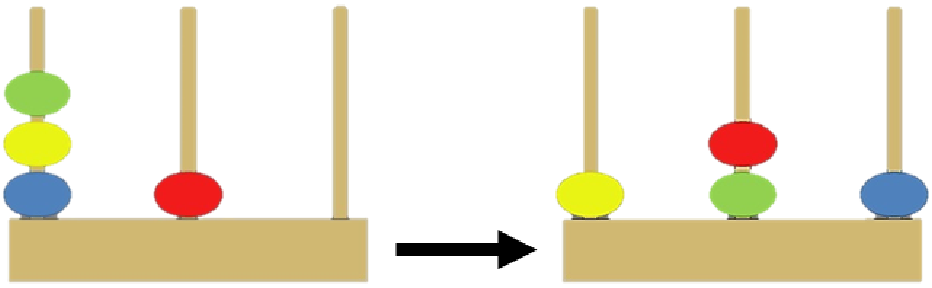


Figure 11. Example stimuli of four-bead Tower of London used in current study depicting a 4-move trial

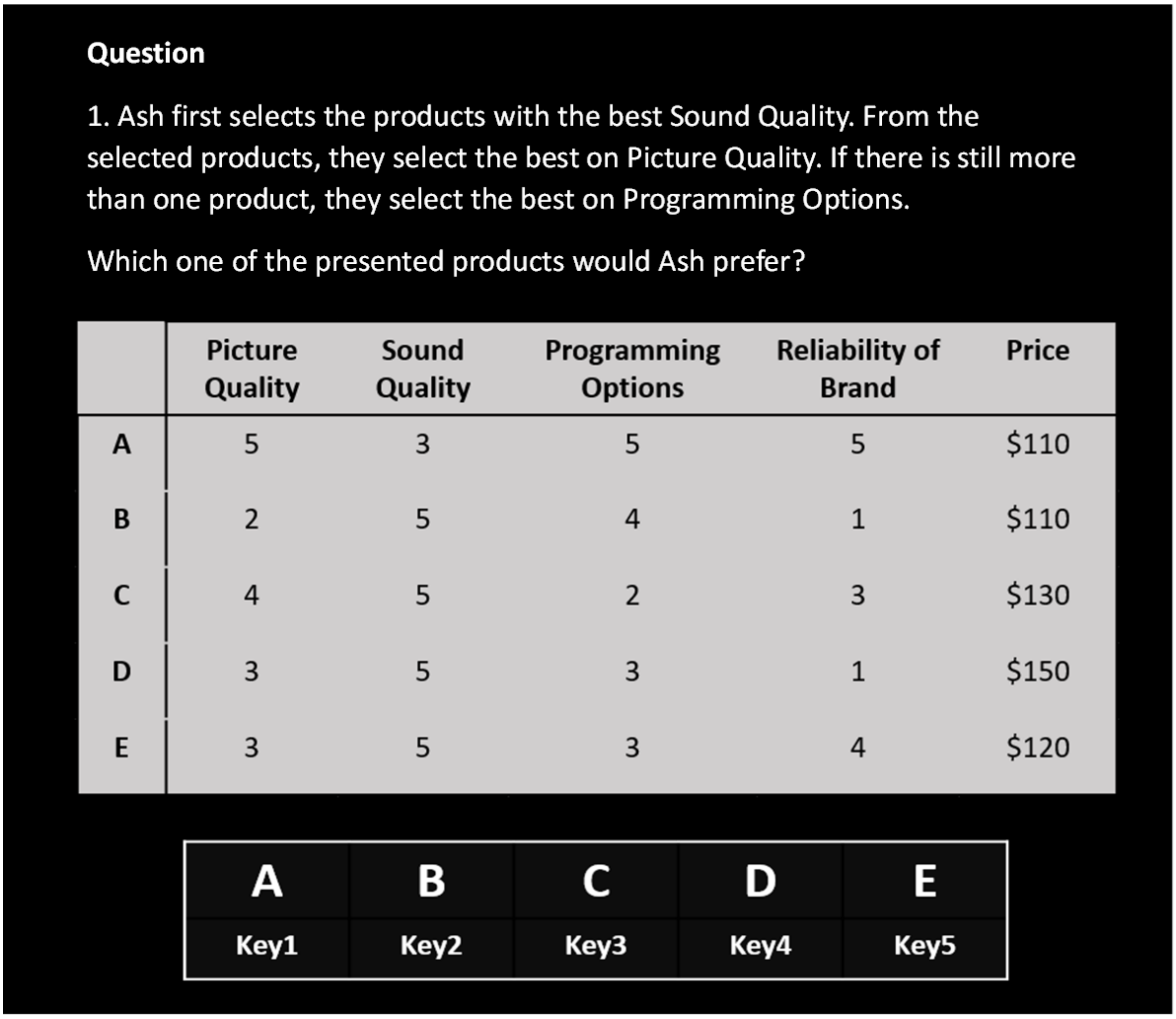
Cold Decision-Making, Novel Task.

To assess cold decision-making ability, a novel computerised task was developed for the purpose of the current study. While the cold Columbia Card Task is presented as a measure of cold decision-making, as discussed in Chapter Two its reliance on risk/benefit calculations lends itself to heuristic decision processes more akin to hot decision-making (Raue & Scholl, 2018). Further, performance on the cold Columbia Card Task provides an indication of risk-preference. Given the definitions of cold decision-making throughout executive function literature, it is proposed here cold decision-making is better assessed using non-emotive, logical rulesets. This allows for examination of decision-making accuracy, rather than style. The task used here is based on the protocol used in the pencil-and-paper Applying Decision Rules subtest of the A-DMC[15]. The overall A-DMC measure has been found to be psychometrically sound, with the Applying Decision Rules subtest separably having demonstrated good reliability and validity (Bruine de Bruin et al., 2007; Del Missier et al., 2010).

[15] Adult Decision-Making Competence battery

The current study's cold decision-making task (DMT) was used to assess the ability to apply logical rulesets during decision-making. The task allowed for manipulation of difficulty levels and used neutral stimuli, similar to the research designs discussed in Chapter One and Chapter Two. Similar to the A-DMC, participants were presented with hypothetical scenarios in which a sales customer was selecting between five products. Product choices were listed as A through E. Each product varied on five dimensions (picture, sound, programming, reliability, and price) which were presented in a 5 × 5 table sized approximately 21cm × 9cm. Participants decided the correct purchase decision by using rulesets that described the required combination of dimensions. An example of the task layout is presented in Figure 12 (overleaf).

At the commencement of each trial, the decision-making ruleset was presented at the top of the screen. Difficulty level varied in the number of product dimensions to be considered (ranging from 1-5), and thus the number of cells to be examined. After reading the ruleset, participants pressed any response key to reveal the 5 × 5 product information table. Participants indicated the item that best matched the ruleset by selecting from one of five keys labelled A through E on a response pad. The delayed onset of the information table was used to distinguish the RT of the decision-making process from the interference of reading speed. Trials were separated by a delay of 500ms, followed by an 800ms *Next Trial* prompt. The task comprised of 48 trials divided into two blocks of 24 trials. Participants were provided three practice trials.



Question

1. Ash first selects the products with the best Sound Quality. From the selected products, they select the best on Picture Quality. If there is still more than one product, they select the best on Programming Options.

Which one of the presented products would Ash prefer?

	Picture Quality	Sound Quality	Programming Options	Reliability of Brand	Price
A	5	3	5	5	$110
B	2	5	4	1	$110
C	4	5	2	3	$130
D	3	5	3	1	$150
E	3	5	3	4	$120

A	B	C	D	E
Key1	Key2	Key3	Key4	Key5

Figure 12. Cold DMT trial with all information onscreen requiring scanning of 15 cells.

Sustained Attention, Rapid Visual Information Processing. The current work evaluated sustained attention using the Rapid Visual Information Processing (RVIP) task, a commonly used and accepted measure of continuous performance (Bakan, 1959; Neale, Johnston, Hughes, & Scholey, 2015; Wesnes et al., 1983). The RVIP uses numerical (non-emotive) stimuli and the identification of two competing sequential targets amongst distractors. As such, the task requires additional coordination of selective attention via discrimination between different target sets (Coull, Frith, Frackowiak, & Grasby, 1996; Knott et al., 2011). The task also requires continual updating of working memory (Knott et al., 2011). The RVIP is a continuous performance task, requiring the sustained attention of participants for between 7 to 12 minutes. While fatigue and boredom effects are encouraged for sustained attention tasks, the current research would require participants to complete four cognitive tasks in a single sitting. Therefore, use of tasks exhibiting excessive length (e.g., over 10 minutes, like the TOVA at 23 minutes or Geen's [1985] continuous performance test at 36 minutes) was considered not feasible.

At the onset of the RVIP, participants were presented with a fixation cross in the centre of the screen for 500ms. At its offset, participants were shown a continuous series of digits, ranging from 1 through to 9. Participants were required to press a response key when they detected a target sequence, of three consecutive odd digits (e.g., 3, 7, 1) or three consecutive even digits (e.g., 2, 6, 4). The identification of odd-number sequences was considered more difficult compared to even-numbered sequences (Dowker & Nuerk, 2016; Heubner et al., 2018; Hines, 1990). Each digit was presented for 300ms with a 900ms interstimulus interval. Responses were scored as a hit if the participant responded within 1200ms of the onset of the last digit of a target sequence. Target sequences were separated by a minimum of five and a maximum of 33 digits (M = 9.30 digits; Wesnes et al., 1983). The testing sequence consisted of 1200 digits with 97 target sequences. An additional practice sequence of 20 digits containing two target sequences was offered prior to the main trials. Including practice trials, the task required approximately 12 minutes to complete. A graphical representation of the task sequence is provided in Figure 13 (overleaf).

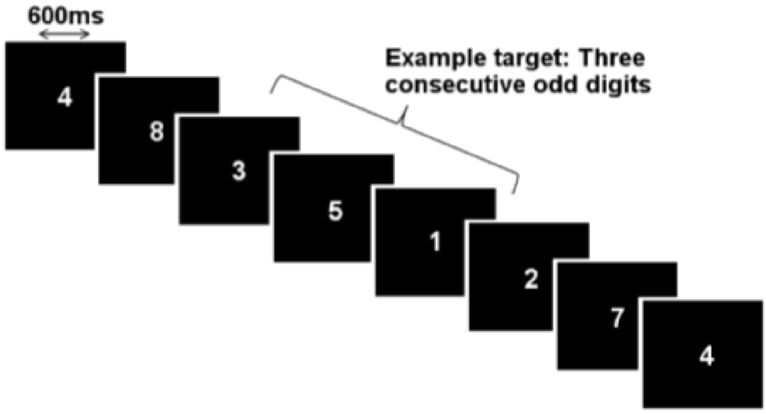


Figure 13. Example of RVIP sequence containing an odd-number target.

Hardware and Software

Participants completed the first phase of research in the School of Psychology Research Laboratories at Bond University. All tasks were created using LabVIEW Builder and run using LabVIEW Run Time Engine via a Dell Precision T3600 computer with Intel Xeon 3.00 GHz processor. Stimuli were presented on a 19-inch LCD. Responses were recorded using an ADInstruments RB-x40 series response pad with RT logged in milliseconds.

Procedure

Participants were tested individually, with each session taking approximately 90 minutes to complete with an additional 30 minutes set aside for debriefing. On arrival, participants were provided with an explanatory statement and were required to provide written consent to participate. In accordance with requests from the university ethics committee, those who scored within the “extremely severe” range of the DASS-Depression subscale (i.e., scores ≥ 28) were released from the study ($N = 1$). Participants who did not meet this threshold continued to complete the STICSA and Stress Rating Questionnaire (baseline score). Participants were allocated alternately to one of two situational stress conditions, including ego-safe (no situational stress) or ego-threat (induced situational stress), based on arrival order to the laboratory. Following the situational stress manipulation (or task-relevant instructions for the ego-safe condition), participants were asked to complete the Stress Rating Questionnaire again (post-manipulation score) before commencement of the cognitive tasks. Based on the arrival order, participants completed the tasks in a counterbalanced sequence[16]. All participants were reminded to respond as accurately and quickly as possible. After each task, participants were required to complete Stress Rating Questionnaire after the situational stress manipulation was reinstated (post-manipulation score). This sequence was repeated until all tasks were completed. Rest periods were encouraged between tasks to avoid excessive fatigue. Once participants had finished all four tasks and measures, they were debriefed and thanked for their time before being released.

[16] Some participants did not complete the full sequence of tests. Exceptions were made when testing exceeded the maximum booking of 120 minutes or participants chose to withdraw their involvement.

Chapter Four: First Research Phase, Analyses and Study Series Results

In Chapter Three, the general methodology of the first research phase was summarised. In Chapter Four, statistical analyses of the research were detailed. The current chapter is divided into four studies, which examined each separable executive function under evaluation. The studies focused on mental rotation (Study 1), forward planning (Study 2), cold decision-making (Study 3), and sustained attention (Study 4). In Study 1, different approaches to the calculation of performance effectiveness and processing efficiency values[17] (as noted in attention control theory) were discussed and a precedent set for the protocols of later studies. Each study detailed the participant demographics and group allocation, data diagnostics, and evaluation of the situational stress manipulation. Each study also summarised the calculations used to determine operational definitions of performance effectiveness and processing efficiency. Two main analyses were conducted for each executive function, the first assessing performance effectiveness and the second assessing processing efficiency.

Study 1: Trait Anxiety, Situational Stress, Cognitive Load, and Mental Rotation

Study 1 examined mental rotation ability. Specifically, the study evaluated if differences in trait anxiety, situational stress, and cognitive load contribute to changes in performance effectiveness and processing efficiency outcomes during a mental rotation task. The methodology of Study 1 is briefly outlined before presentation of results.

Participants and Group Allocation

Basic demographic information of the sample across each cell of the design is presented in Table 6. Participants consisted of 92 undergraduate university students, ranging

[17] Performance effectiveness refers to the quality of task performance. Processing efficiency refers to the relationship between performance effectiveness and utilised cognitive resources.

in age from 18 to 53 years (M_{age} = 23.60, SD_{age} = 7.97; 77 female, 15 male). There was an equal number of participants allocated to the ego-safe condition (*N* = 45) and ego-threat condition (*N* = 45). There was no significant difference of participants' age between the ego-safe (*M* = 23.96, *SD* = 7.98) and ego-threat (*M* = 23.26, *SD* = 8.01) conditions, *t*(90) = 0.42, *p* = .678. Likewise, the distribution of males and females was comparable between conditions, $\chi^2(1) = 0.34$, *p* = .562.

The high and low trait cognitive anxiety categories were created by use of a median split procedure. Within the sample, the median value of trait cognitive anxiety was 18.00. Participants scoring less than (<) 18.00 were allocated to the low trait cognitive anxiety group and those scoring greater than (>) 18.00 were allocated to the high trait cognitive anxiety group. To maintain approximately equivalent group sizes, participants scoring exactly 18.00 were allocated to the high trait cognitive anxiety group (DeCoster, Gallucci, & Iselin, 2011). The low trait anxiety group (*M* = 13.60, *SD* = 2.20) consisted of 45 participants, while the high trait anxiety group (*M* = 23.32, *SD* = 5.27) contained 47 participants. There was no significant difference of age between low (*M* = 23.58, *SD* = 7.84) and high (*M* = 23.64, *SD* = 8.16) trait anxiety groups. There was also no significant difference in the distribution of males and females between groups, $\chi^2(1) = 0.24$, *p* = .623.

Table 6

Demographics for Cells of Situational Stress (Ego-Safe vs. Ego-Threat) × Trait Anxiety (High vs. Low) for Mental Rotation (Study 1)

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	n = 18	*n* = 28	*n* = 27	*n* = 19
M_{Age} (*SD*)	25.44 (10.56)	23.00 (5.79)	22.33 (5.20)	24.58 (10.87)
Females	15	23	24	16
Males	3	5	3	3

Materials

Questionnaires. Participants were presented a questionnaire package inclusive of the STICSA[18] (Ree et al., 2008), DASS-21[19] (Lovibond & Lovibond, 1995), and Stress Rating Questionnaire (Edwards, Edwards, et al., 2015). The trait-cognitive subscale of the STICSA was used to measure trait anxiety of participants and determine high/low groupings. The depression subscale of the DASS-21 was included in analyses to evaluate depression as a possible covariate influencing results. The Stress Rating Questionnaire was employed as a manipulation check of the situational stress induction (described in further detail below). The state-cognitive subscale of the STICSA was also used for the situational stress manipulation check. Further descriptions of the measures, scoring procedures, and reliability/validity information for all scales are presented in Chapter Three's general methodology.

Mental Rotation Task. A computerised mental rotation task using the established paradigm of Shepard and Metzler (1971) was used to evaluate mental rotation ability. The current task used a concurrent-pair presentation of three-dimensional abstract cubed objects.

[18] State-Trait Inventory of Cognitive and Somatic Anxiety
[19] Depression Anxiety Stress Scale – 21 Items

Rotated imagery was done so on the y-axis (longitudinal rotation). Participants compared two objects to determine if they were identical or mirrored. The right-side object acted as a reference, while the left-side object could be rotated by either 0°, 45°, 90°, 135°, or 180°. Participants were instructed to respond as quickly as possible without sacrificing accuracy. Responses were entered using a response box with a two-button configuration. Further details of the mental rotation task and example stimuli are presented in Chapter Three.

Experimental Setup

Participants completed the experiment in the School of Psychology Research Laboratories at Bond University. Testing was conducted individually. Task stimuli were presented on a 19-inch LCD desktop screen. Accuracy and RT data were recorded using an ADInstruments RB-x40 series response pad.

Procedure

Upon arrival to the testing space, participants were provided with an explanatory statement and consent form. Following written consent, participants completed the DASS-21. Those who scored in the "extremely severe" range of the depression subscale (i.e., scores ≥ 28) were released from the study (*N* = 1). For all others, participants completed the STICSA and a baseline Stress Rating Questionnaire. Participants were then allocated to either the ego-safe (control condition) or ego-threat condition (situational stress manipulated condition) based on arrival order[20]. Those allocated to the ego-safe condition were provided task-relevant instructions only and given clarification after practice trials. For those allocated to the ego-threat condition, participants were informed they were about to complete a measure of intelligence. Following practice trials, these participants were informed their performance was poorer compared to previous participants. After the manipulation, participants were

[20] In an alternate allocation order, every second participant was allocated to the ego-threat condition.

asked to complete the Stress Rating Questionnaire once more (post-manipulation score). All participants continued to complete the mental rotation task. Participants were debriefed at the end of the study.

Situational Stress Manipulation

To confirm that the ego-threat instructions increased cognitive situational stress, relative to task-relevant instructions given in the ego-safe condition, a 2 (time; baseline vs. post-manipulation) × 2 (group; ego-threat vs. ego safe) mixed-design ANOVA was run. Total Stress Rating Questionnaire scores were entered as the dependent variable. A significant main effect of time was observed, $F(1, 90) = 60.73$, $p < .001$, $\eta_p^2 = .40$, *power* => 1.00[21]. Within-subjects contrasts reported a significant linear trend, such that Stress Rating Questionnaire values increased from baseline to post-manipulation. The main effect of group was non-significant, $F(1, 90) = 0.12$, $p = .734$, $\eta_p^2 < .01$, *power* = .06[22]. The two-way time × group interaction was also significant, $F(1, 90) = 23.00$, $p < .001$, $\eta_p^2 = .20$, *power* = .98. Within-subject contrasts indicated the linear trend observed across time varied as a function of group. Stress Rating Questionnaire values for each group at separate time points are plotted in Figure 14 (overleaf). Evaluation of plotted values suggested while both groups

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[21]*Note.* Using Cohen's (1988) conventions, effect sizes and power are reported for all results.

Partial eta-squared (η_p^2) is reported for effect size; it expresses the proportion of variance in the dependent variable attributable to a select independent variable. It evaluates ratio of the sum of squares of the effect (SS_{effect}) against the sum of squares of the effect and sum of squares of the error associated with the effect ($SS_{effect} + SS_{error}$). Partial eta-squared is advantageous as it improves comparability between studies due to not relying on a comparison to total variability (a quantity that changes based on the design of the study; Keppel, 1991). Partial eta-squared values may be interpreted as: small ≈ .01, medium ≈ .09, large ≈ .25 (Cohen, 1988).

Power represents the probability of rejecting a false negative result (i.e., Type II error). Cohen (1988; 1992) recommends sufficient power as ≥ .80.

[22] Although some may argue there is limited value in reporting effect size for non-significant results, for the current dissertation such values are reported throughout for consistency.

experienced an increase in self-reported situational stress across time, the increase was more pronounced for the ego-threat condition following a situational stress induction compared to the ego-safe condition receiving task-relevant instructions. The minimal overlap between the confidence intervals (CIs) of the post-manipulation Stress Rating Questionnaire average and baseline average of the ego-threat condition suggested a significant increase in situational stress over time.

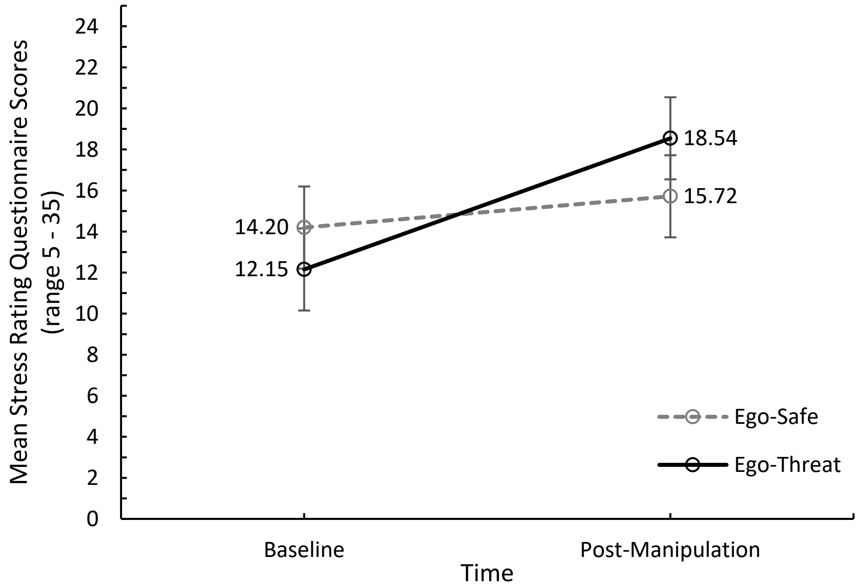

Figure 14. Linear trend of the effect of time at each level of situational stress condition for Stress Rating Questionnaire scores during the mental rotation task. Error bars represent 95% confidence intervals.

Results

Measurement of Mental Rotation

Mental rotation effectiveness. Performance effectiveness for the mental rotation task was indexed as a composite score comprising of the total number of correct responses across trials of 0°, 45°, 90°, 135°, and 180° rotations. Only responses for same-image trials were considered as is the convention in previous literature. It is suggested participants use shortcut non-rotational strategies to solve mirrored-image trials, thereby rendering such trials unrepresentative of mental rotation ability (Jansen-Osmann & Heil, 2007; Jolicœur et al., 1985; Metzler & Shepard, 1974; Shepard & Metzler, 1971; 1988).

Mental rotation efficiency. Processing efficiency for the mental rotation task was operationalised as a ratio between accuracy and total RT. To aid interpretability the ratio was multiplied by 1000 (Edwards, Edwards, et al., 2015). The inclusion of the multiplicative function converts the millisecond range to seconds so that the ratio of the number of solved problems to time is not exceedingly small. Efficiency scores were created using the calculation:

$$\textit{Mental rotation efficiency} = \left(\frac{\text{Number of correct same-image trials}}{\text{RT on correct same-image trials}}\right) \times 1000$$

Data Diagnostics, Unstandardised Effectiveness and Efficiency

The dataset was initially cleaned at the level of individual trials. Any trial demonstrating a RT of < 200ms or ± 3 *SD*s from the participants' mean RT (approx. 1% of trials) was removed. Univariate outliers were identified by evaluating individual *z*-scores. Values ± 3.00 were considered to be extreme. Six cases were identified, three at the level of 0° difficulty, two at 45° difficulty, and one at 90° difficulty. Upon review the values were found to be true extremes within measurement limits and were thus retained. Mahalanobis' Distance revealed one potential multivariate outlier ($p < .001$). Removal of the outlier did not change the trend of results and therefore was retained (final $N = 92$).

The assumption of normality was assessed using the Shapiro-Wilk test. Normality was assessed within all cells of the design. The Shapiro-Wilk test compares the distribution of current data to that of a normal distribution. The Shapiro-Wilk test is recommended for data with less than 50 cases, which is suitable for each cell of the current design. A non-significant *p*-value indicates the analysed data approximates a normal distribution.

Within the low trait anxiety and ego-safe cell, violations to the assumption were observed for the performance effectiveness data at the rotation levels of 0°, 45°, 90°, and

135°. No violations of assumptions were found for processing efficiency data. Within the low trait anxiety and ego-threat cell, violations were found for performance effectiveness at the 45°, 135°, and 180° levels and for processing efficiency at the 90° level. No significance value was generated for performance effectiveness at 0° as there was no distribution of results. For the high trait anxiety and ego-safe cell, normality violations were found for performance effectiveness at all levels and for processing efficiency at the levels of 0°, 45°, and 180° rotations. Within the high trait anxiety and ego-threat cell, the assumption of normality was violated for performance effectiveness at 0°, 45°, 90°, and 135°, and for processing efficiency only at the 135° level. As ANOVA is robust to violations of normality, no transformation was applied to the data and final results were interpreted with caution (Tabachnick & Fidell, 2019).

Missing data analyses identified 4.4% missing data cases across accuracy and RT data, one case within the 135° levels and three cases within the 180° levels. The missing cases represented participants who incorrectly responded to all trials across the noted difficulty levels. As such, no information was recorded by the program. The cases were excluded pairwise where appropriate in the main analyses. All analyses were conducted using SPSS version 25. A significance threshold of $\alpha \leq .050$ was set for all analyses, unless otherwise stated.

Main Analysis, Unstandardised Mental Rotation Effectiveness

A three-way 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 5 (cognitive load; 0° vs. 45° vs. 90° vs. 135° vs. 180°) mixed-design ANCOVA was conducted on mental rotation effectiveness scores. Mauchly’s test of sphericity was found to be violated for the within-subjects variable of cognitive load, $\chi^2(9) = 76.44$, $p < .001$. Consequently, corrected degrees of freedom were used to interpret results using Greenhouse-

Geisser estimations of sphericity (ε = .64[23]; corrected df_{treat} = 3, corrected df_{error} =237). The covariate of depression was found to be a non-significant contributor at all levels of the analyses. Descriptive statistics are shown in Table 7. The high values observed across the easier rotation trials (i.e., 0° and 45°), in addition to the instances of perfect 8.00 values suggested a possible ceiling effect amongst the data. Review of the standard deviations demonstrated small, comparable score variations within all cells of the design.

Table 7

Means and Standard Deviations of Unstandardised Performance Effectiveness Values on Mental Rotation Task Across All Cognitive Load Levels, Trait Anxiety Groups, and Situational Stress Conditions

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
0°	7.94 (0.24)	8.00 (0.00)	8.00 (0.00)	7.89 (0.32)
45°	7.39 (0.85)	7.75 (0.52)	7.19 (1.11)	7.58 (0.77)
90°	7.28 (0.89)	6.93 (1.59)	5.67 (1.73)	7.26 (0.73)
135°	6.50 (1.34)	6.71 (1.27)	5.96 (1.59)	6.53 (1.50)
180°	4.61 (1.85)	5.33 (2.09)	3.81 (1.81)	4.94 (1.95)

The main effect of cognitive load was found to be significant, $F(3, 237) = 57.57$, $p < .001$, $\eta_p^2 = .41$, *power* => 1.00. Estimates of magnitude of effect suggested approximately 41% of variance in performance effectiveness scores could be accounted for by changes in

[23] Epsilon (ε) values greater than .50 and less than .80 indicate moderate violation which can be addressed by reduction of the degrees of freedom. The Greenhouse-Geisser correction creates conservative degrees of freedom by multiplying the degrees of freedom with the estimated epsilon value (Greenhouse & Geisser, 1959).

rotational difficulty of the mental rotation task. Follow-up trend analyses using polynomial contrasts were conducted to evaluate for linear and non-linear relationship between rotation and performance effectiveness (Lavrakas, 2008). Specifically, results were examined for linear and quadratic (i.e., curvilinear) components (see Figure 15 for plotted data). Analyses revealed a significant linear trend amongst the data such that, averaged across trait anxiety and situational stress groups, the mean of correct trials tended to decrease as rotation angle increased, $F(1, 83) = 135.61$, $p < .001$, $\eta_p^2 = .62$, *power* => 1.00. An additional quadratic component was also found to be significant, suggesting curvilinear properties within the trend, $F(1, 83) = 12.84$, $p = .001$, $\eta_p^2 = .13$, *power* = .94. Review of the graphed data suggested this finding may be attributable to the sharp decline in performance effectiveness observed between the levels of 135° and 180° rotation trials.

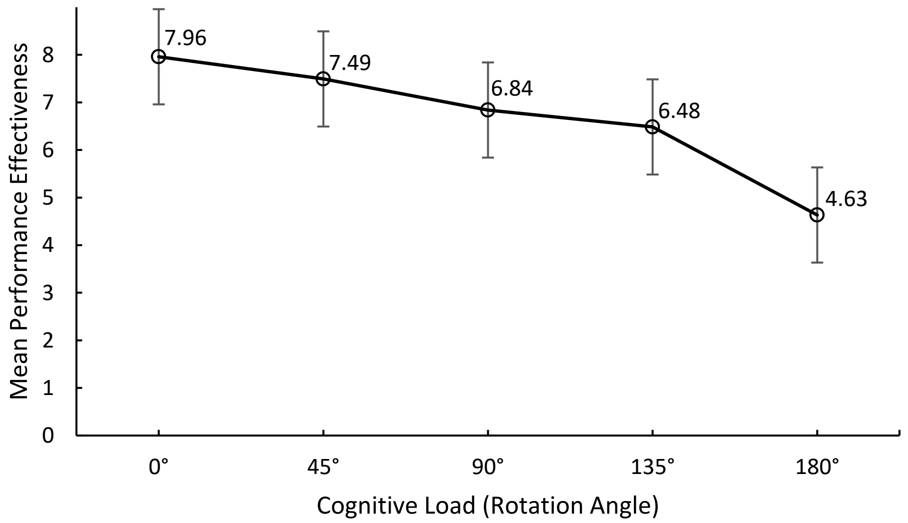

Figure 15. Linear trend of the main effect of cognitive load (rotation level) on performance effectiveness of mental rotation. Error bars represent 95% confidence intervals.

The main effect of situational stress was found to be significant, $F(1, 83) = 4.33$, $p = .041$, $\eta_p^2 = .05$, *power* = .54. When averaged across all other variables, participants allocated to the ego-safe condition demonstrated greater effectiveness on the mental rotation task compared to those allocated to the ego-threat condition. The magnitude of effect was limited as 95% of the variance in performance effectiveness scores remained unaccounted for by changes in situational stress. The main effect of trait anxiety was also significant, with high trait anxiety participants showing greater effectiveness compared to low trait anxiety participants, $F(1, 83) = 4.58$, $p = .035$, $\eta_p^2 = .05$, *power* = .56. The magnitude of effect was limited, such that variations in trait anxiety accounted for 5% of variance in performance effectiveness, with the remaining 95% unaccounted for.

The two-way interaction of cognitive load × trait anxiety was non-significant, $F(2.85, 236.70) = 1.59$, $p = .194$, $\eta_p^2 = .02$, *power* = .41. The two-way interaction cognitive load × situational stress was also non-significant, $F(3, 237) = 1.35$, $p = .261$, $\eta_p^2 = .02$, *power* = .35. Likewise, the two-way interaction of trait anxiety × situational stress was found to be non-significant, $F(1, 83) = 1.98$, $p = .164$, $\eta_p^2 = .02$, *power* = .29. With the Greenhouse-Geisser correction applied, the three-way interaction of cognitive load × trait anxiety × situational stress was not significant, $F(3, 237) = 4.47$, $p = .060$, $\eta_p^2 = .03$, *power* = .61.

Main Analysis, Unstandardised Mental Rotation Efficiency

A three-way 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 5 (cognitive load; 0° vs. 45° vs. 90° vs. 135° vs. 180°) mixed-design ANCOVA was conducted on mental rotation effectiveness scores. Mauchly’s test of sphericity was violated for the within-subjects variable of cognitive load, $\chi^2(9) = 69.61$, $p < .001$. Greenhouse-Geisser estimations of sphericity were used to calculate corrected degrees of freedom for interpretation of results ($\varepsilon = .69$; corrected $df_{treat} = 3$, corrected $df_{error} = 230$). The covariate of depression was a non-significant contributor at all levels of the analysis. Descriptive statistics are reported in Table 8. The reported mean values suggested a trend of decreasing processing efficiency as cognitive load increased with rotational difficulty. The standard deviation values demonstrated the variance within each cell was small and comparable amongst one another.

Table 8

Means and Standard Deviations of Unstandardised Processing Efficiency Values on Mental Rotation Task Across All Cognitive Load Levels, Trait Anxiety Groups, and Situational Stress Conditions

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	M **(*SD*)**	***M*** **(*SD*)**	***M*** **(*SD*)**	***M*** **(*SD*)**
0°	0.78 (0.19)	0.81 (0.21)	0.87 (0.20)	0.82 (0.19)
45°	0.50 (0.15)	0.53 (0.19)	0.61 (0.19)	0.56 (0.14)
90°	0.41 (0.19)	0.46 (0.17)	0.52 (0.21)	0.50 (0.19)
135°	0.36 (0.15)	0.41 (0.15)	0.47 (0.18)	0.44 (0.19)
180°	0.28 (0.14)	0.33 (0.16)	0.44 (0.20)	0.36 (0.15)

The main effect of cognitive load was found to be significant, $F(3, 230) = 136.26$, $p < .001$, $\eta_p^2 = .62$, *power* => 1.00. Changes in rotation levels accounted for approximately 62% of the variance in processing efficiency scores. Follow-up trend analyses using polynomial contrasts revealed a significant linear relationship, $F(1, 83) = 278.42$, $p < .001$, $\eta_p^2 = .77$, *power* => 1.00. Figure 16 shows a monotonic decline with increasing rotation. Averaged across trait anxiety and situational stress groups, processing efficiency scores tended to decrease as rotation angle increased. The trend was also found to contain a significant quadratic component, suggesting curvilinear properties, $F(1, 83) = 40.90$, $p < .001$, $\eta_p^2 = .33$, *power* => 1.00. Review of the data indicated this finding may have been due to the sharp decrease of processing efficiency observed between 0° and 45° rotations juxtaposed against the intermediate change between 45° and 90° trials.

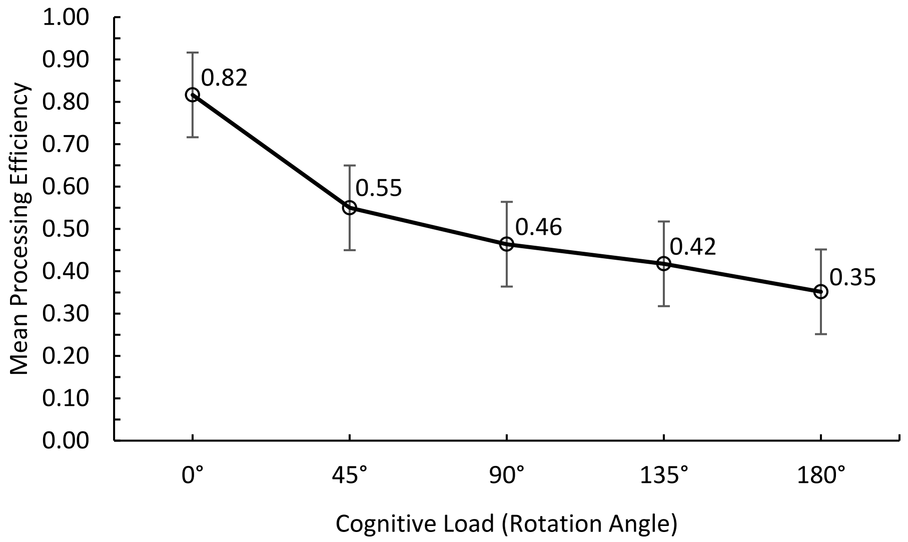

Figure 16. Linear trend of the main effect of cognitive load (rotation level) on processing efficiency of mental rotation. Error bars represent 95% confidence intervals.

The main effect of situational stress was found to be significant, $F(1, 83) = 4.77$, $p = .032$, $\eta_p^2 = .05$, *power* = .58. Across all other variables, participants allocated to the ego-safe condition demonstrated poorer efficiency compared to participants in the ego-threat condition. Magnitude of effect estimates suggested 5% of the variance in processing efficiency scores was accounted for by differences in the experimental manipulation. The main effect of trait anxiety was non-significant, $F(1, 83) < 0.01$, $p = .998$, $\eta_p^2 < .01$, *power* = .05.

The two-way interaction of cognitive load × trait anxiety was found to be non-significant, $F(3, 230) = 1.05$, $p = .382$, $\eta_p^2 = .01$, *power* = .33. The two-way interaction cognitive load × situational stress was also non-significant, $F(3, 230) = 0.41$, $p = .734$, $\eta_p^2 = .01$, *power* = .13. The final two-way interaction of trait anxiety × situational stress was also non-significant, $F(1, 83) = 0.88$, $p = .352$, $\eta_p^2 = .01$, *power* = .15. The three-way interaction of cognitive load × trait anxiety × situational stress was not significant, $F(23, 230) = 0.73$, $p = .523$, $\eta_p^2 = .01$, *power* = .20.

Standardisation of Mental Rotation Effectiveness and Efficiency Values

Following initial analyses of results, limitations of the current performance effectiveness and processing efficiency calculations were evaluated (Edwards & Edwards, 2018; Edwards, Edwards, et al., 2015; Edwards, Moore et al., 2015). An alternative calculation of performance effectiveness and processing efficiency was applied to address limitations of the traditional formula. Within the traditional formula, processing efficiency is derived from the division of raw accuracy and RT data (Edwards & Edwards, 2018). It is suggested here that this calculation is problematic, as the range and scaling of accuracy values will be dependent on the chosen task. Similarly, the RT data will also fluctuate for this reason, with more complex tasks producing inherently greater RTs. As such, the values derived from the traditional processing efficiency formula are arbitrary and uninformative beyond the insulated experiment to which it is applied. Further, the units of measurement used to compute the ratio are not comparable, given they are derived from different scales. Use of standardised and scaled data can address these issues.

For mental rotation effectiveness, a total accuracy score was computed for same-image trials across all rotation levels. Values were standardised to yield *z*-scores. To aid interpretability, scores were translated positively by shifting all values +3.00. Within the dataset the new mental rotation effectiveness values ranged from 0.51 to 4.58 (*M* = 3.00, *SD* = 1.00). For mental rotation efficiency, total RT values of correct same-image trials were standardised and scaled in the same manner (see equation, overleaf). The new processing efficiency ratio was derived from the division of scaled accuracy values by scaled RT. Across the dataset the new mental rotation efficiency values ranged from 0.35 to 2.29 (*M* = 1.05, *SD* = 0.37). The average of processing efficiency value suggested the presence of a positive skew amongst RT values influenced the final ratio (as standardised performance effectiveness retained a normal distribution).

$$\textit{Mental rotation efficiency} = \left(\frac{\text{Standardised scaled accuracy}}{\text{Standardised scaled RT}}\right)$$

Data Diagnostics, Standardised Effectiveness and Efficiency

All participant information and situational stress checks remained comparable to the details summarised in the methodology section of Study 1.. Six cases were identified as univariate outliers, demonstrating *z*-scores exceeding ±3.00. These cases were the same as those of the prior analyses. The cases were found to be true responses and were retained for analysis. Mahalanobis' Distance revealed one possible multivariate outlier ($p < .001$). Removal of the outlier did not change the trend of results and was thus retained ($N = 92$).

Normality was assessed within all cells of the design. The assumption of normality was assessed using the Shapiro-Wilk test. For the low trait anxiety and ego-safe cell, violations to normality were found for performance effectiveness data at the rotation levels of 0°, 45°, 90°, and 135°. A violation was found for processing efficiency data at the 0° level. Within the low trait anxiety and ego-threat cell, violations were found for performance effectiveness at the 45°, 90°, and 135° levels. No values were generated for the 0° level as there was no variation in scores. For processing efficiency, there was a violation of the assumption at the 45° level. For the high trait anxiety and ego-safe cell, normality violations were found for performance effectiveness at all levels and for processing efficiency at the level of 0° rotations. No values were generated for 0° rotation in performance effectiveness due to a lack of score variation. Within the high trait anxiety and ego-threat cell, the assumption of normality was violated for performance effectiveness at the levels of 0°, 45°, 90°, and 135°, and for processing efficiency only at the 0° level. As ANOVA is robust to violations of normality, and the Shapiro-Wilk test can be overly sensitive to detecting violations of normality, no transformation was applied to the data (Tabachnick & Fidell, 2019).

Missing data analyses identified approximately 4.4% missing data across accuracy and RT data. One case was identified within the 135° level and three cases within the 180° level. The missing cases were identical to those observed in the unstandardised analyses of Study 1. No transformations were performed. The cases were excluded pairwise in the main analyses. All analyses were conducted using SPSS version 25. A significance threshold of $\alpha \leq .050$ was set for evaluating the significance of results.

Main Analysis, Standardised Mental Rotation Effectiveness

A three-way 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 5 (cognitive load; 0° vs. 45° vs. 90° vs. 135° vs. 180°) mixed-design ANOVA was conducted on scaled mental rotation effectiveness scores. Mauchly's test of sphericity was found to be violated for the within-subjects variable cognitive load, $\chi^2(9) = 22.91$, $p = .006$. Results were interpreted using corrected degrees of freedom determined by a Greenhouse-Geisser calculation ($\varepsilon = .87$, corrected $df_{treat} = 3$, corrected $df_{error} = 292$). Descriptive statistics are reported in Table 9. Lack of variability in two of the cells (0°, high trait anxiety and ego-safe; 0°, low trait anxiety and ego-threat) suggested the presence of a ceiling effect. Across all cells, score variance appeared small and comparable.

Table 9

Means and Standard Deviations of Standardised Performance Effectiveness Values on Mental Rotation Task Across All Cognitive Load Levels, Trait Anxiety Groups, and Situational Stress Conditions

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
0°	2.87 (1.32)	3.18 (0.00)	3.18 (0.00)	2.59 (1.77)
45°	2.90 (0.99)	3.32 (0.60)	2.66 (1.29)	3.12 (0.90)
90°	3.38 (0.59)	3.15 (1.04)	2.33 (1.14)	3.37 (0.48)
135°	3.06 (0.93)	3.21 (0.88)	2.68 (1.10)	3.08 (1.05)
180°	2.97 (0.93)	3.34 (1.05)	2.57 (0.91)	3.14 (0.98)

The main effect of situational stress was found to be significant, $F(1, 84) = 4.40$, $p = .039$, $\eta_p^2 = .05$, *power* = .55. This effect accounted for approximately 5% of the variance in mental rotation effectiveness scores. Averaged over all other variables, participants allocated to the ego-safe condition demonstrated greater effectiveness compared to the ego-threat condition. The main effect of trait anxiety was also significant, with high trait anxiety participants showing greater effectiveness compared to low trait anxiety participants, $F(1, 84) = 4.40$, $p = .039$, $\eta_p^2 = .05$, *power* = .56. This result accounted for a similar amount of variance as the influence of situational stress. In contrast to the prior analysis, the main effect of cognitive load was non-significant, $F(3, 292) = 0.36$, $p = .809$, $\eta_p^2 < .01$, *power* = .13.

Results demonstrated the two-way interaction of cognitive load × trait anxiety was non-significant $F(3, 292) = 1.92$, $p = .117$, $\eta_p^2 = .02$, *power* = .53. Likewise, the two-way interaction cognitive load × situational stress was also non-significant, $F(3, 292) = 0.33$, $p =$

.834, $\eta_p^2 < .01$, *power* = .12. The two-way interaction of trait anxiety × situational stress was similarly found to be non-significant, $F(1, 84) = 0.26$, $p = .610$, $\eta_p^2 < .01$, *power* = .08. However, the three-way cognitive load × trait anxiety × situational stress interaction was significant, $F(3, 292) = 4.13$, $p = .005$, $\eta_p^2 = .05$, *power* = .86.

To follow up the three-way interaction, the simple interaction effects of trait anxiety × rotation were examined at each level of situational stress. Greenhouse-Geisser corrected degrees of freedom were used for interpretation of results. When examined at the level of the ego-safe condition, there was no significant interaction between trait anxiety and cognitive load, $F(3, 148) = 0.96$, $p = .425$, $\eta_p^2 = .02$, *power* = .28. That is, within the ego-safe condition, performance effectiveness on the mental rotation task did not vary as a function of differences in trait anxiety across the levels of cognitive load. However, at the level of the ego-threat condition, the two-way trait anxiety × cognitive load interaction was significant, $F(3, 133) = 4.60$, $p = .003$, $\eta_p^2 = .10$, *power* = .90. Follow-up within-subject contrasts demonstrated the trend of performance effectiveness across cognitive load conditions varied between high and low trait anxiety groups. The differing trends were found to contain both linear and quadratic components, $F(1, 41) = 8.21$, $p = .007$, $\eta_p^2 = .17$, *power* = .80 and $F(1, 41) = 5.07$, $p = .030$, $\eta_p^2 = .11$, *power* = .59 respectively.

Examination of the plotted trends in Figure 17 suggested high trait anxiety participants showed a linear increase in performance effectiveness from 0° rotation trials onward, peaking at 90° trials before declining and levelling off across 135° and 180° trials. The low trait anxiety participants demonstrated an inverse pattern. Participants within the low trait anxiety group declined from the baseline 0° trials, hitting a negative peak at 90° trials before showing an improvement on 135° trials. Differences between the high and low trait anxiety groups were most pronounced at 90° trials with minimal overlap between CIs. While low trait anxiety participants appeared to outperform their high trait anxious counterparts on the easier baseline trials, during more difficult trials requiring 90° rotation the high trait anxiety participants showed greater performance effectiveness.

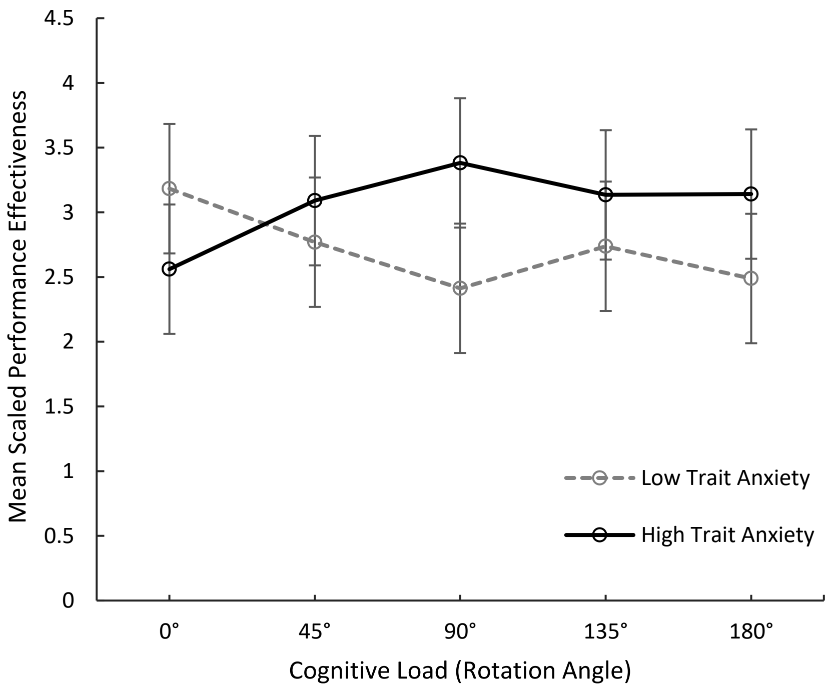

Figure 17. Linear trend of performance effectiveness on mental rotation task within the ego-threat condition. Data plotted across levels of cognitive load (rotation level). Separate lines represent trait anxiety groups. Error bars represent 95% confidence intervals.

Main Analysis, Standardised Mental Rotation Efficiency

A mixed-design three-way 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 5 (cognitive load; 0° vs. 45° vs. 90° vs. 135° vs. 180°) ANOVA was run using scaled mental rotation effectiveness scores as the dependent variable. Mauchly's test of sphericity was found to be violated for the cognitive load variable, $\chi^2(9) = 135.45$, $p =$ < .001. Results were interpreted with caution using Greenhouse-Geisser corrected degrees of freedom to estimate significance ($\varepsilon = .86$, $df_{\text{treat}} = 2$, $df_{\text{error}} = 188$). Descriptive statistics are displayed in Table 10. Processing efficiency values showed little score variation around the mean, as demonstrated by the generally small standard deviations.

Table 10

Means and Standard Deviations of Standardised Processing Efficiency Values on Mental Rotation Task Across All Cognitive Load Levels, Trait Anxiety Groups, and Situational Stress Conditions

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
0°	0.88 (0.68)	1.13 (0.33)	1.21 (0.33)	0.87 (0.83)
45°	0.94 (0.35)	1.10 (0.40)	1.02 (0.49)	1.12 (0.39)
90°	1.04 (0.38)	1.08 (0.39)	0.91 (0.32)	1.22 (0.33)
135°	0.96 (0.36)	1.08 (0.36)	1.01 (0.34)	1.11 (0.39)
180°	0.94 (0.28)	1.04 (0.29)	1.01 (0.23)	1.06 (0.23)

Results found the main effect of cognitive load to be non-significant, $F(2, 188) = 0.28$, $p = .780$, $\eta_p^2 < .01$, *power* = .10. Similarly, the main effect of trait anxiety also failed to reach significance, $F(1, 84) = 2.23$, $p = .139$, $\eta_p^2 = .03$, *power* = .31. The main effect of situational stress was also non-significant, $F(1, 84) = 0.37$, $p = .540$, $\eta_p^2 < .01$, *power* = .09.

The two-way interaction of cognitive load × trait anxiety was ultimately non-significant $F(2, 188) = 1.33$, $p = .268$, $\eta_p^2 = .02$, *power* = .30. Similarly, the two-way interaction of cognitive load × situational stress was non-significant, $F(2, 188) = 0.05$, $p = .962$, $\eta_p^2 < .01$, *power* = .06. The two-way interaction of trait anxiety × situational stress also failed to reach significance, $F(1, 84) = 0.64$, $p = .427$, $\eta_p^2 < .01$, *power* = .13. In contrast, the three-way cognitive load × trait anxiety × situational stress interaction was significant, $F(2, 188) = 4.42$, $p = .010$, $\eta_p^2 = .05$, *power* = .94.

To follow up the three-way interaction, the dataset was split by situational stress condition and the simple interaction effect of trait anxiety × rotation was examined at each level. Greenhouse-Geisser corrected degrees of freedom were used for interpretation of results. At the level of the ego-safe condition, there was no significant interaction between trait anxiety and cognitive load, $F(2, 80) = 0.61$, $p = .536$, $\eta_p^2 = .01$, *power* = .15. For participants allocated to the ego-safe condition, processing efficiency did not vary as a function of differences in trait anxiety across the levels of cognitive load. At the level of the ego-threat condition, the interaction between trait anxiety and cognitive load was significant, $F(2, 101) = 4.53$, $p = .008$, $\eta_p^2 = .10$, *power* = .82. Follow-up within-subject contrasts indicated the trend of processing efficiency across cognitive load conditions differed between high and low trait anxiety groups. The results demonstrated a significant quadratic trend, $F(1, 41) = 9.46$, $p = .004$, $\eta_p^2 = .18$, *power* = .85. The linear trend was non-significant, $F(1, 41) = 4.02$, $p = .051$, $\eta_p^2 = .09$, *power* = .50.

Examination of the trends, depicted in Figure 18, suggested low trait anxiety and high trait anxiety participants demonstrated contrasting curvilinear patterns of processing efficiency. For the low trait anxiety participants, processing efficiency values declined from 0° rotation trials until 90° trials before improving slightly across 135° trials and levelling off at 180° trials. Within the high trait anxiety group, processing efficiency increased from 0° rotation trials, peaking at 90° trials, and then declining across 135° and 180° trials. The greatest points of difference appeared at 0° and 90° trials. Though low trait anxiety participants demonstrated improved processing efficiency at the easier 0° trials, the high trait anxiety participants demonstrated greater processing efficiency values during the more complex 90° trials.

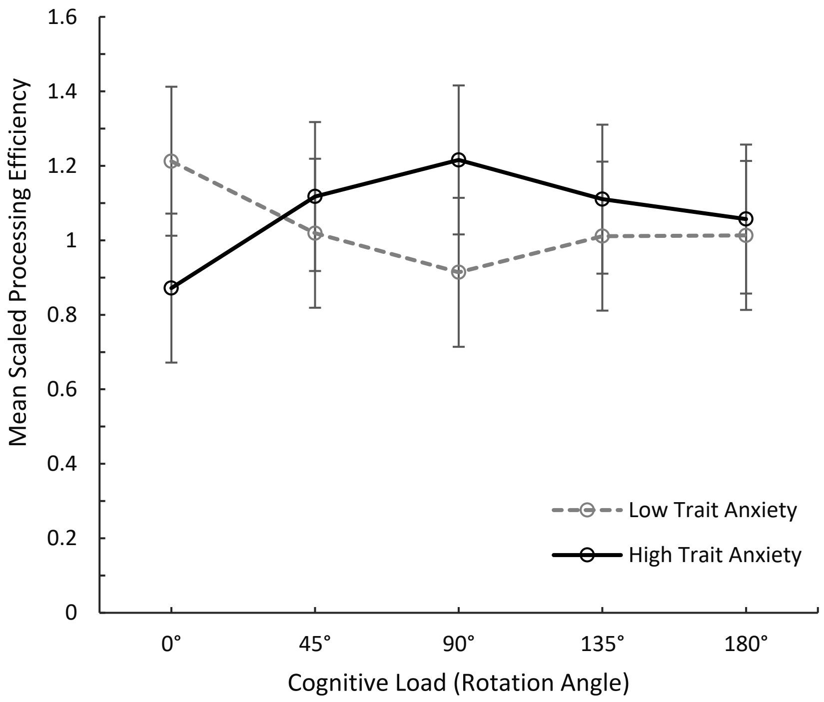

Figure 18. Linear trend of processing efficiency on mental rotation task within the ego-threat condition. Data plotted across levels of cognitive load (rotation level). Separate lines represent trait anxiety groups. Error bars represent 95% confidence intervals.

Discussion: Trait Anxiety, Situational Stress, Cognitive Load, and Mental Rotation

Study 1 examined the interactive influence of trait anxiety, situational stress, and cognitive load on the performance effectiveness and processing efficiency of mental rotation ability. Methodological limitations of prior literature were addressed, including statistical controls for depression and the use of a ratio-based efficiency measure rather than reliance on simple RT. The study initially used unstandardised calculations of performance effectiveness and processing efficiency similar to prior works (Edwards & Edwards, 2018; Edwards, Edwards, et al., 2015; Edwards, Moore et al., 2015). However, limitations of these calculations were reviewed. These limits included the scaling and range of values remaining dependent on the selected task thus precluding cross-task comparisons, as well as the incompatibility of measurement units during computation of the ratio (i.e., accuracy and RT values being derived from difference scales). With consideration, new standardised equations were adopted. Use of the standardised calculations showed a change in the pattern of results from use of unstandardised alternative. Thus, the results of the standardised analyses are discussed here.

It was hypothesised that a trait anxiety × situational stress × cognitive load three-way interaction would be observed for performance effectiveness and processing efficiency outcomes of the mental rotation task. Specifically, in the ego-threat condition during low cognitive load levels, the high trait anxious group was expected to demonstrate greater performance effectiveness, but lower processing efficiency compared to the low trait anxiety group. Results of Study 1 provided partial support for these hypotheses. Though participants allocated to the high trait anxiety group did demonstrate greater performance effectiveness compared to the low trait anxiety group within the ego-threat condition, these results were observed at higher cognitive load levels (specifically, the 90° rotation trials). Further and in contrast to the hypothesis, under these conditions the high trait anxiety participants demonstrated greater processing efficiency than their low anxiety counterparts.

Results of the current study contrast with works that have suggested trait anxiety impairs the performance of mental rotation (Kaltner & Jansen, 2014). This discrepancy may be due to differences of operationalisation of trait anxiety. Unlike the reviewed work of Kaltner and Jansen who evaluated trait anxiety as a continuous covariate, the present research examined trait anxiety as a dichotomised (high vs. low) independent variable. As such, the current work could better identify point-based differences of groups. Alternatively, the differences may be attributed to context. While Kaltner and Jansen examined trait anxiety and cognitive load, the current study included additional variations of environment (i.e., situational stress). The current study suggests the influence of trait anxiety on mental rotation performance is indeed dependent on variations in situational stress, hence discrepancy to prior work. Specifically, increased stress may elevate the performance of some higher trait anxious individuals. However, in the current work the average trait anxiety score of the high trait anxiety group was approximately 26, on a scale which recommends cut-off values for clinical anxiety at 40. As such, the improved performance under stress observed here may only be relevant for sub-clinical individuals.

The findings of the current work are however complementary to other works which found elevated anxiety amongst sub-clinical participants does improve visuospatial rotation skills (Borst et al., 2012; Ramirez et al., 2012). These prior works had focused on state-based elevations of anxiety, as such, the current work adds to this foundation to suggest individual differences in trait anxiety further moderate such influence. The findings of the current work are somewhat akin to that of Borst et al. (2012) who found elevations in state-based anxiety improved the speed of mental rotation. While Borst and colleagues examined state anxiety to suggest transient changes in emotions can improve mental rotation performance, their work was unclear as to how individual difference in trait-abased anxiety may be altered. Theoretically, some may assume those with heightened trait anxiety would become overwhelmed by the additional change to state (Eysenck et al., 2007). However, the present work contradicts this, in that high trait anxious participants benefited more-so than low trait anxious participants.

In particular, the present findings align with the work of Ramirez et al., who found high trait anxiety participants outperformed low trait anxious participants only in situations where working memory capacity was consumed. That is, high trait anxiety individuals can outperform low trait anxious individuals at higher levels of difficulty. Ramirez et al. suggest this is due to highly trait anxious individuals employing less effective/efficient rotation strategies when tasks are too easy and promote self-doubt and overly cautious self-checking tendencies. This is akin to what was observed here, in that the high trait anxiety group was less effective and efficiency at lower levels of cognitive load where the task was easier and allowed for the intrusion of task-irrelevant thoughts. However, at more difficult levels where a greater load was placed on the participant (as such, limiting the opportunity to explore alternative strategies), higher trait anxious participants improved their performance. If the intrusion of worrisome or self-doubting thoughts is to be considered the main contributor to poorer performance of anxious individuals, such as proposed by cognitive interference theories (Sarason, 1988; Eysenck & Calvo, 1992; Eysenck et al., 2007), then this is somewhat logical. That is, high trait anxious participants may focus on either task-relevant strategies or task-irrelevant thoughts. Perhaps the observation of the current work is that the additional pressure of cognitive load on high trait anxious participants precluded the conflict of task-irrelevant thoughts thus promoting improved performance, but only under conditions of increased situational stress and cognitive load.

Of note, the patterns of performance effectiveness and processing efficiency outcomes for the high trait anxiety participants (under ego-threat at high cognitive load) are almost identical. That is, both outcomes demonstrate poorer scores at lower cognitive loads before a peak of performance at the 90° rotation trials. The key computational difference between these outcome variables is the addition of RT when calculating the processing efficiency ratio[24]. As such, this suggests that while the high trait anxiety group were able to correctly identify a greater number of trials than their low trait anxiety counterparts, they were also able to maintain RTs similar to or faster than the low trait anxiety group. This observation is against the predictions of attentional control theory, which expect higher trait anxious participants exhibit longer RTs as a trade-off for maintaining greater accuracy.

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[24] *Mental rotation efficiency* = $\left(\frac{\text{Standardised scaled accuracy}}{\text{Standardised scaled total RT}}\right)$

Together, the data provides partial support for theory and prior literature. The predictions are complementary to attentional control theory, in that when extended to executive functions beyond those explicitly listed by the theory, situational stress, trait anxiety, and cognitive load all exert some effect. This is of special interest to attentional control theory, which had initially suggested trait anxiety and situational stress could not impair tasks reliant on the visuospatial system, given that anxiety supposedly has a limited visual component (that is, it is more likely to manifest impairments in verbal-based tasks). The current work suggests this assumption is incorrect and trait anxiety can alter task performance on non-verbal-based measures. The findings also have implications for future anxiety/cognition research, in that tasks need not be limited to only verbal stimuli. This is particularly relevant as some cognitive tasks are only readily available with visual stimuli (e.g., planning ability and Tower of London tasks).

A limitation of the current work is its use of a trait anxiety measure which assessed only cognitive symptomatology and a cognitively oriented situational stress manipulation. This choice was made as attentional control theory is based on a history of assessing test anxiety, which encapsulates predominantly cognitive symptoms. Future research might evaluate if the trend of results differs when evaluating trait somatic anxiety or when using a somatic-oriented stress manipulation (e.g., threat of shock; cold press).

Study 2: Trait Anxiety, Situational Stress, Cognitive Load, and Forward Planning

Study 2 evaluated the executive function of planning ability. The study measured forward planning ability, the mental rehearsal of a problem to identify the optimal solution sequence prior to any manual task manipulation. The study examined if variations of trait anxiety, situational stress, and cognitive load could disrupt the performance effectiveness and processing efficiency of participants during a common planning task. The methodology of Study 2 is outlined briefly prior to detailing of results.

Participants and Group Allocation

The initial sample consisted of 90 undergraduate university students, aged 18 to 52 years and predominantly female (M_{age} = 23.21, SD_{age} = 7.42; 77 female, 13 male). Forty-six participants were allocated to the ego-safe situational stress condition, with the remaining 44 participants comprising the ego-threat condition. Collapsed across all other groups, there was no significant difference in the number of females or males between groups, $\chi^2(1) = 0.45$, p = .831. There was no significant difference of age between the ego-safe (M = 23.93, SD = 8.00) and ego-threat conditions (M = 23.41, SD = 8.16), $t(88) = 0.31$, p = .758.

High and low trait anxiety groups were created using a median split procedure. The median value of trait cognitive anxiety was 18.00. Participants who scored less than 18.00 were allocated to the low trait anxiety group, while those scoring above the median were allocated to the high trait anxiety group. Participants scoring the exact median value were allocated to the high trait anxiety condition to maintain approximately equal group sizes (DeCoster et al., 2011). The low trait anxiety group (M = 13.67, SD = 2.21) consisted of 43 participants, and the high trait anxiety group (M = 23.31, SD = 5.27) consisted of 47 participants. Collapsed across all other groups, there was no significant difference in the ratio of males to females between conditions, $\chi^2(1) = 0.53$, p = .467. There was also no significant difference of age between the low trait anxiety (M = 23.72, SD = 8.00) and high trait anxiety groups (*M* = 23.64, *SD* = 8.16), $t(88) = 0.05$, $p = .961$. A summary of the demographic information of the sample across each cell of the study design is presented in Table 11.

Table 11

Demographics for Cells of Situational Stress (Ego-Safe vs. Ego-Threat) × Trait Anxiety (High vs. Low) for Forward Planning (Study 2)

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	n = 17	*n* = 29	*n* = 26	*n* = 18
M_{Age} (*SD*)	25.76 (10.80)	22.86 (5.73)	22.38 (5.30)	24.89 (11.10)
Females	15	24	23	15
Males	2	5	3	3

Materials

Questionnaires. Participants completed a series of questionnaires consisting of the STICSA[25] (Ree et al., 2008), DASS-21[26] (Lovibond & Lovibond, 1995), and Stress Rating Questionnaire (Edwards, Edwards, et al., 2015). The trait-cognitive subscale of the STICSA was used to determine high/low trait anxiety groups. The depression subscale of the DASS-21 was used to assess depression as a possible covariate to analyses. The Stress Rating Questionnaire and state-cognitive subscale of the STICSA were included as part of a manipulation check for the study's situational stress induction. Further descriptions of all measures, including scoring procedures and reliability/validity information, are presented in Chapter Three.

[25] State-Trait Inventory of Cognitive and Somatic Anxiety
[26] Depression Anxiety Stress Scale – 21 Items

One-Touch Tower of London. Planning ability of participants was assessed using a computerised, one-touch Tower of London variant. Participants were concurrently presented two digital pegboards, each with three pegs and four differently coloured beads. The two pegboards displayed different patterns of bead arrangement. Participants were asked to mentally plan how many moves it would take to convert the first pegboard's arrangement (start) into the second pegboard's arrangement (goal). Task difficulty varied between 2-move and 7-move problems. Responses were made by selecting the appropriate number on a 7-key response box. Further details of the task and example stimuli are given in Chapter Three.

Experimental Setup

Testing was conducted individually in the School of Psychology Research Laboratories at Bond University. Task stimuli were presented using a 19-inch LCD desktop screen. Accuracy and RT data were recorded using an ADInstruments RB-x40 series response pad.

Procedure

Upon arrival to the testing space, participants were provided with an explanatory statement and consent form. Following this, participants completed the DASS-21, with those who scored in the "extremely severe" range of the depression subscale (i.e., scores ≥ 28) being released from the study ($N = 1$). All other participants continued to complete the STICSA and a baseline Stress Rating Questionnaire. Participants were allocated to either the ego-safe (control condition) or ego-threat condition (situational stress manipulated condition) based on arrival to the testing location[27]. Those assigned to the ego-safe condition were provided task-relevant instructions and given clarification after practice trials. For those assigned to the ego-threat condition, participants were informed they were about to complete

[27] In an alternate allocation order, every second participant was allocated to the ego-threat condition.

a measure of intelligence, and that their performance following practice trials was poorer compared to previous participants. After the manipulation, participants were asked to complete the Stress Rating Questionnaire again (post-manipulation score). All participants then continued to complete the Tower of London planning task. Participants were debriefed at the conclusion of the study.

Situational Stress Manipulation

The situational stress manipulation was evaluated via a 2 (time; baseline vs. post-manipulation) × 2 (group; ego-threat vs. ego safe) mixed-design ANOVA. Composite Stress Rating Questionnaire values were used as the dependent variable. A significant main effect of time was found, $F(1, 88) = 38.01$, $p < .001$, $\eta_p^2 = .30$, *power* => 1.00. The main effect of group was non-significant, $F(1, 88) = 1.05$, $p = .310$, $\eta_p^2 = .01$, *power* = .17. A significant time × group interaction was also observed, $F(1, 88) = 31.35$, $p < .001$, $\eta_p^2 = .26$, *power* => 1.00. Follow-up within-subject contrasts demonstrated the linear trend across time varied as a function of group allocation. Mean Stress Rating Questionnaire values for each group at baseline and post-manipulation are displayed in Figure 19. Examination of the ego-threat condition showed a lack of overlap in the 95% CIs of baseline and post-manipulation values. This trend suggested a significant increase in Stress Rating Questionnaire response points across time for participants undergoing ego-threat instructions. The trend appeared non-significant for the ego-safe condition.

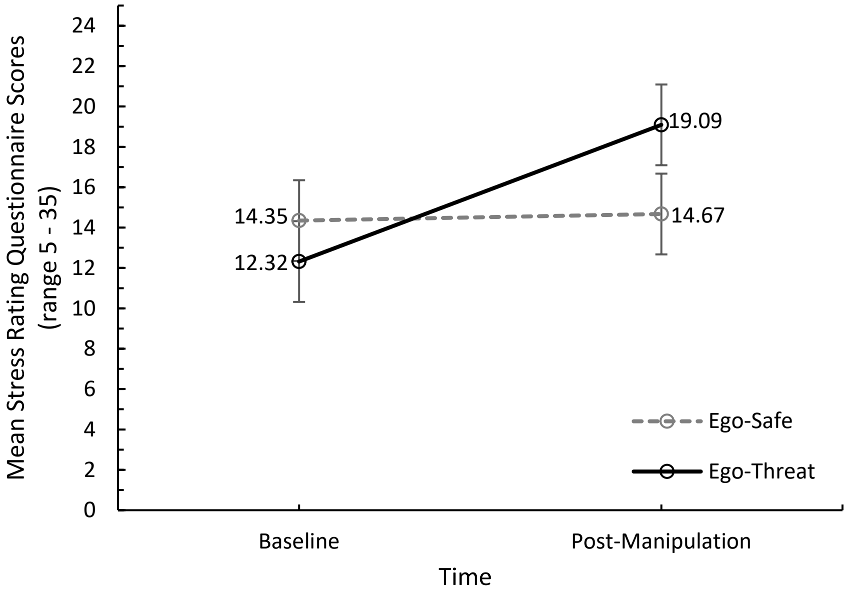

Figure 19. Linear trend of the effect of time at each level of situational stress condition for Stress Rating Questionnaire scores during the forward planning task. Error bars represent 95% confidence intervals.

Results

Measurement of Forward Planning

Forward planning effectiveness. Performance effectiveness of forward planning ability was operationalised as the total number of correct trials, indexed individually at all task difficulty levels (2-move through to 7-move trials). Values were transformed into standardised *z*-scores and then translated to a positive range using an increase of +3.00 units. This additional transformation was used to aid interpretability.

Forward planning efficiency. To derive forward planning efficiency scores, the average RTs across correct trials at each level of task difficulty were standardised and scaled in the same manner as effectiveness scores. The final processing efficiency ratio divided the scaled accuracy values by scaled RT.

$$\textit{Forward planning efficiency} = \left(\frac{\text{Standardised scaled accuracy}}{\text{Standardised scaled RT}}\right)$$

Data Diagnostics

Data were cleaned at the level of individual trials. Anticipatory RTs < 200ms and RTs ± 3.00 *SD*s from each participant's mean were removed prior to analyses (approx. 2% of trials). Univariate outliers were identified using *z*-scores, with values ±3.00 considered to be extreme. Three cases were identified as being below the -3.00 threshold; one case from the 2-move level, one case from the 4-move level, and one case from the 5-move level. Review of the data found the responses to be within range and were not excluded from analyses. Calculation of Mahalanobis' Distance found no multivariate outliers.

The assumption of normality was assessed using a Shapiro-Wilk test within all cells of the design. Within the low trait anxiety and ego-safe cell, violations to the assumption of normality were observed for performance effectiveness at 2-move, 3-move, 4-move, 5-move, and 7-move difficulty levels. For processing efficiency, there was an assumption violation at the 2-move level. Within the low trait anxiety and ego-threat cell, assumption violations were found for 2-move, 3-move, 4-move, 5-move, and 7-move levels. For processing efficiency, the normality assumption was met at all levels. For the high trait anxiety and ego-safe cell, normality was found to be violated demonstrated across all levels. However, for processing efficiency values no violations to normality were observed. For the high trait anxiety and ego-threat cells, normality was violated at 2-move and 4-move levels. Processing efficiency values demonstrated a violation of the normality assumption at the level of 2-move difficulty. Given that the Shapiro-Wilk test is an overly sensitive measure and that ANOVA is robust to violations of normality, no transformation was applied to the data and results were interpreted with caution (Tabachnick & Fidell, 2019).

Missing data analyses were conducted across the entirety of the dataset, collapsed across situational stress and trait anxiety groups. Analyses identified a cumulative 15.5% missing data across all levels of accuracy, two cases from 5-move, three cases from 6-move, and nine cases from 7-move levels. This pattern of missing data was identical across RT data. The missing cases represent participants who incorrectly responded across all trials of the identified difficulty levels. Therefore, no information was recorded by the program. The large number of missing cases (particularly the final 7-move level) may reflect the greater difficulty embedded within these levels of the task. The missing cases were excluded pairwise where applicable in the main analyses. Analyses were conducted using SPSS version 25. A significance level of $\alpha \leq .050$ was set for all analyses.

Main Analysis, Standardised Forward Planning Effectiveness

A three-way mixed-design 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 6 (cognitive load; 2-move vs. 3-move vs. 4-move vs. 5-move vs. 6-move vs. 7-move) ANCOVA was conducted on forward planning effectiveness. Mauchly's test of sphericity was found to be met for the within-subjects variable cognitive load, $\chi^2(14) = 15.28$, $p = .359$. Results were interpreted using original uncorrected degrees of freedom. The depression covariate was found to be non-significant at all levels of the analysis and was not interpreted further. Descriptive statistics are displayed in Table 12. The mean values demonstrate little variety of performance effectiveness across cells, while the small standard deviations demonstrate the variance of scores is slight and comparable across the design.

Results demonstrated the main effect of cognitive load was non-significant, $F(5, 365) = 0.34$, $p = .888$, $\eta_p^2 = .01$, *power* = .14. Similarly, the main effect of trait anxiety was also found to be non-significant, $F(1, 73) = 2.67$, $p = .107$, $\eta_p^2 = .04$, *power* = .36. In contrast, the main effect of situational stress was significant, $F(1, 73) = 23.48$, $p < .001$, $\eta_p^2 = .24$, *power* => 1.00. Averaged across all other variables, participants in the ego-safe condition ($M = 3.32$, $SE = 0.08$) demonstrated greater performance effectiveness compared to participants allocated to the ego-threat condition ($M = 2.72$, $SE = 0.09$). This result accounted for approximately 24% of the variance in performance effectiveness.

Table 12

Means and Standard Deviations of Standardised Performance Effectiveness Values on Forward Planning Task Across All Cognitive Load Levels, Trait Anxiety Groups, and Situational Stress Conditions

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	M **(*SD*)**	***M*** **(*SD*)**	***M*** **(*SD*)**	***M*** **(*SD*)**
2-move	3.26 (1.14)	3.17 (0.95)	2.82 (0.95)	2.93 (0.83)
3-move	3.37 (0.91)	3.42 (0.85)	2.83 (0.96)	2.79 (0.71)
4-move	3.04 (1.08)	3.44 (0.85)	2.65 (0.75)	3.02 (1.01)
5-move	3.19 (0.89)	3.57 (0.80)	2.37 (0.71)	2.72 (1.24)
6-move	3.40 (0.91)	3.31 (0.85)	2.37 (0.90)	3.08 (1.01)
7-move	3.15 (0.96)	3.56 (0.86)	2.37 (0.93)	2.63 (0.89)

The two-way interaction between trait anxiety and cognitive load was non-significant, $F(5, 365) = 1.12$, $p = .349$, $\eta^2_p = .02$, *power* = .40. The two-way interaction between situational stress and cognitive load was also non-significant, $F(5, 365) = 1.30$, $p = .266$, $\eta^2_p = .02$, *power* = .46. Similarly, the two-way interaction between trait anxiety and situational stress was found to be non-significant, $F(1, 73) = 0.22$, $p = .642$, $\eta^2_p < .01$, *power* = .08. Finally, the three-way interaction of trait anxiety × situational stress × cognitive load also was non-significant, $F(5, 365) = 0.89$, $p = .486$, $\eta^2_p = .01$, *power* = .32.

Main Analysis, Standardised Forward Planning Efficiency

A three-way mixed-design 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 6 (cognitive load; 2-move vs. 3-move vs. 4-move vs. 5-move vs. 6-move vs. 7-move) ANCOVA was conducted on forward planning efficiency scores.

Mauchly's test of sphericity was found to be violated for the within-subjects variable of cognitive load, $\chi^2(14) = 26.28$, $p = .024$. To address this, corrected degrees of freedom were calculated using a Greenhouse-Geisser estimation ($\varepsilon = .86$; corrected $df_{treat} = 4$, corrected $df_{error} = 314$). The depression covariate was found to be non-significant at all levels of the analysis and was not interpreted further. Descriptive statistics are displayed in Table 13. The mean values across cells showed some variability in processing efficiency scores. The small standard deviations demonstrated the score variance surrounding the mean was small and comparable across cells of the study.

Table 13

Means and Standard Deviations of Standardised Processing Efficiency Values on Forward Planning Task Across All Cognitive Load Levels, Trait Anxiety Groups, and Situational Stress Conditions

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
2-move	0.95 (0.39)	1.21 (0.61)	1.25 (0.45)	1.12 (0.60)
3-move	1.09 (0.45)	1.26 (0.53)	1.24 (0.52)	1.00 (0.37)
4-move	1.00 (0.41)	1.16 (0.47)	1.13 (0.32)	1.06 (0.29)
5-move	1.07 (0.40)	1.31 (0.53)	1.06 (0.35)	0.98 (0.50)
6-move	1.08 (0.27)	1.15 (0.45)	1.25 (0.60)	1.04 (0.37)
7-move	1.07 (0.36)	1.21 (0.38)	1.17 (0.47)	1.02 (0.38)

The overall main effect of cognitive load was found to be non-significant, $F(4, 314) = 0.31$, $p = .882$, $\eta^2_p < .01$, *power* = .12. Despite the large range of difficulty levels, changes to inherent cognitive load requirements accounted for less than 1% of variance in processing efficiency scores. The main effect of trait anxiety was also non-significant, $F(1, 73) = 0.01$, *p*

= .945, $\eta_p^2 < .01$, *power* = .05. Similarly, the main effect of situational stress was also non-significant, $F(1, 73) = 0.07$, $p = .791$, $\eta_p^2 = .07$, *power* = .06.

The two-way interaction between trait anxiety and cognitive load was non-significant, $F(4, 314) = 0.50$, $p = .780$, $\eta_p^2 = .01$, *power* = .17. The two-way interaction between situational stress and cognitive load was also non-significant, $F(4, 314) = 1.46$, $p = .212$, $\eta_p^2 = .02$, *power* = .47. The three-way interaction between all study variable was non-significant, $F(4, 314) = 0.18$, $p = .956$, $\eta_p^2 < .01$, *power* = .09. In contrast, the two-way interaction of trait anxiety and situational stress was significant, $F(1, 73) = 4.24$, $p = .043$, $\eta_p^2 = .05$, *power* = .53. Though statistically significant, the interaction only accounted for approximately 5% of the total variance of processing efficiency scores. Follow-up analyses were conducted for the simple effect of trait anxiety at each level of situational stress. Results found within the ego-safe condition, the simple effect of trait anxiety was non-significant, $F(1, 43) = 0.31$, $p = .582$, $\eta_p^2 = .01$, *power* = .08. Likewise, the simple effect of trait anxiety was also non-significant at the level of the ego-threat condition, $F(1, 43) = 1.65$, $p = .206$, $\eta_p^2 = .04$, *power* = .24. Regardless of the non-significant simple effects, the two-way interaction still indicates the influence of trait anxiety on processing efficiency varied as a function of participants' allocation to either situational stress condition. Inspection of the interaction, displayed in Figure 20 (overleaf), suggests that while the high trait anxiety group demonstrated greater processing efficiency compared to the low trait anxiety group within the ego-safe condition (i.e., in the absence of extraneous situational stress), this trend was reversed for participants in the ego-threat condition.

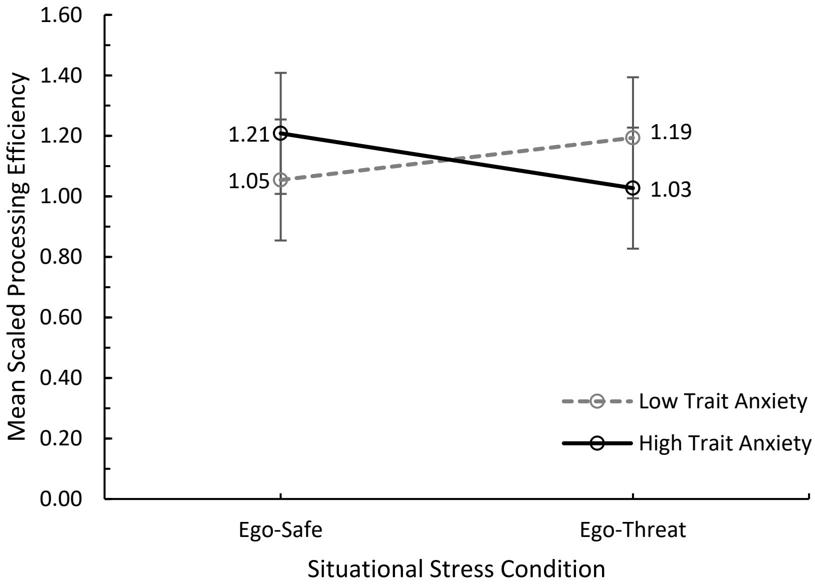

Figure 20. Two-way interaction of trait anxiety × situational stress for forward planning processing efficiency.

Discussion: Trait Anxiety, Situational Stress, Cognitive Load, and Forward Planning

Study 2 investigated the interactive impact of trait anxiety, situational stress, and cognitive load on performance during a planning task. Specifically, Study 2 measured the performance effectiveness (standardised accuracy) and processing efficiency (ratio of standardised accuracy to RT) on a computerised, one-touch Tower of London task. Choice of a one-touch task variant was made to minimise confounding effects of motor control variations amongst participants. The study also statistically controlled for the influence of depression, which has previously been found to correlate with both trait anxiety and executive functioning (Clark & Watson, 1991; Kizilbash et al., 2002). Hypotheses were derived from attentional control theory. It was predicted that a three-way trait anxiety × situational stress × cognitive load interaction would be observed. Specifically, participants allocated to the high trait anxiety conditions were expected to demonstrate better performance effectiveness scores compared to the low trait anxiety group when observed under ego-threat conditions and at low cognitive levels. Under the same conditions, the high trait anxiety group was also expected to demonstrate poorer processing efficacy scores compared to the low trait anxiety group.

The performance effectiveness hypothesis was not met. No significant results were observed for standardised accuracy on the Tower of London task. The results suggested neither trait anxiety, situational stress, nor cognitive load affected standardised accuracy on a planning task such as the one adopted here. These findings are in line with the prior work that had found planning accuracy to be unaffected by changes to emotional states (Robinson, Vytal, et al., 2013; Van Tol et al., 2011). In extending the work of Van Tol et al. who observed this null effect within a clinical sample (i.e., those formally diagnosed with an anxiety disorder), the current work found this trend in a sub-clinical sample. The findings, however, contrast with Unterrainer et al. (2018) who found higher levels of subclinical anxiety were predictive of poorer accuracy in solving a Tower of London task. However, Unterrainer et al. examined participants manually solving Tower of London trials. As such, their measure of accuracy was indexed as the number of moves beyond the minimum to solve. Arguably this is more indicative of an efficiency measure, as the variable implies all participants were able to solve the puzzle eventually, some more quickly than others. Further, Unterrainer et al. observed a sample aged 40 to 80 years old. Give the current study examined a younger sample (M_{age} = 23.21, *SD* = 8.16), it is possible young/middle adults and older adults display distinct differences in how trait anxiety influences planning ability.

Regarding processing efficiency, the results of the current study suggest the influence of trait anxiety on planning performance is dependent on changes in situational stressors. A two-way interaction between trait anxiety and situational stress was observed. Despite the simple effects of the interaction being non-significant, the trend of the interaction suggested processing efficiency of high trait anxiety participants was impaired in the ego-threat condition compared to the ego-safe condition. This finding was reversed for low trait anxiety participants. No prior work has reported processing efficiency of planning ability to be affected by changes in emotionality, either trait-based or state-induced (Robinson, Vytal, et al., 2013, Unterrainer et al., 2018; Van Tol et al., 2011). Unlike the current work which implemented a processing efficiency ratio of performance effectiveness and RT[28], earlier works recorded only simple RTs (or included no measure of RT at all). The discrepancy of findings for processing efficiency may therefore be due to these operationalisation differences. The current approach to use an accuracy/RT ratio over to simple RT as an estimate of processing efficiency is more informative and less likely to evoke contradictory findings between accuracy and RT data (Vandierendonck, 2017). Further, more specific to the current work, the ratio better aligns with the theoretical underpinnings of the current work's selected foundation in attentional control theory.

Overall, the performance effectiveness and processing efficiency findings, while contentious in their comparison to prior literature, nonetheless align with the theoretical predictions of attentional control theory. The theory suggests that when placed under additional situational stress, highly trait anxious individuals use compensatory strategies (i.e., recruitment of additional resources, slowing RT) to maintain the accuracy of their performance (Derakshan & Eysenck, 2009; Eysenck et al., 2007). As such, the theory would support no differences between trait anxiety groups for performance effectiveness when combined with variations in processing efficiency. As observed in the current work, higher trait anxious participants undergoing ego-threat demonstrated worse processing efficiency than their low trait anxious peers, though there was no such difference observed for performance effectiveness. The trend of results may suggest high trait anxious individuals

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[28] *Forward planning efficiency* = $\left(\frac{\text{Standardised scaled accuracy}}{\text{Standardised scaled RT}}\right)$

under stress used less efficiency strategies to maintain their performance at a level comparable to their lower anxious peers.

Attentional control theory notes the discrepancy in performance effectiveness can become noticeable at high levels of cognitive load (Eysenck et al., 2007). While the influence of cognitive load was not found in the current study, this may be due to the complexity of the planning executive function under investigation. Previous work cited as supporting attentional control theory's predictions of task difficulty (see Eysenck et al., 2007 for review) have often used simpler tasks. Such works typically focused only on tasks of inhibition, shifting, and updating; all of which are specifically noted to be assessed with tasks less complex than the Tower of London (Miyake et al., 2000). In these simpler measures, task difficulty may exert a greater influence on performance not seen in tasks like the Tower of London that are more cognitively demanding even at their lower loads. While cognitive load was not found to interact with the trait anxiety/situational stress interaction, an alternate variable may contribute to moderating this finding. Cognitive load is cited as a moderator of trait anxiety/situational stressors effects as it places additional demand on the underlying cognitive system responsible for the coordination of executive functioning (Derakshan & Eysenck, 2009; Redifer et al., 2019; Shackman et al., 2006). Specifically, cognitive load places demand on the central executive, which acts as the coordination subsystem of working memory (Baddeley, 2001; Baddeley & Hitch, 1974; Eysenck et al., 2007). However, perhaps for more robust executive functions like planning ability, rather than task difficulty further altering performance, the difference might be observed amongst individual differences in the cognitive resources available for recruitment. That is, it is not the demand for resources, but the amount of resources available to be accessed. To pursue this line of inquiry, the second phase of research extended the work of Study 2 with the inclusion of a working memory capacity variable.

Study 3: Trait Anxiety, Situational Stress, Cognitive Load, and Cold Decision-Making

Study 3 focused on the executive function of decision-making. Emphasis was placed on the cold variation of the function. That is, decision-making devoid of heuristic shortcuts or emotional stimuli. Study 3 examined how variations of trait anxiety, situational stress, and cognitive load might disrupt the performance effectiveness and processing efficiency of decision-making.

Participants and Group Allocation

Participants consisted of 91 undergraduate university students, ranging in age from 18 to 53 years (M_{age} = 23.64, *SD* = 8.01) and were predominantly female (female *n* = 77, male *n* = 14). Forty-five participants were allocated to the ego-safe condition, and 46 allocated to the ego-threat condition. There was no significant difference in age of participants between the two conditions, $t(89) = -0.41$, $p = .684$. When collapsed across all other variables, analyses also demonstrated no significant difference in the number of males or females between conditions, $\chi^2(1) < 0.01$, $p = .964$.

High and low trait anxiety groups were determined with a median split (median of sample = 18.00). Participants who scored below the median on the trait anxiety self-report measure were allocated to the low trait anxiety condition. Those who scored higher than the median were allocated to the high trait anxiety condition. Participants who scored exactly the median were also allocated to the high trait anxiety condition to maintain approximately equal group sizes (DeCoster et al., 2011). The low trait anxiety group (*M* = 13.61, *SD* = 2.22) consisted of 44 participants, while the high trait anxiety group (*M* = 23.32, *SD* = 5.27) included 47 participants. Collapsed across all other variables, there was no significant difference of age between the two groups, $t(89) = 0.81$, $p = .420$. Analyses also found that difference in the number of males or females between groups was non-significant, $\chi^2(1)$ =

0.02, p = .893. Demographic information of the sample across each cell of the study design is summarised in Table 14.

Table 14

Demographics for Cells of Situational Stress (Ego-Safe vs. Ego-Threat) × Trait Anxiety (High vs. Low) for Cold Decision-Making (Study 3)

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	n = 16	n = 29	n = 28	n = 18
M_{Age} **(*SD*)**	24.13 (8.69)	22.83 (5.76)	24.46 (9.91)	23.22 (7.69)
Females	14	24	23	16
Males	2	5	5	2

Materials

Questionnaires. A questionnaire package consisting of the STICSA[29] (Ree et al., 2008), DASS-21[30] (Lovibond & Lovibond, 1995), and Stress Rating Questionnaire (Edwards, Edwards, et al., 2015) was administered to participants. Further details regarding the measures, inclusive of the scoring procedure and psychometric information, are presented in Chapter Three. The trait-cognitive subscale of the STICSA scale was used to assess the trait anxiety of participants and determine the allocation to high/low trait anxiety groups. The state-cognitive subscale was used to aid in a manipulation check of the study's situational stress induction. The Stress Rating Questionnaire was also used to facilitate this manipulation check. Only the depression subscale of the DASS-21 was used in order to include depression as a possible covariate in analyses.

[29] State-Trait Inventory of Cognitive and Somatic Anxiety
[30] Depression Anxiety Stress Scale – 21 Items

Cold Decision-Making Task. To measure the effectiveness and efficiency of cold decision-making, a novel task was developed for use in the current study. The task was based on the protocol of the pencil-and-paper Applying Decision Rules subtest of the A-DMC[31] battery (Bruine de Bruin et al., 2007). The current task was computerised, to allow for more effective assessment of accuracy and RT responses. During the task, participants were presented with a hypothetical sales scenario that required them to compare five products. Comparison was made on five dimensions (picture, sound, programming, reliability, and price). Participants were required to apply rulesets – specifying the exact combination of dimensions – to infer the correct purchase decision. Responses were made by selecting from a 5-key response pad. Refer to Chapter Three for further details of task presentation and example task layout.

Experimental Setup

Task stimuli were presented using a 19-inch LCD desktop screen. Accuracy and RT data were recorded using an ADInstruments RB-x40 series response pad. Testing was conducted individually in the School of Psychology Research Laboratories at Bond University.

Procedure

On arrival, participants were provided with an explanatory statement and consent form. Following this, participants completed the DASS-21. Participants who scored in the “extremely severe” range of the depression subscale (i.e., scores ≥ 28) were released from the study ($N = 1$). Participants were asked to complete the STICSA and Stress Rating Questionnaire (baseline measurement). Based on arrival to the testing location[32], participants were assigned to either the ego-safe (control condition) or ego-threat condition (situational

[31] Adult Decision-Making Competence battery
[32] In an alternate allocation order, every second participant was allocated to the ego-threat condition.

stress manipulated condition). For the ego-safe condition, participants were given task-relevant instructions only. For the ego-threat condition, participants were informed they were completing a measure of intelligence. Further, they were informed their performance was poor in comparison to previous participants. Following this manipulation, participants completed the Stress Rating Questionnaire once more (post-manipulation score). All participants completed the full decision-making task. At the conclusion of the study, participants were thanked and debriefed.

Situational Stress Manipulation

The situational stress manipulation using ego-threat instructions was assessed using a 2 (time; baseline vs. post-manipulation) × 2 (group; ego-threat vs. ego safe) mixed-design ANOVA. Composite scores on the Stress Rating Questionnaire were used as the dependent variable. Results demonstrated a significant main effect of time, $F(1, 89) = 70.96$, $p < .001$, $\eta_p^2 = .45$, *power* => 1.00. The main effect of situational stress condition was non-significant, $F(1, 89) = 0.41$, $p = .523$, $\eta_p^2 < .01$, *power* = .10. The two-way interaction between time and group condition was significant, $F(1, 89) = 34.26$, $p < .001$, $\eta_p^2 = .28$, *power* => 1.00. Within-subject contrasts found the linear trend of Stress Rating Questionnaire scores across time varied significant between conditions. As displayed in Figure 21, participants allocated to the ego-threat condition demonstrated an increase in average Stress Rating Questionnaire values from baseline to post-manipulation. Evaluation of the ego-threat condition demonstrated no overlap in the 95% CIs of post-manipulation and baseline values, suggesting a significant change. The ego-safe condition also demonstrated an increase in Stress Rating Questionnaire values across time, but this change was less pronounced and displayed overlap between the 95% CIs of baseline and post-manipulation time points.

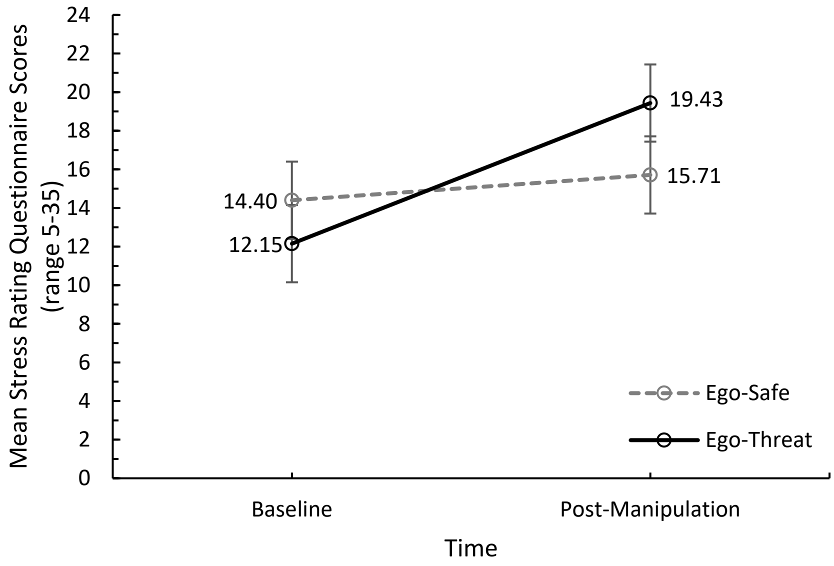

Figure 21. Linear trend of the effect of time at each level of situational stress condition for Stress Rating Questionnaire scores during the decision-making task. Error bars represent 95% confidence intervals.

Results

Measurement of Decision-Making

Decision-making effectiveness. Performance effectiveness for decision-making was indexed as the total number of correct trials, assessed at all task difficulty levels (single rule through to five rule trials). Values were standardised to create *z*-scores and subsequently scaled into a positive range using an increase of +3.00 units. The additional scaling transformation was used to improve interpretability.

Decision-making efficiency. Decision-making efficiency values were calculated using a ratio of decision-making effectiveness and average RTs across correct trials at each level of difficulty. RT data were standardised and scaled in the same manner as decision-making effectiveness before being imputed into the final calculation.

$$\textit{Decision-making efficiency} = \left(\frac{\text{Standardised scaled accuracy}}{\text{Standardised scaled RT}}\right)$$

Data Diagnostics

At the level of individual trials, the dataset was screened for anticipatory RTs of < 200ms as well as RTs ± 3.00 *SD*s. Such trials were removed before entry into the main analysis (approx. 1% of trials). Amongst the collated data, univariate outliers were identified as *z*-scores of ± 3.00. Two cases were identified as being below the -3.00 threshold, both within the cognitive load level of four rulesets. Examination of the values found the responses to be within range and were not removed from the analyses. No multivariate outliers were identified.

The assumption of normality was assessed using the Shapiro-Wilk statistic. Data were evaluated within all cells of the design. Values exceeding a $p = .050$ threshold were indicative of violations to the normality assumption. Within the ego-safe and low trait anxiety cells, the assumption of normality was not met for performance effectiveness data at all levels of cognitive load. For processing efficiency data, the assumption of normality was not met for the cognitive load level for four rulesets. Within the ego-threat and low trait anxiety cells, normality was violated once more for performance effectiveness at all cognitive load levels. For processing efficiency values, the normality assumption was violated at the cognitive load levels of one ruleset and two rulesets. Within the ego-safe and high trait anxiety cells, for the performance effectiveness data the assumption of normality was violated at all cognitive load levels. Amongst processing efficiency data, normality was violated at the cognitive load level of one ruleset and two rulesets. Within the ego-threat and high trait anxiety cells, the performance effectiveness data demonstrated normality was violated at all levels of cognitive load. For processing efficiency data, the assumption of normality was met at all cognitive load levels. As ANOVA is robust to violations of normality, no corrections were applied to the data (Tabachnick & Fidell, 2019).

Missing data analyses were conducted for the full dataset, collapsed over trait anxiety and situational stress groups. Analyses found no missing values for either accuracy or RT data. All analyses were carried out using SPSS version 24. A significance level of $\alpha \leq .050$ was used for all analyses.

Main Analysis, Standardised Cold Decision-Making Effectiveness

A three-way 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 5 (cognitive load; one rule vs. two rules vs. three rules vs. four rules vs. five rules) ANCOVA was conducted with decision-making effectiveness as the dependent variable. Mauchly's test of sphericity was found to be met for the within-subjects variable of cognitive load, $\chi^2(9) = 13.32$, $p = .149$. Results were thus interpreted using uncorrected degrees of freedom. The depression covariate was found to be non-significant at all levels of the analysis. Descriptive statistics are displayed in Table 15 (overleaf). The mean values demonstrated little variety of performance effectiveness across cells, while the small standard deviations demonstrated the variance of scores was slight and comparable across the design. The standard deviations did not appear to indicate the presence of floor or ceiling effects.

Table 15

Means and Standard Deviations of Standardised Performance Effectiveness Values on Cold Decision-Making Task Across All Cognitive Load Levels, Trait Anxiety Groups, and Situational Stress Conditions

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	M **(*SD*)**	***M*** **(*SD*)**	***M*** **(*SD*)**	***M*** **(*SD*)**
One rule	3.25 (0.69)	3.23 (0.71)	2.74 (1.22)	2.81 (1.18)
Two rules	3.04 (0.92)	3.20 (0.79)	2.57 (1.30)	3.31 (0.58)
Three rules	3.19 (0.83)	3.49 (0.71)	2.31 (1.00)	3.11 (1.02)
Four rules	3.21 (0.75)	3.38 (0.75)	2.29 (1.12)	3.30 (0.80)
Five rules	3.23 (0.74)	3.41 (0.68)	2.52 (1.20)	2.88 (1.01)

The analyses found the main effect of cognitive load was non-significant, $F(4, 344) = 0.74$, $p = .567$, $\eta_p^2 = .01$, *power* = .24. The differing number of rulesets required across trials had no discernible influence on the performance effectiveness of participants. In contrast, the main effect of trait anxiety was significant, $F(1, 86) = 8.45$, $p = .005$, $\eta_p^2 = .09$, *power* = .82. Averaged across all other variables, participants allocated to the high trait anxiety group (*M* 3.23, *SE* = 0.10) demonstrated improved performance effectiveness compared to the low trait anxiety group (*M* = 2.82, *SE* = 0.09). Despite the statistical significance, this influence accounted for only 9% of the total variance in performance effectiveness scores, leaving the remaining 91% unaccounted. The main effect of situational stress was also found to be significant, $F(1, 86) = 15.58$, $p < .001$, $\eta_p^2 = .15$, *power* = .97. When averaged across all other study variable, participants allocated to the ego-safe condition (*M* = 3.27, *SE* = 0.09) demonstrated greater performance effectiveness over participants allocated to the ego-threat condition (*M* = 2.78, *SE* = 0.09). The main effect contributed to 15% of the variance in performance effectiveness scores.

The two-way interaction between trait anxiety and situational stress was non-significant, $F(1, 86) = 3.17$, $p = .073$, $\eta_p^2 = .04$, *power* = .43. The two-way interaction between trait anxiety and cognitive load was also not significant, $F(4, 344) = 1.64$, $p = .163$, $\eta_p^2 = .02$, *power* = .51. The interaction between situational tress and cognitive load was similarly non-significant, $F(4, 344) = 1.01$, $p = .402$, $\eta_p^2 = .01$, *power* = .32. The three-way interaction between all variable was ultimately non-significant, $F(4, 344) = 0.71$, $p = .588$, $\eta_p^2 = .01$, *power* = .23.

Main Analysis, Standardised Cold Decision-Making Efficiency

A mixed-design 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 6 (cognitive load; 2-move vs. 3-move vs. 4-move vs. 5-move vs. 6-move vs. 7-move) three-way ANCOVA was run, with the dependent variable being decision-making efficiency scores. The depression covariate was non-significant at all levels of the analysis and was not interpreted further. The assumption of sphericity using Mauchly's test was violated for the within-subjects variable cognitive load, $\chi^2(9) = 23.89$, $p = .004$. As such, conservative degrees of freedom calculated from a Greenhouse-Geisser correction were used to interpret results ($\varepsilon = .89$; corrected $df_{\text{treat}} = 3$, corrected $df_{\text{error}} = 306$). Descriptive statistics are displayed in Table 16. The mean values across cells showed some variability in processing efficiency scores. The small standard deviations demonstrated score variance was small and comparable across the cells of the study.

Table 16

Means and Standard Deviations of Standardised Processing Efficiency Values on Cold Decision-Making Across All Cognitive Load Levels, Trait Anxiety Groups, and Situational Stress Conditions

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	M **(*SD*)**	***M*** **(*SD*)**	***M*** **(*SD*)**	***M*** **(*SD*)**
One rule	1.07 (0.33)	1.08 (0.32)	1.16 (0.68)	1.10 (0.58)
Two rules	1.00 (0.35)	1.14 (0.30)	0.90 (0.50)	1.17 (0.27)
Three rules	0.96 (0.31)	1.15 (0.32)	1.01 (0.52)	1.14 (0.49)
Four rules	1.01 (0.38)	1.09 (0.28)	0.97 (0.61)	1.18 (0.40)
Five rules	1.01 (0.28)	1.06 (0.28)	1.09 (0.52)	0.98 (0.40)

The main effect of trait anxiety was found to be non-significant, $F(1, 86) = 3.07$, $p = .084$, $\eta_p^2 = .03$, *power* = .041. The main effect of situational stress was also non-significant, $F(1, 86) = 0.02$, $p = .883$, $\eta_p^2 < .01$, *power* = .05. The overall main effect of cognitive load was found to be non-significant, $F(4, 314) = 0.31$, $p = .882$, $\eta_p^2 < .01$, *power* = .12. The two-way trait anxiety × situational stress interaction was not significant, $F(1, 86) < 0.01$, $p = 952$, $\eta_p^2 < .01$, *power* = .05. The interaction between trait anxiety and cognitive load was also not significant, $F(3, 305) = 1.54$, $p = .188$, $\eta_p^2 = .02$, *power* = .45. The two-way situational stress × cognitive load interaction was also non-significant, $F(3, 305) = 0.20$, $p = .921$, $\eta_p^2 < .01$, *power* = .09. The three-way interaction between trait anxiety, situational stress, and cognitive load was found to be non-significant, $F(3, 305) = 0.82$, $p = .500$, $\eta_p^2 = .01$, *power* = .25.

Discussion: Trait Anxiety, Situational Stress, Cognitive Load, and Cold Decision-Making

Study 3 examined the influence of trait anxiety, situational stress, and cognitive load on the performance of a novel cold decision-making task. Specifically, outcome measures of performance effectiveness (standardised accuracy) and processing efficiency (standardised accuracy and standardised RT ratio) were evaluated. It was initially hypothesised that a three-way trait anxiety × situational stress × cognitive load interaction would be observed for both performance effectiveness and processing efficiency. Specifically, it was expected that high trait anxiety participants would outperform low trait anxiety participants on performance effectiveness, at the level of ego-threat, during low cognitive load trials. The hypothesis was not met, as only independent main effects of trait anxiety and situational stress were observed. For processing efficiency, it was expected high trait anxiety participants would demonstrate poorer scores compared to low trait anxiety participants, specifically when under conditions of ego-threat and lower cognitive load. However, this hypothesis was also found to be unsupported as no significant results were observed for the processing efficiency variable. Comparison to prior literature is hampered by the limited literature available.

As noted, significant main effects of trait anxiety and situational stress were observed for performance effectiveness of cold decision-making. For trait anxiety, it was found that across all other conditions the high trait anxiety group performed with greater accuracy compared to the low trait anxiety group. For situational stress, results found participants allocated to the ego-safe condition performed more accurately than those in the ego-threat condition. The trend of results may suggest transient, situation-based stress is likely to cause disturbance to the accuracy of cold decision-making processes, more so than individual differences. For participants allocated to the ego-threat condition, the emotional and cognitive interference of the ego-threat instructions might have contributed to distraction, encouraging mistakes in understanding the criteria to be applied or during the comparison of options (e.g., missing relevant item information). That is, the attention of participants might have been focused inward to address the intrusion of self-appraising thoughts rather than external task demands (Moran, 2016; South et al., 2003). By contrast, for the ego-safe condition attention could be focused solely on the task.

Regarding the role of individual differences, it was observed the high trait anxiety group demonstrated greater accuracy than the low trait anxiety group. One suggestion is that high trait anxious individuals exhibit more conservative decision-making processes, potentially manifesting as improved attention to detail when evaluating rulesets or comparing options. That is, high trait anxious participants were potentially less likely to overlook information, which contributed to improved identification of the correct answer. This suggestion is based on literature pertaining to hot decision-making, which has consistently found high trait anxiety to be associated with risk-avoidant strategies (Giorgetta et al., 2012; Heilman, et al., 2010; Maner & Schmidt, 2006; Mueller, et al., 2010; Raghunathan & Pham, 1999; Shields, et al., 2016). Whilst this comparison crosses between hot and cold decision-making variants, at present there is little information available regarding how trait anxiety impairs the accuracy of decisions.

Cognitive load was found to have no influence on either performance effectiveness or processing efficiency. Cognitive load may not vary performance for a more complex executive function like decision-making (akin to what was proposed in the discussion of Study 2). Instead, variations in working memory individual differences might better explain performance (following the line of reasoning proposed in Study 2). Alternatively, the null results may be due to error, in that the difficulty levels embedded in the utilised novel task were not distinct enough. Though all care was taken to construct a task akin to a sound measure of cold decision-making (the A-DMC, Bruine de Bruin et al., 2007) the task nonetheless is not independently validated. Future work might therefore consider continuing to use readily available and validated tests of decision-making. As such, research may continue to preferentially focus on hot decision-making over cold decision-making.

Overall, the results of Study 3 suggest that trait anxiety and situational stress influence cold decision-making processes to some extent. The influence of acute (i.e., situational stress) and chronic (i.e., trait anxiety) emotionality shows differential effects on the accuracy, but not efficiency, or logical decision-making. Future research might consider evaluating the replicability of results in other rule-based tasks. Ultimately, the results are incompatible with attentional control theory, which would have expected heightened accuracy of high trait anxious individuals to be accompanied by worsened processing efficiency. In the current study, it appeared high trait anxious individuals had no need to sacrifice additional cognitive resources to outperform those who were low trait anxious. Given the results contrast with attentional control theory, it would be of interest to examine if a similar discrepancy is observed for hot decision-making. Though the addition of emotional stimuli was discouraged for the first phase of research, its inclusion presents an opportunity for extension in the second phase. The predictions of attentional control theory should not change with the shift to hot decision-making, as the theory's authors suggest the framework is applicable even in the presence of threating stimuli (Berggren & Derakshan, 2013; Derakshan & Eysenck, 2009). The second phase of research will complete the examination of decision-making by examining this hot variant.

Study 4: Trait Anxiety, Situational Stress, Cognitive Load, and Sustained Attention

Study 4 examined sustained attention during a continuous performance task. The study evaluated how differences of trait anxiety, situational stress, and cognitive load may disrupt performance effectiveness and processing efficiency outcome measures. A brief summary of Study 4's methodology is provided before detailing of results.

Participants and Group Allocation

Participants consisted of 90 undergraduate university students, with the sample being predominantly female (female $n = 77$, male $n = 13$) and aged 18 to 53 years ($M_{Age} = 23.68$ years, $SD = 8.03$). Forty-six participants were allocated to the ego-threat condition, with the remaining 44 allocated to the ego-safe condition. There was no significant difference of age between the two conditions, $t(88) = 0.31$, $p = .758$. Similarly, when collapsed across all other variables, there was no significant difference in the number of males or females allocated between the ego-threat and ego-safe conditions, $\chi^2(1) = 0.05$, $p = .831$.

To determine high and low trait anxiety groups, a median split procedure was applied to self-reported cognitive trait anxiety. The median value of the measure was 18.00. Participants scoring less than the median were allocated to the low trait anxiety group, whereas those that scored higher than the median were placed in the high trait anxiety group. To maintain approximately equal group sizes, participants who scored the exact median were allocated to the high trait anxiety group (DeCoster et al., 2011). The low trait anxiety group ($M = 13.67$, $SD = 2.21$), therefore, consisted of 43 participants while the high trait anxiety group ($M = 23.32$, $SD = 5.27$) contained 47 participants. There was no significant difference of age between the groups, $t(88) = 0.05$, $p = .961$. Further, when collapsed across all other variables, there was no significant difference between groups in the number of females and males, $\chi^2(1) = 0.53$, $p = .467$. Further demographic information across each cell of the study design (i.e., trait anxiety × situational stress) is presented in Table 17.

Table 17

Demographics for Cells of Situational Stress (Ego-Safe vs. Ego-Threat) × Trait Anxiety (High vs. Low) for Sustained Attention (Study 4)

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	n = 17	n = 29	n = 26	n = 18
M_{Age} (*SD*)	25.76 (10.80)	22.86 (5.73)	22.38 (5.30)	24.89 (11.10)
Females	15	24	23	15
Males	2	5	3	3

Materials

Questionnaires. A series of questionnaires comprised of the STICSA[33] (Ree et al., 2008), DASS-21[34] (Lovibond & Lovibond, 1995), and Stress Rating Questionnaire (Edwards, Edwards, et al., 2015) were administered to participants. Refer to Chapter Three for further details regarding descriptions of the measures, inclusive of scoring procedure and psychometric information. The trait-cognitive subscale of the STICSA scale was used to assess trait anxiety of participants. This information was used to determine high/low trait anxiety groupings. The state-cognitive subscale of the STICSA was used in a manipulation check of the study's situational stress induction. The Stress Rating Questionnaire was also used in this manipulation check. Only the depression subscale of the DASS-21 was entered into analyses, to evaluate depression as a possible covariate.

Rapid Visual Information Processing (RVIP). Sustained attention was evaluated using a computerised RVIP task. Participants were shown a continuous series of numeric stimuli, ranging from 1 to 9. The task required participants to make a button-press response

[33] State-Trait Inventory of Cognitive and Somatic Anxiety
[34] Depression Anxiety Stress Scale – 21 Items

on the provided response-pad each time they identified a target sequence. Target sequences consisted of either three consecutive odd digits (e.g., 3, 7, 1) or three consecutive even digits (e.g., 2, 6, 4). Target sequences were separated by a minimum of five and a maximum of 33 digits (*M* = 9.30 digits; Wesnes et al., 1983). The identification of odd-number sequences was considered more difficult than even-numbered sequences (Heubner et al., 2018). The task required approximately 12 minutes to complete. For further details of the task sequence and example of task presentation, refer to Chapter Three.

Experimental Setup

Testing was conducted individually in the School of Psychology Research Laboratories at Bond University. A 19-inch LCD desktop screen was used to present task stimuli to participants. Accuracy and RT data were recorded using an ADInstruments RB-x40 series response pad.

Procedure

Before commencement of the study, participants were provided with an explanatory statement and consent form. Participants then completed the DASS-21, with those scored in the “extremely severe” range of the depression subscale (i.e., scores ≥ 28) being released from the study ($N = 1$). The remaining participants completed the STICSA and Stress Rating Questionnaire (baseline measurement). Based on arrival to the testing location[35], participants were allocated to either the ego-safe (control condition) or ego-threat condition (situational stress manipulated condition). In the ego-safe condition, participants were given task-relevant instructions only. In the ego-threat condition, participants were informed they were completing a measure of intelligence and that their performance was poor in comparison to other participants. Following the manipulation, participants completed the Stress Rating

[35] In an alternate allocation order, every second participant was allocated to the ego-threat condition.

Questionnaire once more (post-manipulation score). All participants then completed the full sustained attention task. At the end of the study, participants were thanked and debriefed.

Situational Stress Manipulation

The manipulation of situational stress was assessed using a 2 (time; baseline vs. post-manipulation) × 2 (group; ego-threat vs. ego safe) mixed-design ANOVA. Total Stress Rating Questionnaire scores were entered as the dependent variable. A significant main effect of time was observed, $F(1, 88) = 67.80$, $p < .001$, $\eta_p^2 = .44$, *power* => 1.00. In contrast, the main effect of group was non-significant, $F(1, 88) = 0.06$, $p = .814$, $\eta_p^2 < .01$, *power* = .06. The two-way interaction between time and group was found to be significant and is illustrated in Figure 22, $F(1, 88) = 16.95$, $p < .001$, $\eta_p^2 = .17$, *power* = .98. Follow-up trend analyses demonstrated the linear trend across time varied significantly between the ego-safe and ego-threat conditions. Within the ego-threat condition, participants reported greater Stress Rating Questionnaire values following the situational stress manipulation. There was no overlap in 95% CIs, which demonstrated the increase was significant. While this trend was also observed in the ego-safe condition following administration of task instructions, the increase was marginal. An overlap of 95% CIs suggested the change was non-significant.

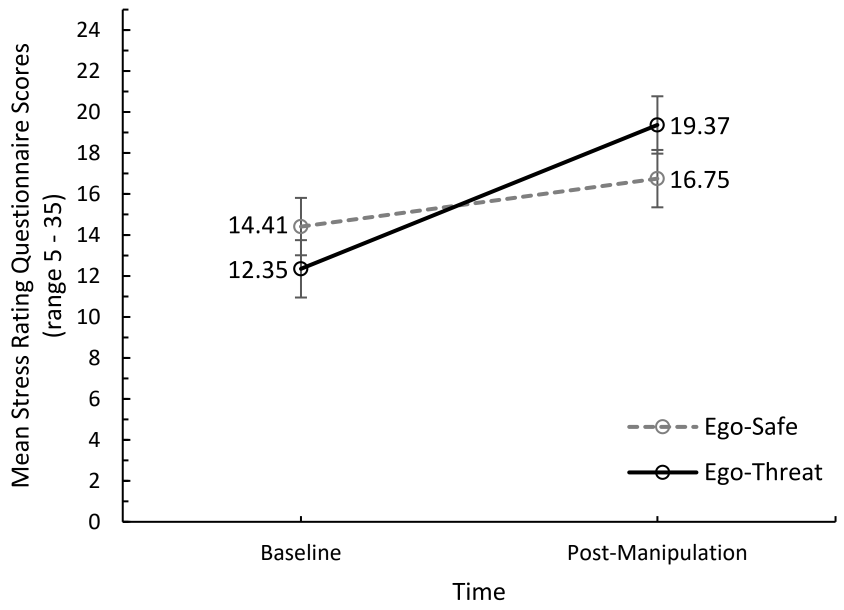

Figure 22. Linear trend of the effect of time at each level of situational stress condition for Stress Rating Questionnaire scores during the sustained attention task. Error bars represent 95% confidence intervals.

Results

Measurement of Sustained Attention

Sustained attention effectiveness. Performance effectiveness of sustained attention was indexed as the proportion of hits (i.e., correct target identification). Values were standardised and scaled into a positive range using an addition of 3.00. This scaling was used to aid the interpretation of results.

Sustained attention efficiency. The processing efficiency values of sustained attention were calculated as a ratio of hit proportion over average RT on correct trials. Both accuracy and RT data were standardised and scaled as per performance effectiveness data, prior to entry into the final processing efficiency calculation:

$$\textit{Sustained attention efficiency} = \left(\frac{\text{Standardised scaled hit proportion}}{\text{Standardised scaled RT}}\right)$$

Data Diagnostics

The dataset was initially cleaned at the level of individual trials. RTs of less than 200ms were considered anticipatory responses and was removed. RTs of ± 3.00 *SD*s from the participant's mean were also removed (approx. 1% of total trials). Univariate outliers were detected using examination of *z*-scores exceeding ±3.00. No cases were identified, and all data points were retained. No multivariate outliers were identified using Mahalanobis' Distance. There was no missing data for either accuracy or RT data.

The assumption of normality within each cell of the study design was assessed using the Shapiro-Wilk test. Within the low trait anxiety and ego-safe cell, the assumption of normality was met for performance effectiveness within the odd-number and even-number conditions. Normality was also met for processing efficiency in both the odd-number and even-number conditions. For the low trait anxiety and ego-threat cell, the normality assumption was violated for performance effectiveness in both the odd-number and even-number conditions. For processing efficiency, normality was violated within the even-number condition. Within the high trait anxiety and ego-safe cell, the assumption of normality was not met for performance effectiveness or processing efficiency in both odd-number and even-number conditions. Finally, amongst the high trait anxiety and ego-threat cell, the assumption of normality was met for performance effectiveness and processing efficiency at both odd-number and even-number levels of cognitive load. As ANOVA is robust to violations of normality, no transformation was applied to the data and analyses proceeded with caution (Tabachnick & Fidell, 2019).

Main Analysis, Standardised Sustained Attention Effectiveness

A three-way mixed-design 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 2 (cognitive load; even-sequence vs. odd-sequence) ANCOVA was conducted on sustained attention effectiveness. The cognitive load within-subjects variable consisted of only two levels, as such the assumption of sphericity was automatically met without the need for Mauchly's test (Tabachnick & Fidell, 2019). Results were interpreted using original uncorrected degrees of freedom. The depression covariate was found to have a significant effect on performance effectiveness scores, $F(1, 85) = 4.72$, $p = .033$, $\eta_p^2 = .05$, *power* = .57. All results were subsequently interpreted while controlling for the influence of depression. Table 18 presents the descriptive statistics for each cell of the study design, corrected for self-reported depression.

Table 18

Means and Standard Deviations of Standardised Performance Effectiveness Values on Sustained Attention Task Across All Cognitive Load Levels, Trait Anxiety Groups, and Situational Stress Conditions

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
Even-Sequence	2.93 (0.97)	3.01 (1.15)	2.86 (1.05)	3.27 (0.76)
Odd-Sequence	2.94 (0.91)	3.28 (1.02)	2.77 (1.11)	3.15 (0.97)

Note. Corrected values reported when covariate of depression = 2.54.

Results demonstrated no significant main effect of cognitive load, $F(1, 85) = 1.80$, $p = .183$, $\eta_p^2 = .02$, *power* = .26. Similarly the main effect of trait anxiety was also found to be non-significant, $F(1, 85) = 1.63$, $p = .206$, $\eta_p^2 = .02$, *power* = .24. The main effect of situational stress was also found to be non-significant, $F(1, 85) = 0.03$, $p = .870$, $\eta_p^2 < .01$, *power* = .05. The two-way interaction between trait anxiety and cognitive load was ultimately non-significant, $F(1, 85) = 0.20$, $p = .657$, $\eta_p^2 < .01$, *power* = .07. The two-way interaction between situational stress and cognitive load was also non-significant, $F(1, 85) = 2.22$, $p =$

.140, η_p^2 = .03, *power* = .31. Likewise, the interaction between trait anxiety and situational stress was also found to be non-significant, $F(1, 85) = 0.06$, $p = .808$, $\eta_p^2 < .01$, *power* = .06. The three-way interaction between all study variables was not significant, $F(1, 85) = 0.73$, $p = .396$, η_p^2 = .01, *power* = .14.

Main Analysis, Standardised Sustained Attention Efficiency

For the analysis of processing efficiency scores, the depression covariate was found to be non-significant at all levels and was therefore removed for interpretation of results. A three-way mixed-design 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 2 (cognitive load; even-sequence vs. odd-sequence) ANOVA was conducted on sustained attention efficiency. Table 19 presents descriptive statistics for each cell of the study design.

Table 19

Means and Standard Deviations of Standardised Processing Efficiency Values on Sustained Attention Across All Cognitive Load Levels, Trait Anxiety Groups, and Situational Stress Conditions

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
Even-Sequence	1.02 (0.18)	0.98 (0.25)	0.98 (0.27)	1.01 (0.19)
Odd-Sequence	1.05 (0.22)	1.00 (0.21)	0.99 (0.19)	1.06 (0.17)

Results determined the main effect of cognitive load was not significant, $F(1, 85) = 1.99$, $p = .162$, η_p^2 = .02, *power* = .29. The main effect of trait anxiety was also found to be not significant, $F(1, 85) = 0.05$, $p = .827$, $\eta_p^2 < .01$, *power* = .06. The main effect of situational stress also had no significant effect on sustained attention efficiency scores, $F(1, 85) = 0.08$, $p = .778$, $\eta_p^2 < .01$, *power* = .06.

The two-way interaction of trait anxiety × cognitive load was non-significant, $F(1, 85) = 0.33$, $p = .567$, $\eta_p^2 < .01$, *power* = .09. Likewise, the two-way interaction of situational stress × cognitive load was also not significant, $F(1, 85) = 0.01$, $p = .938$, $\eta_p^2 < .01$, *power* = .05. The interaction between trait anxiety and situational stress was also found to be non-significant, $F(1, 85) = 1.97$, $p = .164$, $\eta_p^2 = .02$, *power* = .28. The three-way interaction of trait anxiety × situational stress × cognitive load was not significant, $F(1, 85) = 0.53$, $p = .470$, $\eta_p^2 = .01$, *power* = .11.

Discussion: Trait Anxiety, Situational Stress, Cognitive Load, and Sustained Attention

Study 4 provided a systematic test of the relationships amongst trait anxiety, situational stress, mental effort, and sustained attention as evaluated using a twelve-minute RVIP task. Based on attentional control theory, the study hypothesised a trait anxiety × situational stress × mental effort three-way interaction, such that within the ego-threat condition higher reports of trait anxiety and mental effort would both predict improved sustained attention effectiveness but lower efficiency. The hypotheses were not supported. After controlling for depression, results suggested trait anxiety, situational stress, and mental effort were unrelated to either sustained attention effectiveness or efficiency.

The current results were similar to the null associations observed by Righi and colleagues (2009). This may suggest no association exists between trait anxiety, situational stress, cognitive load, and sustained attention. Alternatively, the results were in contrast to numerous other studies which established sustained attention to be associated with trait anxiety (Elliman et al., 1997), situational stress (Robinson, Krimsky, et al., 2013), and their interaction (Geen, 1985). One difference between current and prior work may be the form of situational stress manipulation. Robinson, Krimsky, et al. used a somatic-oriented threat of shock procedure to induce situational stress while the current study used a cognitive-oriented ego-threat procedure. However, this does not account for other work (Geen, 1985) which applied similar ego-threat procedures as the current study and obtained significant effects of situational stress. Another reason may be differences in measures of trait anxiety. While the current study focused on cognitive symptomatology, prior work typically reported scales which combined somatic and cognitive symptomatology. However, this is also unlikely given the STICSA's excellent convergent validity with other measures of anxiety (Grös et al., 2007; Ree et al., 2008).

A further reason for the variation of results is a possible floor effect in the data which may have masked the relationship between anxiety, situational stress, and sustained attention. In the selected RVIP, target stimuli consisted of any chain of three consecutive odd or even numbers. This choice of target is less common than single-stimulus targets (e.g., 'X' vs 'O'). It is suggested that the task was made unintentionally difficult by using multiple-stimuli string targets of a numerical nature. A solution for further investigation may be to reduce the complexity of the target and non-target stimuli. Of note, only the proportion of hits was recorded for analysis. Although used in past literature, this ultimately may have been a flawed choice of outcome variable. Sustained attention requires the ability to discriminate target stimuli from distracting noise over long periods of time. Upon reflection, a more appropriate measure may have been the use of a sensitivity index. One such index is *d'*, seen in prior work by Geen (1985), which can identify degrading target discrimination ability over time (Shalev et al., 2018; Warm et al. 2008). Use of a sensitivity index like *d'* may therefore offer a better measure of sustained attention performance. This alternative measure is discussed further in Chapter Five.

Further, though the initial choice to use the RVIP was made for feasibility, it is possible the seven-minute duration was not long enough to adequately sample sustained attention. Indeed, some guidelines of clinical attentional engagement tests suggest tasks of sustained attention should exceed approx. 15-20 minutes to induce boredom and fatigue (Leark et al., 2007). While fatigue may seem counterintuitive to the research design, the ability to resist distraction brought on by fluctuations in emotional or physical standing is embedded in the operationalisation of sustained attention. Given the possibility Study 4 was undermined by unforeseen methodological difficulties, it was suggested the relationships between trait anxiety, situational stress, mental effort, and sustained attention require further investigation. Changes to the task of sustained attention are outlined in Chapter Six and adopted in Study 7.

Chapter Five: Introduction to Second Phase of Research

The first phase of research detailed in Chapter Three and Chapter Four examined the influence of trait anxiety, situational stress, and cognitive load on the performance effectiveness and processing efficiency of executive functions mental rotation (Study 1), planning ability (Study 2), cold decision-making (Study 3), and sustained attention (Study 4). In the second phase of research, the executive functions of planning, decision-making, and sustained attention were examined further. The construct of working memory capacity was also introduced and examined as a potential buffer to trait anxiety's influence in lieu of cognitive load.

New tasks were used to examine planning, decision-making, and sustained attention in the second research phase. This is partly due to feasibility restrictions of participant recruitment. The current research relied on the sampling of an undergraduate student population, some of whom may have been resampled from the first phase. Exclusion of these previous participants would have restricted the sampling procedure and was expected to extend the duration of data collection unduly. As such, with the anticipation that some participants would be resampled, alternate tasks of executive function were implemented. Executive functions are used in novel situations where individuals are unable to rely on automatic response strategies. As such, repeated use of the prior phases' tasks was anticipated to risk resampled participants applying strategies learned from prior exposure, thereby confounding performance (Chan et al., 2008). Further, the use of alternate tasks could have provided evidence the results observed in the first research phase were replicable across variations of executive function assessments.

In addition to improving the novelty of tasks, the reselection of tasks allowed for limitations of the prior phase to be addressed. Specifically, the measurement of sustained attention and use of a hit proportion to operationalise the construct was problematic.

Summaries of hit or false alarms alone offer no information about a participant's ability to discriminate between target and non-target stimuli. This is despite such discrimination being the primary requirement of continuous performance tasks (Shalev et al., 2018; Warm et al. 2008). The solution adopted in the second phase of research is to implement use of a sensitivity index, such as *d*'. Derived from signal detection theory (Pastore & Scheirer, 1974), *d*' separates an individual's ability to separate a target (or signal) amongst noise by evaluating differences of correct target identification (hit, correct rejection) and noise-related error rates (false alarm, miss; Stanislaw & Todorov, 1999). Use of a sensitivity index like *d'* provides a more complete understanding of sustained attention performance. As individuals are required to monitor and maintain performance, a sensitivity index can highlight decreased effectiveness stemming from either an increase in errors of omission (miss), errors of commission (false alarms), or both. While other sensitivity indices are available, *d'* was selected due to it being a prominent choice in recent research of broader sustained attention (e.g., Baldwin & Lewis, 2017; Birkett et al., 2007; Cassarino, Tuohy, & Setti, 2019; Mitko et al., 2019). To assess sustained attention in the second phase of research, the TOVA[36] (Leark et al., 2007) was used. This measure is approximately twice the duration of the previous task, uses simple visual stimuli, and recommends use of the *d'* index. The TOVA is further described in Chapter Six.

For the evaluation of planning ability and decision-making, alternate tasks were also used. The sequence-based view of planning described in Chapter Two was retained in the second phase. As such, a sequence-driven planning task was chosen, specifically the *N*-Puzzle task (O'Hara & Payne, 1998). Rather than the rearrangement of beads on pegboards, the *N*-Puzzle required rearrangement of tiled patterns while conforming to restrictive task rules. The task is described in further detail in Chapter Six. For decision-making, cold

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[36] Test of Variables of Attention. A brief summary of the TOVA is given in Table 5 located in Chapter Two

decision-making was found to be unrelated to trait anxiety, situational stress, or cognitive load in the first research phase. Therefore, to more fully assess the executive function in the second phase, evaluation of the executive function was extended to its hot variant. That is, while cold decision-making was unrelated to trait anxiety, it was of interest to determine if hot decision-making may instead show this association. As was discussed in Chapter Two, the predominant trend in literature is that tasks of hot decision-making are associated with trait anxiety (Giorgetta et al., 2012; Heilman et al., 2010; Maner et al., 2007; Maner & Schmidt, 2006; Mueller et al., 2010). Concerns were raised in the first phase of the emotional interference embedded within hot decision-making tasks. However, it possible the embedded emotionality and reliance on heuristic strategies makes hot decision-making more likely to interact with trait anxiety rather than cold, logic-bound deliberations. This approach was examined in the second research phase with use of the IGT[37] (Bechara et al., 1994), a task previously described in Chapter Two[38]. The IGT, in comparison to other tasks of hot decision-making, has been attributed as the task option that best evaluates the executive functioning properties of decision-making (Brand, Grabenhorst, Starcke, & Vandekerckhove, Gansler, Jerram, Vannorsdall, & Schretlen, 2011; Markowitsch, 2007; Buelow & Blaine, 2015). The IGT is further discussed in Chapter Six.

Further to the change of tasks, a new variable was introduced into the current research. In the first phase of research, cognitive load was found to be unrelated (both independently and interactively) to the functions of planning, decision-making, and sustained attention. This contrasted with what had been predicted by theory (e.g., attention control theory, processing efficiency theory) which expected the effects of trait anxiety and situational stress to be heightened at greater levels of difficulty/load. However, as proposed in

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[37] Iowa gambling task
[38] A summary of the task is given during the literature review and in Table 4 of Chapter Two

Chapter Four, this interactive trend may not be as clearly observable in the examined functions of planning, decision-making, and sustained attention, which are more complex in nature compared to the select functions identified within prior theory (i.e., inhibition, shifting, updating). Remaining in the theoretical framework of attention control theory, the second phase of research proposed it is not the cognitive load consumed by difficulty level that moderates the relationship between trait anxiety and executive functions. Rather, it is the underlying amount of cognitive resources generally available for recruitment during task completion. As such, a greater capacity of working memory was expected to improve the performance of high trait anxious participants, particularly under conditions of additional interference (i.e., situational stress). The current chapter provides a brief overview of working memory capacity given its introduction into the second phase of research.

Working Memory Capacity and Executive Functions

Working memory is a limited capacity cognitive system involved in the rehearsal, maintenance, and manipulation of information (Goldstein, 2008). Working memory is often used to refer synonymously to short-term memory (STM), though some models illustrate working memory as a subcomponent of STM (Aben, Stapert, & Blokland, 2012). In such models, the systems are distinguished as primarily facilitating temporary storage of information (STM), or manipulation and rehearsal during complex cognition (working memory; Aben et al., 2012; Cowan, 2008; Miyake & Shah, 1999). This capacity limit of working memory (i.e., the maximum amount of information that can be held within the system) may vary between individuals. The larger the working memory capacity, the greater the cognitive resources available (Jarrold & Towse, 2006). Research has suggested a greater capacity of working memory is associated with improved performance on tasks of reading comprehension (Daneman & Carpenter, 1980), adherence to instruction (Engle, Carullo, & Collins, 1991), reasoning (Kyllonen & Stephens, 1990), fluid intelligence (Carpenter, Just, &

Shell, 1990), and attentional control (Conway, Tuholski, Shisler, & Engle, 1999; Kane & Engle, 2002; Law, Morrin, & Pelligrino, 1995). Tasks used to assess working memory capacity usually involve a distinction between simple-span tasks and complex-span tasks. Simple-span tasks typically comprise of a standalone serial recall task. Individuals are presented with a series of stimuli and are asked to recall the relevant information, either in presentation order or reversed (Redick, Broadway, et al., 2012). Previously, simple-span tasks have been critiqued as too basic of an assessment of working memory capacity (Colom, Rebollo, Abad, & Shih, 2006; Unsworth, Redick, Heitz, Broadway, & Engle, 2009). It has been suggested that simple-span tasks are more likely to be measures of short-term memory storage, rather than information manipulation. Complex-span tasks address this critique. Complex-span tasks use a dual-task paradigm, comprised of a primary memory recall task (e.g., remembering a series of letters, remembering a visual layout) interspersed with a secondary distractor task (e.g., evaluating accuracy of mathematical equations, comparing symmetry of objects; Daneman & Carpenter, 1980; Redick, Broadway, et al., 2012; Unsworth et al., 2009). Use of the distractor task inhibits memory rehearsal strategies and allows for the estimation of available memory storage during concurrent information processing (Unsworth et al., 2009).

Several models of working memory have been proposed, including attention-based models such as those by Cowan (1995) and Engle, Tuholski, Laughlin, and Conway (1999), time-sensitive decay models by Towse and Hitch (1995) and Barrouillet, Bernardin, and Camos (2004), as well as resource sharing models like that of Daneman and Carpenter (1980). The most popular model of working memory capacity is likely to be the multicomponent model designed by Baddeley and Hitch (1974; Baddeley, 2001). Generally, most models of working memory capacity can be integrated into this multicomponent model proposed by Baddeley and Hitch, due to the model’s structure flexibly allowing for the accommodation of new research. Particularly, models which highlight susceptibility to variations in cognitive load and external interference (i.e., Barrouillet et al., 2004; Daneman & Carpenter, 1980; Towse & Hitch, 1995) complement the multicomponent model (Byrne, 2017). The multicomponent model suggests working memory is responsible for both short-term storage and processing of information, and is also integrated into the framework of attentional control theory (Eysenck et al., 2007). While some models propose systems quite distinct and in opposition to the multicomponent model, the multicomponent model remains the most comprehensive and inclusive model of working memory (Byrne, 2017). The current dissertation retains a focus on interpreting working memory and working memory capacity as set out by the multicomponent model and attentional control theory.

Attentional control theory, as a cognitive interference model, assumes working memory capacity is advantageous for performance until the point at which excessive task-irrelevant demands causes capacity limits to be exceeded (Berggren & Derakshan, 2013; Eysenck et al., 2007; Gazzaley, 2011). For attentional control theory, the interaction of trait anxiety and situational stress represents such a circumstance. The increased demand for cognitive resources produced by either trait anxiety or situational stress reduces working memory capacity (Owens, Stevenson, Hadwin, & Norgate, 2014). This reduction in capacity impairs coordination abilities of the central executive, to which complex executive functions are reliant, resulting in impairments to task reliant on executive functioning (Berggren & Derakshan, 2013; Edwards, Moore et al., 2015; Otto, Raio, Chiang, Phelps, & Daw, 2013). Consequently, the greater the extent of working memory capacity, the greater the extent to which an individual can accommodate emotional interference before performance decrements manifest.

While literature has found trait anxiety, situational stress, and broader executive functioning to be interrelated (Edwards, Moore, et al., 2015; Luo, Zhang, & Wang, 2017;

Moran, 2016; Otto et al., 2013; Owens et al., 2014; Wright, Dobson, & Sears, 2014), few have examined the interactions of all three constructs concurrently. Of the studies that do link these constructs together (e.g., Edward, Moore, et al., 2015), the examined executive functions are restricted to those of Miyake et al.'s (2000) model (inhibition, shifting, updating; see Chapter One for discussion). Such studies suggest working memory capacity buffers higher trait anxious participants against the influence of situational stress. Specifically, when examining participants with greater working memory capacity, those with higher trait anxious individuals can outperform their lower trait anxious peers under stress(Edward, Moore, et al., 2015). Literature pertaining to the executive functions examined in the current research and working memory capacity is reviewed here. Literature associating planning, hot decision-making, and sustained attention with trait anxiety was summarised Chapter Two, and as such is not repeated here.

Planning Ability and Working Memory Capacity

Few studies have investigated an association between working memory capacity and planning ability. Of the work that is available, much is aged. Generally, there is support for the proposal that greater working memory capacity is associated with improved performance on tasks of planning ability (Gilhooly, Wynn, Phillips, Logie, & Della Sala, 2002; Owen, Downes, Sahakian, Polkey, & Robbins, 1990; Phillips, 1999; St Clair-Thompson, 2011). In a study by Owen and colleagues (1990), individual differences in working memory capacity were found to relate to planning ability. Participants were patients diagnosed with frontal lobe excisions, compared to controls matched for age and IQ. Working memory capacity was assessed using a computerised spatial working memory task. Participants were required to locate a virtual token by selecting on-screen boxes, while refraining from revisiting previously selected options. Planning was assessed using a computerised Tower of London. Participants rearranged the Tower of London puzzles using a touchscreen computer and were instructed to begin only once they had considered the minimum number of necessary moves. Error rates and RTs were recorded. The frontal-lobe damaged patients demonstrated lower working memory capacity compared to control participants, indicated by significantly more errors in the working memory task. Clinical patients also responded with more errors and longer RTs on the Tower of London task. Owen et al. interpreted the results as the impaired working memory capacity of the patients having underscored their poorer planning performance. Though theoretically plausible, the study failed to directly examine associations between these constructs. Further, while a spatial working memory task was chosen to complement the visual nature of the Tower of London, the task appeared more adept at assessing short-term storage rather than information processing.

Another study by Phillips (1999) reported results complementary to Owen et al.'s. Phillips used a dual-task paradigm, assessing planning ability as the primary task via a computerised Tower of London, and manipulating working memory load within-subjects by a secondary distractor task. The distractor task included control (no secondary task), verbal (articulatory suppression), and visual (tapping sequence) conditions. Error rates and RTs were recorded. Analyses found when the cognitive load on working memory was increased through concurrent completion of either the verbal or visual secondary task, participants made more errors compared to the control condition. That is, participants who experienced greater limits on their working memory capacity demonstrated poorer planning performance. Further, compared to completing the primary task alone, concurrent completion of the verbal and visual secondary tasks was associated with faster RTs between onset of trial and initiation of the first move on the Tower of London. Faster RTs and increased errors were assumed to be linked, such that the limited time participants spent on forward planning contributed to the rise in mistakes.

Other work has suggested planning ability and working memory capacity to be unrelated. Lehto (1996) tested a sample of adolescents using a battery of cognitive tests. Working memory capacity was measured using a combination of simple-span and complex-span tasks. Planning ability was assessed using a traditional Tower of Hanoi. The total number of errors (i.e., moves beyond the minimum necessary to solve) and total time taken to solve the problems were recorded. Correlational analyses demonstrated no significant association between planning effectiveness or efficiency with working memory capacity. The study, however, suggested these null findings were due to the poor reliability of the Tower of Hanoi, citing low internal consistency. Alternatively, the lack of association between working memory capacity and planning efficiency might have been due to the measurement of total solving time. This measured time included both the initial planning phase and manual solving of the task. The manual act of rearranging the Tower of Hanoi represents very little planning ability and is more likely to represent variations in motor control. Its inclusion likely inflated measurement error.

Overall, literature associating working memory capacity and planning is scarce. However, the more salient trend in the available literature appears to suggest working memory capacity can influence planning ability. The current research extended on this limited area while continuing the general methodological strategies implemented in the first phase of research (e.g., use of an accuracy/RT ratio to assess processing efficiency, controlling for the influence of depression).

Decision-Making and Working Memory Capacity

Hot decision-making is defined by its use of quick, heuristic strategies when required to interpret and apply decision criteria to a series of choices (Buelow & Blaine, 2015). Most hot decision-making tasks replicate gambling scenarios, asking participants to balance risk and benefit ratios (Bechara et al., 1994; Brand et al., 2002). Outcome measures of hot decision-making tasks do not use an estimate of accuracy, but rather an evaluation of advantageous and disadvantageous choices. That is, choices that lead towards an overall gain or an overall loss, respectively. Individuals who favour advantageous choices may also be identified as risk-avoidant, while those who favour disadvantageous choices are noted to be less sensitive to such risk (Bechara, 2008). Most research has found working memory capacity to influence decision-making preferences (Corbin, McElroy, & Black, 2010; Dougherty & Hunter, 2003; Fletcher, Marks & Hine, 2011; Hinson et al., 2003).

Research conducted by Bagneux, Thomassin, Gonthier, and Roulin (2013) suggested individuals with greater capacity of working memory demonstrated a preference for advantageous choices on the IGT (See Chapter Two, Table 4 for brief review). The task required participants to make continual selections from four card decks (labelled A, B, C, and D). Each card deck produced a potential gain or loss outcome. Decks A and B were disadvantageous, with continued sampling leading to an overall loss. Decks C and D were advantageous, with continued sampling resulting in an overall gain. Immediate feedback was given following each choice regarding the quantity of loss or gain. The task consisted of 100 trials divided into five blocks. Decision-making preference was indexed as the number of disadvantageous choices subtracted from advantageous choices. Further to this, participants' working memory capacity was also assessed by use of complex-span tasks. A high working memory capacity group and low working memory capacity group were determined by selecting participants from the upper and lower quartiles of the tasks' distributions. No significant difference between working memory capacity groups was found within the first two blocks of the IGT, though this was expected as the initial trials serve as a learning phase (Elvemo, Nilsen, Landrø, Borchgrevink, & Håberg, 2014; Stocco, Fum, & Napoli, 2009; Turnbull, Bowman, Shanker, & Davies, 2014). Throughout the third and fourth blocks, participants in the high working memory capacity group demonstrated significantly more advantageous selections. This difference was non-significant in the final block. Participants with high working memory capacity appeared to recognise the distinction between advantageous and disadvantageous decks sooner than those with low working memory capacity. As such, the high working memory capacity participants were able to alter their decision-making behaviour earlier.

Another work conducted by Bechara and Martin (2004) also evaluated hot decision-making using a computerised IGT. Selections between the two advantageous (low risk) and two disadvantageous (high risk) decks were made using a mouse and keyboard. The test was conducted using participants diagnosed with a substance abuse disorder compared against non-clinical controls. Working memory capacity was assessed using a computerised delayed nonmatching to sample (DNMS) task. Participants were shown either a red or black card on-screen. Following a random delay period, participants were shown four further cards, two red and two black. Participants were required to select the cards that were nonmatching to the original target. During the delay period, participants completed a distraction task to avoid rehearsal. Participants diagnosed with substance dependence demonstrated significantly lower working memory capacity and more disadvantageous decisions during the IGT when compared to non-clinical participants. Bechara and Martin suggested the impaired working memory capacity of substance-dependent participants contributed to their ineffective decision-making. To follow-up this proposal, clinical participants were divided based on IGT performance into groups of impaired (primarily disadvantageous selections/low effectiveness; n = 16) and non-impaired (primarily advantageous selections/high effectiveness; n = 25). Results found the impaired clinical participants demonstrated significantly lower working memory capacity compared to non-impaired participants. This trend was also observed for non-clinical participants, though the imbalance of groups (impaired n = 4, non-impaired n = 33) meant results were interpreted with caution. Though the study further supported an association between working memory capacity and hot decision-making, additional investigation of decision-making is needed in a non-clinical sample.

Most hot decision-making includes an element of risk evaluation due to the replication of gambling scenarios (e.g., Brand et al., 2002; Bechara et al., 1994; Figner et al., 2009; Lejuez et al., 2002; Romer et al., 2009). Of these, the IGT has been identified as the best for evaluating the executive functioning properties of decision-making, rather than risk preference alone (Lehto & Elorinne, 2003). However, IGT outcomes do not lend themselves to calculations of processing efficiency, as is required in the current research. Processing efficiency refers to the relationship between performance effectiveness (i.e., quality of performance) and the cognitive resources invested (i.e., generally considered as RT). The recording of RTs in IGT can be problematic, as use of physical card decks introduces confounds of motor skill. This is also true of digital variants that require deck selection to be made by using a computer mouse. As such, researchers intending to capture decision-making efficiency using the IGT must select task variations that minimise the use of motor skills. This can be accomplished by requiring the computer to randomly select the decks which participants subsequently accept/reject, rather than allowing unframed manual selection. This change has been introduced in a recently modified version of the IGT (Cauffman et al., 2010) which has demonstrated sound psychometrics and is adopted in the current research.

Sustained Attention and Working Memory Capacity

Few studies directly examine an association between working memory capacity and sustained attention. Instead, literature focuses on working memory capacity's role in influencing related but separable attentional inconsistencies, such as thought suppression and mind wandering. In turn, a reduction of these issues is thought to contribute to improved sustained attention over prolonged durations.

The predominant view of literature is that greater working memory capacity contributes to improved performance on sustained attention due to better regulation of task-irrelevant thought suppression (Barrett, Tugade, & Engle 2004; Brewin & Beaton, 2002; Brewin & Smart, 2005). An example, McVay and Kane (2009) investigated the link between working memory capacity and sustained attention, via assessment of mind wandering, amongst a sample of undergraduate students. Working memory capacity was assessed using three complex-span tasks (operation span, reading span, symmetry span). Performance on each task was standardised and compiled into a global measure of working memory capacity. Sustained attention was assessed using a 30-minute computerised SART[39]. Participants were required to respond to infrequent target stimuli amongst frequent distractors. Intermittently throughout the task, participants would be asked to vocalise what they had been thinking prior to the thought probe (e.g., task performance, current physiological state, personal worries). Sustained attention was evaluated by use of a *d*' outcome, while efficiency was recorded as RT variability (*SD*) on target trials. Results indicated larger working memory capacity predicted improved sustained attention effectiveness (higher *d*' values) and improved efficiency (smaller RT *SD*s). Larger working memory capacity was also predictive of less off-task thoughts during mind-wandering. McVay and Kane proposed the ability to maintain task-relevant thoughts (e.g., thoughts about task stimuli and performance) partially explained the association between capacity and sustained attention performance. This data was re-examined in McVay and Kane's (2012a) later work, which suggested associations between working memory capacity and tests of complex cognition were attributable to a shared factor of executive control. Applied to the multicomponent theory of working memory, this factor might represent reliance on central executive coordination properties.

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[39] Sustained attention to response task. Refer to Chapter 2, Table 5 for a brief summary

Though less common, other work has suggested greater working memory capacity may impair sustained attention. In contrast to McVay and Kane’s (2009; 2012a) work, research conducted by Levinson, Smallwood, and Davidson (2012) implied greater working memory capacity facilitated mind-wandering rather than reduced it. Participants were recruited from the general community and their working memory capacity was assessed using a complex-span task. Participants were also required to complete a 30-minute visual search task. Participants viewed strings of letters and were asked to identify a target (X or N) contained within. Trials were separated into low-load (distinct distractors; e.g., OOOXOOO) and high-load (similar distractors; e.g., KKKXKKK) conditions. The task was divided amongst eight blocks of 48 trials. Between blocks, participants were probed to assess mind-wandering by vocalising whether they had been engaging in task-relevant or task-irrelevant thoughts. Results demonstrated that at low-load conditions, higher working memory capacity predicted increased mind-wandering. At high-load conditions, working memory capacity and mind-wandering were unrelated. Levinson et al. interpreted the results to suggest higher working memory capacity was a prerequisite to facilitate mind-wandering. The study suggested when tasks required low cognitive load or were viewed as easy by the participant, those with greater working memory capacity could engage in off-task thinking. As such, in a situation where prolonged sustained attention is necessary, only those with higher working memory capacity could be disadvantaged if they were able to engage in further task-irrelevant processing. However, the study did not report the accuracy or RT data from the visual search task, leaving it ambiguous if this facilitated mind-wandering did have detrimental effects on the effectiveness or efficiency of task performance.

Unlike Levinson et al. (2012), most other sources associate the increased resources attributable to greater working memory capacity to be beneficial in restraining mind wandering (Brewin & Beaton, 2002; Brewin & Smart, 2005; McVay & Kane, 2012b). This work however only implies benefits to sustained attention, as most studies have evaluated mind wandering in the context of simple tasks or measures of fluid intelligence (e.g., reading comprehension; McVay & Kane, 2012b) rather than continuous performance tests designed for sustained attention. The current research addressed this limitation by using a reliable measure of sustained attention, the TOVA (Leark et al., 2007) to directly assess the executive function. Further details of the measure are presented in Chapter Six. Overall, no current research has investigated the influence of trait anxiety, situational stress, working memory capacity and sustained attention concurrently. This was the aim of the current work.

Current Research

The second phase of research examined the interrelationships amongst trait anxiety, situational stress, working memory capacity, and their interactions on tasks of planning, hot decision-making, and sustained attention. The current research controlled for the influence of depression, which has been found to correlate with both measures of anxiety (Clark & Watson, 1991) and working memory capacity (Baddeley, 2013; Hubbard et al., 2016). Trait anxiety and depression were assessed using self-report scales. Situational stress was manipulated by an ego-threat procedure as per the procedure of the first research phase (see Chapter Three). Individual differences in working memory capacity were measured using a complex-span task.

Hypotheses, Second Research Phase

For the second experimental series, the following hypotheses were proposed based on literature and attentional control theory[40]. The pattern of predictions pertained to all observed

[40] Attentional control theory predicts (1) anxiety impairs performance by through the preferencing of stimulus-driven processing (e.g., external stressors, worrisome thoughts) over goal-driven processing, (2) trait anxiety and situational stress combine to impair processing efficiency to a greater extent than performance effectiveness, and (3) impairments are expected in tasks functions derived from the central executive. Later revisions to attentional control theory have suggested anxiety-related impairments might be further moderated by variations of cognitive load and/or mental effort.

outcomes in planning ability, hot decision-making, and sustained attention. Individual calculations of performance effectiveness and processing efficiency are detailed in Chapter Seven.

H1: After controlling for depression, a significant three-way interaction between trait anxiety × situational stress × and working memory capacity is predicted for performance effectiveness. Higher trait anxiety and higher working memory capacity are predicted to be associated with greater effectiveness in the ego-threat condition.

H2: After controlling for depression, a significant three-way interaction between trait anxiety × situational stress × and working memory capacity is predicted for processing efficiency. Higher trait anxiety and higher working memory capacity are predicted to be associated with poorer efficiency in the ego-threat condition.

Chapter Six: General Methodology of Second Phase of Research

Chapter Six describes the general methodology used in the current dissertation's second phase of research. Approval for the research was sought through the Bond University Human Research Ethics Committee. The second phase evaluated the influence of trait anxiety on the series of chosen executive functions (planning, decision-making, sustained attention), in addition to the interactive influence of situational stress, cognitive load, and working memory capacity. Specifically, Study 5 examined planning, Study 6 assessed hot decision-making, and Study 7 investigated sustained attention. Information regarding the situational stress manipulation, psychological measures, and cognitive tasks selection is detailed here.

Participant Recruitment

Participants were undergraduate university students recruited from Bond University through the School of Psychology's research participation pool and advertisement in Bond University's *Student Daily Digest*. Participants obtained partial research credit towards a subject for their involvement. All participants provided informed consent prior to the commencement of the research. Due to the different levels of attrition between tasks and data cleaning (i.e., removal of outliers), the demographic information and final participant numbers varied between each study. To minimise repetition, final demographic summaries are detailed before each study in Chapter Seven.

Situational Stress Manipulation

The situational stress manipulation used in the first phase of research was replicated in the second phase. Participants allocated to the ego-threat condition received a false feedback procedure to induce stress. Regardless of actual performance, participants were informed they were slower and less accurate than their peers. False feedback was repeated during rests between tasks. Participants assigned to the ego-safe condition were given only task-relevant instructions. As noted in Chapter Three, the use of an false feedback procedure was selected given its reported effectiveness in previous literature (Edwards et al., 2015; Leary et al., 2009; Moran, 2016). For further detail on the use of ego-threat procedures, refer to Chapter Three.

Questionnaire Materials

State and Trait Inventory of Cognitive and Somatic Anxiety (STICSA; Ree et al., 2008). The STICSA is a self-report measure evaluating state and trait variants of cognitive and somatic anxiety. Only scores pertaining to the cognitive subscales of the STICSA were used in the current research. Scoring procedures and psychometric properties of the measure are provided in Chapter Three.

Depression Anxiety Stress Scale – 21 Item Version (DASS-21; Lovibond & Lovibond, 1995). The DASS-21 is a measure of self-reported psychological distress experienced in the past week. The scale is separated into subscales assessing depression, anxiety, and stress symptomatology. Only scores from the depression subscale (DASS-D) were used in the current research. Scoring procedures and psychometric properties of the measure are provided in Chapter Three.

Stress Rating Questionnaire (Edwards, Edwards, et al., 2015**).** The Stress Rating Questionnaire is a brief measure of self-reported situational stress. The Stress Rating Questionnaire was used to evaluate the situational stress manipulation. Scoring procedures and psychometric properties of the measure are provided in Chapter Three.

Cognitive Tasks

Automated Operation Span (AOSPAN; Unsworth, Heitz, Schrock, & Engle, 2005). The AOSPAN is a computerised task designed to assess working memory capacity. The task is a complex-span measure, such that it is comprised of two interchanging tasks including a primary memory task and secondary distractor task to prevent rehearsal strategies. The AOSPAN specifically is comprised of a serial recall task interspersed with a repeating distraction activity that requires solving of simple mathematics equations. The AOSPAN has been found to demonstrate good internal consistency, test-retest reliability, and construct validity (Redick, Unsworth, Kelly, & Engle, 2012; Unsworth et al., 2005).

Participants completed three practice blocks for the individual components of the AOSPAN. All responses were made using a computer mouse. During the first practice block participants were required to recall a series of letters. Each letter was presented sequentially in the centre of the computer screen for 800ms with an inter-stimulus interval of 200ms. Participants were shown a 4 × 3 matrix of letters (F, H, J, K, L, N, P, Q, R, S, T, Y) and instructed to select the letters from the previous sequence, in the order of presentation. A "Blank" option was available if participants could not recall specific letters. Participants moved to the next trial by selecting an "Exit" option. The second practice block demonstrated the distraction activity. Participants were instructed to solve math operations (e.g., [3/3] + 1 = ?) as quickly as possible, responding to potential solutions as "true" or "false". This practice block set the time limit for the main trials as mean RT plus 2.5 *SD*. The third practice block consisted of the recall and distraction activities in combination. The distraction task was presented between each letter to be recalled.

The main trials consisted of 75 letters and 75 math operations, distributed across sequence sizes ranging from three to seven letters. Sequences were presented randomly. A time limit was imposed on the distraction task as the mean RT of practice trials plus 2.5 *SD.* This time-limit prevented rehearsal of letters during the distractor task. The sequence of the task is illustrated in Figure 23 (overleaf).

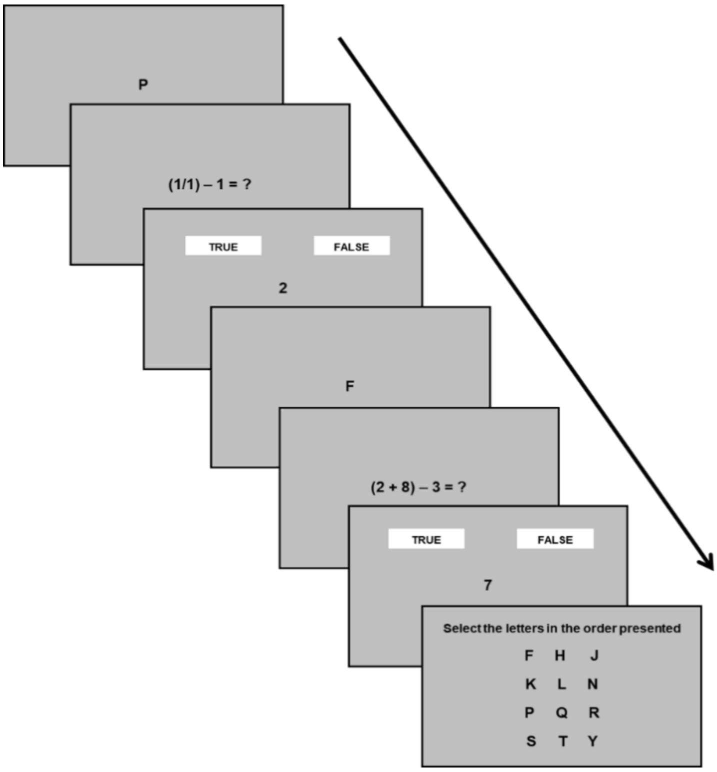

Figure 23. AOSPAN sequence demonstrating two-letter recall set.

***N*-Puzzle (O'Hara & Payne, 1998).** The *N*-puzzle task is an assessment of forward planning ability similar to Shallice's (1982) Tower of London (O'Hara & Payne, 1998; Pizlo & Li, 2005). The *N*-puzzle uses stimuli reminiscent of a sliding-tile game, with variants ranging in configurations of 5, 8, 15, and 35+ tiles (e.g., Pizlo & Li, 2005). While greater numbers of tiles can be used for both human and computer learning scenarios, the current study employed an 8-tile task to match the difficulty level to the modified Tower of London used in the first research phase. Participants completed eight practice trials followed by two blocks of 20 test trials.

On each trial, two puzzle configurations were presented positioned above (START image) and below (GOAL image) one another. Puzzles consisted of a 4 × 4 matrix layout, with seven spaces occupied by numbered tiles. Participants were instructed to mentally plan the minimum number of moves to rearrange the configuration of the START image to match the GOAL image. Tiles could only be moved singularly and only if adjacent to an empty space (see Figures 24 and 25). The task involved five difficulty levels ranging from 2-move to 6-move solutions. Responses were provided on a 6-key response box. Images remained onscreen until participants responded or timed out after two minutes. A 500ms inter-trial delay and 800ms fixation cross were presented between trials. Puzzles were balanced for the direction of tile movement (e.g., predominantly right vs. left). Participants were instructed to respond as quickly and accurately as possible.

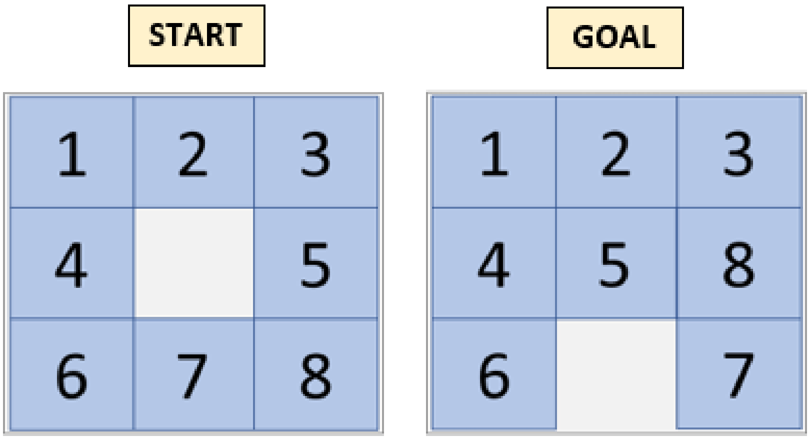

Figure 24. Example START and GOAL configurations of the *N*-puzzle task demonstrating a 3-move problem.

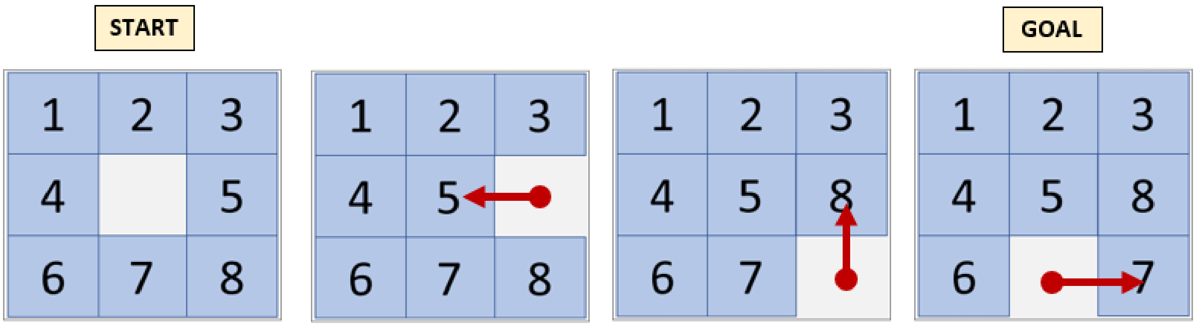

Figure 25. 3-move solution conforming to *N*-puzzle's move restriction rules.

Modified Iowa Gambling Task (IGT; Bechara et al., 1994). The IGT is a common and well-accepted measure of hot decision-making (Cauffman et al., 2010; Bechara, 2008). Compared to other tasks of hot decision-making (e.g., Balloon Analogue Risk Task, Columbia Card Task) the IGT has been suggested to be the better option for evaluating the executive functioning properties of decision-making (Brand et al., 2007; Buelow & Blaine, 2015; Gansler et al., 2011). A computerised variant was used in the current research, with participants presented four digital card decks. Decks A and B were disadvantageous and produced a net loss over repeated play, while decks C and D were advantageous with continual selection producing a net profit. Participants were required to keep track of their current winnings, in addition to the gain/loss probabilities of the individual decks. A summary of the decks' loss and profit details is presented in Table 20.

Table 20

Summary of Payoff Variations for all Card Decks in the Modified Iowa Gambling Task

Variables	Deck A	Deck B	Deck C	Deck D
Gain per card	$100	$100	$50	$50
Loss per 10 cards	$1250	$1250	$250	$250
Net product per 10 cards	-$250	-$250	+$250	+$250

At the start of each trial, an arrow appeared over one of the four decks. Participants could choose to play the highlighted deck using the "A" key of the keyboard or pass using the "L" key. Responses timed out after 4000ms. If participants chose to play the deck, feedback indicating the amount won/lost was provided at the bottom of the screen. Participants who opted not to play the deck were shown a brief "Pass" message. Feedback remained onscreen until the Spacebar was pressed. The task consisted of six blocks of 20 trials, sampling each deck equally. Selection of the decks was randomised in each block. The automated play/pass variation was chosen over the traditional point-and-click method to minimise RT discrepancies due to varying dexterity or motor control ability, as well as avoid unintentional non-sampling of decks. An example of the task layout is presented in Figure 26 (overleaf).

Figure 26. Example layout of cards during the IGT with feedback.

Test of Variables of Attention (TOVA; Leark et al. 2007). The TOVA is a continuous performance task used to assess sustained attention ability. The task has been reported to display good test-retest reliability, internal consistency, and construct validity (Greenberg, 2007; Leark et al., 2007). Participants were required to discriminate between two visual stimuli, one representing a target and the other a distractor (see Figure 27 for example). For each trial, participants were presented either the target or distractor stimuli in the centre of the screen for 100ms followed by an inter-stimulus interval of 2000ms. If the trial contained a target, participants were instructed to press the Spacebar. Responses were recorded as a hit if the response was made within 2000ms of target onset. If the trial contained a distractor, participants were told to make no response. Participants were provided 50 practice trials. The task consisted of one block of 640 trials, containing 320 target trials and 320 distractor trials. The task required approximately 23 minutes to complete.

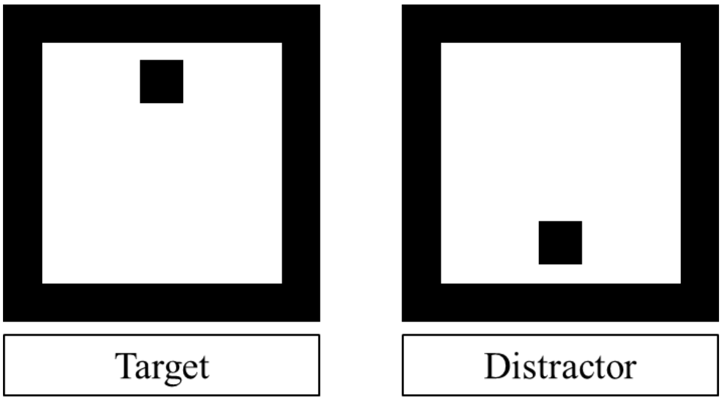

Figure 27. Example target and distractor stimuli presented during the TOVA.

Hardware and Software

Data were collected in the School of Psychology Research Laboratories at Bond University. The planning task was created using LabVIEW Builder and run using the LabVIEW Run Time Engine. The remaining tasks (working memory capacity, hot decision-making, and sustained attention) were derived from the Millisecond test library and run using Inquisit Lab version 4. Stimuli were presented on a 19-inch LCD monitor via a Dell Precision T3600 computer with Intel Xeon 3.00 GHz processor. Task responses were made using a combination of computer mouse input, keyboard input, and an ADInstruments RB-x40 series response pad.

Procedure

Testing was conducted individually, with each session lasting approximately 120 minutes in duration inclusive of debriefing. Upon arrival at the laboratory, individuals were given an explanatory statement and asked to provide written consent to participate in the research. In accordance with ethical regulations, participants were initially screened for depression symptomatology using the DASS-D. Participants who demonstrated “extremely severe” scores (≥ 28) were to be released prior to commencement of the study. However, no participants met this criterion. Participants completed the STICSA and Stress Rating

Questionnaire (baseline score) followed by the AOSPAN. Following task completion, participants were allocated between situational stress conditions, with every second participant allocated to the ego-threat condition. After the situational stress manipulation (or task-relevant instructions for the ego-safe condition) participants completed the Stress Rating Questionnaire once more (post-manipulation score). Participants then completed the remaining cognitive tasks, while reminded to respond as accurately and quickly as possible. Based on arrival order, administration of the *N*-puzzle and IGT was counterbalanced. All participants completed the TOVA as their final task due to its extensive duration. Rest periods were provided between each task to limit fatigue effects. The situational stress manipulation was repeated after each task and followed by the Stress Rating Questionnaire. When all tasks had been completed, participants were debriefed and thanked for their time before release.

Chapter Seven: Second Research Phase, Analyses and Study Series Results

Chapter Six described the general methodology implemented in the second research phase. In Chapter Seven, statistical analyses of each study are reported. The current chapter is divided across three studies, each of which evaluated a separable executive function. The studies detailed here examine forward planning (Study 5), hot decision-making (Study 6), and sustained attention (Study 7). Each study summarised participant demographics and group allocation, data diagnostics, and manipulation checks of the situational stress induction. Calculations used to determine operational definitions of performance effectiveness and processing efficiency for each executive function task are also presented. Two main analyses were conducted for each executive function, the first assessing performance effectiveness and the second assessing processing efficiency.

Study 5: Trait Anxiety, Situational Stress, Working Memory Capacity, and Forward Planning

Study 5 examined how variations of trait anxiety, situational stress, and working memory capacity might alter planning ability. Two outcome measures were examined, inclusive of performance effectiveness and processing efficiency. A brief summary of the study's methodology is provided, followed by the study results.

Participants and Group Allocation

The sample was comprised of 90 undergraduate university students. The sample was predominantly female (70 female, 20 male) with participants ages ranging from 18 to 56 years (M_{age} = 24.31, SD_{age} = 8.25). Participants were allocated equally between situational stress conditions, with 45 participants allocated to the ego-safe condition and 45 allocated to the ego-threat condition. When collapsed across all other groups, there was an equal distribution of males and females between the groups, $\chi^2(1) = 0.00$, $p = 1.00$. Further, there was no significant difference in age between the ego-safe (*M* = 25.18, *SD* = 9.06) and ego-threat groups (*M* = 23.44, *SD* = 7.36), *t*(88) = 1.00, *p* = .322.

High and low trait anxiety groups were determined using a median split. The median value of trait cognitive anxiety for the sample was 18.50. Therefore, participants who scored up to and including 18.00 were allocated to the low trait anxiety group, while those who scored 19.00 and above were allocated to the high trait anxiety group. Both high trait anxiety (*M* = 23.42, *SD* = 5.38) and low trait anxiety (*M* = 15.00, *SD* = 2.49) groupings consisted of 45 individuals. Collapsed across all other variables, there was no significant difference in the number of females or males between high trait anxiety and low trait anxiety groups, $\chi^2(1)$ = 1.03, *p* = .310. There was also no significant difference of age between the groups, *t*(88) = 0.25, *p* = .800.

The high and low groups for working memory capacity were also determined by a median split. The median value among AOSPAN scores was 42.00. Participants who scored below this value were allocated to the low working memory capacity group, while those exceeding the median were allocated to the high working memory capacity group. To keep approximately equal group sizes, participants who scored the median value (*n* = 3) were allocated to the low working memory capacity group (DeCoster et al., 2011). Forty-seven participants comprised the low working memory capacity group (*M* = 29.89, *SD* = 8.49) and 43 participants to the high working memory capacity group (*M* = 58.75, *SD* = 7.75). Collapsed across other variables, there was no significant difference in the number of females or males between high and low groups, $\chi^2(1)$ = 0.54, *p* = .463. Also, there was no significant difference in age between the two groups, *t*(88) = 0.72, *p* = .471. A summary of the demographic information of the sample across each cell of the study design is presented in Table 21.

Table 21

Demographics for Cells of Situational Stress (Ego-Safe vs. Ego-Threat) × Trait Anxiety (High vs. Low) × Working memory Capacity (High vs. Low) for Forward Planning Study

	Ego-Safe				**Ego-Threat**			
	Low Trait Anxiety		**High Trait Anxiety**		**Low Trait Anxiety**		**High Trait Anxiety**	
	Low WMC	**High WMC**	**Low WMC**	**High WMC**	**Low WMC**	**High WMC**	**Low WMC**	**High WMC**
	n = 10	*n* = 11	*n* = 13	*n* = 11	*n* = 14	*n* = 10	*n* = 10	*n* = 11
M_{Age} (*SD*)	25.50 (6.06)	24.18 (7.87)	25.54 (11.07)	25.45 (10.83)	26.36 (10.33)	21.40 (3.41)	21.33 (3.67)	23.33 (7.27)
Females	8	8	11	8	10	7	9	9
Males	2	3	2	3	4	3	1	2

Note. WMC = Working Memory Capacity

Materials

Questionnaires. All participants completed a series of questionnaires inclusive of the STICSA[41] (Ree et al., 2008), the DASS-21[42] (Lovibond & Lovibond, 1995), and Stress Rating Questionnaire (Edwards, Edwards, et al., 2015). Completion of the STICSA's trait-cognitive subscale was used to estimate levels of trait-based cognitive anxiety. Scores derived from this subscale were also used to determine the allocation to high/low trait anxiety groupings. The STICA's state-cognitive subscale was also used as part of a manipulation check for the study's situational stress induction (described further below). The Stress Rating Questionnaire was also used in this manipulation check. Scores on the depression subscale of the DASS-21 were used to isolate depression symptomatology as a potential covariate of

[41] State-Trait Inventory of Cognitive and Somatic Anxiety
[42] Depression Anxiety Stress Scale – 21 Items

results. Further details regarding measure descriptions, example items, scoring procedures, and psychometric properties are available in Chapter Three.

One-Touch *N*-Puzzle. A computerised task known as the one-touch *N*-puzzle was used to estimate participant's forward planning ability. Participants are presented with two concurrent 4 × 4 matrix layouts. For each matrix, seven of the possible eight spaces are occupied by numbered tiles. Each matrix displays a different tile pattern. Participants are required to mentally plan how many moves it would take to turn the starting matrix into the goal matrix. Tiles can only be moved singularly, and only if they are adjacent to an empty space (see Figures 24 and 25 presented in Chapter Six for example layouts and solving routine). Task difficulty ranged between 2-move and 6-move solutions. Participants made their responses using a 6-key response pad. Further details of the task protocol are provided in Chapter Six.

Automatic Operation Span (AOSPAN; Unsworth et al., 2005). The AOSPAN is a computerised task designed to assess trait-based working memory capacity. The task is a complex-span measure, in that it is comprised of a primary memory task and secondary distraction task to prevent memory rehearsal strategies. The AOSPAN used in the current work used a letter-based serial recall task interspersed with distractor mathematic calculations. Greater scores on the AOSPAN are indicative of greater working memory capacity. Full details of the task protocol and procedure are presented in Chapter Six.

Experimental Setup

Participants were tested individually. Task stimuli were presented on a 19-inch LCD desktop screen. Responses to the *N*-puzzle were made using an ADInstruments RB-x40 series response pad. Responses to the AOSPAN were made using mouse and keyboard.

Procedure

Upon arrival to the testing space, participants were provided with an explanatory statement and consent form for the study. Following this, participants were screened for depression symptomatology using the DASS-21.None of the participants were found to fulfil the exclusion criteria of scores ≥ 28 (i.e., "extremely severe). Remaining participants continued to complete the STICSA, a baseline measure of the Stress Rating Questionnaire, and the AOSPAN. Based on the arrival order, participants were alternately allocated to either the ego-safe (control condition) or ego-threat condition (situational stress manipulation) in an effort to achieve balanced groups. Participants in the ego-safe condition received only task-relevant information. Participants in the ego-threat condition were informed they were completing a test of intelligence and that their performance on the AOSPAN appeared worse in comparison to prior participants. Following the situational stress induction, participants completed the Stress Rating Questionnaire once more. All participants continued to complete the *N*-puzzle. At the completion of the study, participants were thanked and debriefed.

Situational Stress Manipulation

The situational stress manipulation was evaluated using a 2 (time; baseline vs. post-manipulation[43]) × 2 (group; ego-threat vs. ego safe) mixed-design ANOVA. Composite Stress Rating Questionnaire scores were entered as the dependent variable. The main effect of time was significant, $F(1, 88) = 16.16$, $p < .001$, $\eta_p^2 = .16$, *power* = .98. In contrast, the main effect of group was non-significant, $F(1, 88) = 2.84$, $p = .095$, $\eta_p^2 = .03$, *power* = .39. The two-way time × group interaction was found to be significant, $F(1, 88) = 5.31$, $p = .024$, $\eta_p^2 = .06$, *power* = .63. Follow-up within-subject contrasts demonstrated the linear trend of time

[43] Reminder: Post-manipulation is used here to refer to the second time point at which participant Stress Rating Questionnaire values for sampled. For participants allocated to the *ego-threat group*, this time point followed exposure to ego-threat instructions. For the *ego-safe group*, the time point followed exposure to task-relevant instructions.

varied as a function of group allocation (ego-safe vs. ego-threat). Mean Stress Rating Questionnaire scores for each group at both baseline and post-manipulation are displayed in Figure 28. At the level of the ego-threat condition, the 95% CIs showed a lack of overlap for baseline and post-manipulation values. The trend suggested a significant increase in Stress Rating Questionnaire scores at post-manipulation for participants experiencing ego-threat instructions. The trend was non-significant for the ego-safe condition, which demonstrated an overlap of the 95% CIs at baseline and post-manipulation.

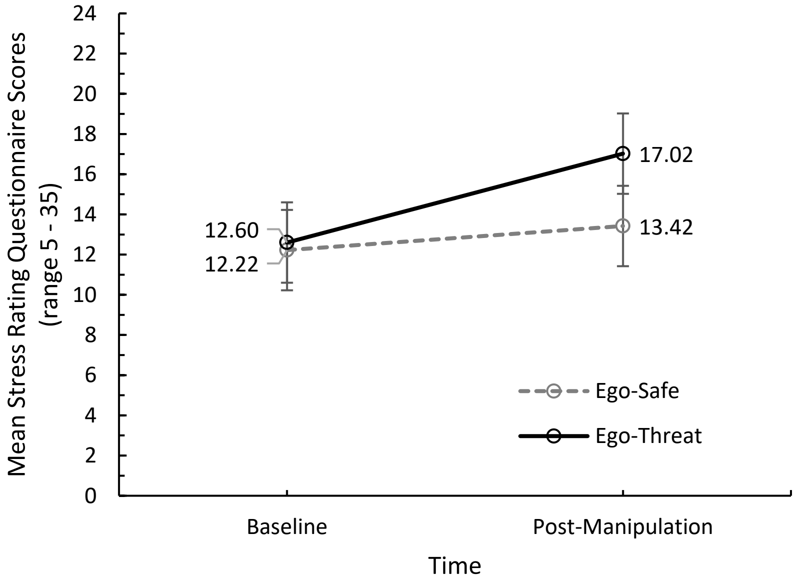

Figure 28. Linear trend of time at each level of situational stress condition for Stress Rating Questionnaire scores during the forward planning task. Error bars represent 95% confidence intervals.

Results

Measurement of Forward Planning

Forward planning effectiveness. Performance effectiveness of forward planning was operationalised as the total number of correct trials, indexed individually at all task difficulty levels (2-move through to 6-move trials). Values were transformed into *z*-scores and then translated to a positive range via an increase of +3.00 units to aid interpretability.

Forward planning efficiency. Forward planning efficiency scores were derived from a ratio of accuracy and RT data. RTs across correct trials, at each level of task difficulty, were standardised and scaled in the same manner as effectiveness scores. Standardised and scaled performance effectiveness values were then divided by the standardised and scaled RTs, as per the following calculation:

$$\textit{Forward planning efficiency} = \left(\frac{\text{Standardised scaled accuracy}}{\text{Standardised scaled RT}}\right)$$

Data Diagnostics

The dataset was initially cleaned at the level of individual trials. Trials with RTs less than 200ms were considered anticipatory and thus removed. Trials with RTs ± 3.00 *SD*s from the participant's mean were also removed prior to analyses. Overall, this constituted < 1% of trials. Once data were collated, univariate outliers were identified via calculation of *z*-scores, with values ±3.00 considered extreme. By these criteria, no univariate outliers were identified. Calculation of Mahalanobis' Distance suggested the presence of one multivariate outlier ($p < .001$) for the planning efficiency outcome variable. Removal of the case did not alter the trend of results, therefore it was retained and is reported in the final analyses (N = 90).

The assumption of normality was assessed via the Shapiro-Wilk test for all cells of the research design. Within the low working memory capacity/ego-safe/low trait anxiety cell, violations to normality were observed for performance effectiveness at 2-move, 3-move, and 4-move levels. For processing efficiency, the assumption of normality was not met for the 4-move level. Within the low working memory capacity/ego-safe/high trait anxiety cell, the normality assumption was found to be violated for performance effectiveness at 2-move, 3-move, and 4-move levels. For processing efficiency, the assumption of normality was met for all levels. Within the high working memory capacity/ego-safe/low trait anxiety cell, the assumption of normality was violated for performance effectiveness at the levels of 2-move and 3-move trials. For processing efficiency, the normality assumption was not met for the 2-move level. For the high working memory capacity/ego-safe/high trait anxiety cell, the normality assumption was violated for performance effectiveness at 2-move and 3-move levels. Normality was met for all levels of processing efficiency. For the low working memory capacity/ego-threat/low trait anxiety cell, the assumption of normality for performance effectiveness was not met at the 2-move and 3-move levels. For processing efficiency, the assumption was met for all levels. Within the low working memory/ego-threat/high trait anxiety cell, the assumption of normality was found to be violated for the 2-move and 3-move levels. The assumption was met for processing efficiency at all levels. For the high working memory capacity/ego-threat/low trait anxiety, normality was not found for 2-move, 3-move, and 4-move levels. In this cell, the assumption was not met for processing efficiency at 3-move and 4-move levels. Within the high working memory/capacity/ego-threat/high trait anxiety cell, the normality assumption was not met for 2-move, 3-move, and 4-move levels. For processing efficiency, the assumption was not met for the 2-move level. However, as the Shapiro-Wilk test has been found to be an overly sensitive measure, in conjunction with ANOVA being robust to violations of normality, no transformations were applied to the data (Tabachnick & Fidell, 2019). Results are interpreted with caution.

Missing data analyses found a cumulative 7.8% of data missing across all levels of accuracy. One case from the 3-move level, one from the 5-move level, and five from the 6-move level. This pattern of missing data was identical for RT data. The missing cases originated from participants who incorrectly responded to all trials of the relevant difficult levels. As such, no information was recorded by the computerised task. Missing cases were excluded pairwise where applicable during the main analyses. All analyses were conducted using SPSS version 26 with an applied significant level of $\alpha \leq .050$ set for all findings.

Main Analysis, Standardised Forward Planning Effectiveness

Initially, a four-way mixed-design 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 2 (working memory capacity; low vs. high) × 5 (cognitive load; 2-move vs. 3-move vs. 4-move vs. 5-move vs. 6-move) ANCOVA (with depression entered as a covariate) was to be conducted on forward planning effectiveness. However, evaluation of cell-sizes found individual *n*s to be small, ranging between 10 and 14 participants. The reduced number of cases per cell was considered inappropriate for the application of a four-factor ANOVA model and likely to result in misleading interpretive issues (Cohen, 2002; Tabachnick & Fidell, 2019). Further, cognitive load showed no significant contribution in an exploratory application of the four-factor model[44]. With all this considered, a simplified three-factor model was investigated. Cognitive load was dropped from the analysis given its lower priority in relation to the research questions of the second research phase. The repeated-measures variable of cognitive load was therefore collapsed across levels to produce a singular outcome variable.

Following amendments to the model, a three-way between-subjects 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 2 (working memory capacity; low vs. high) ANCOVA was conducted. Standardised and scaled accuracy values averaged across all levels of difficulty were examined as the outcome variable. Levene's test for homogeneity of variance was found to be satisfied, $F(7, 82) = 1.74$, $p = .112$. Though depression was entered as a covariate, it was found to contribute non-significantly and as such was not interpreted further. Descriptive statistics for performance effectiveness values across all groups are displayed in Table 22.

[44] All results containing cognitive load (both main effect and interactions) were non-significant at $p \geq .135$

Table 22

Means and Standard Deviations of Standardised Performance Effectiveness Values on Forward Planning Task Across All Trait Anxiety, Situational Stress, and Working Memory Capacity Groups

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
Low Working Memory Capacity	2.75 (1.17)	3.06 (1.01)	2.96 (0.77)	2.97 (0.89)
High Working Memory Capacity	3.22 (0.92)	2.96 (0.81)	2.79 (1.75)	3.25 (0.66)

Results demonstrated the main effect of trait anxiety was non-significant, $F(1, 81) = 0.20$, $p = .660$, $\eta_p^2 < .01$, *power* = .07. Similarly, the main effect of situational stress was also non-significant, $F(1, 81) < 0.01$, $p = .978$, $\eta_p^2 < .01$, *power* = .05. The main effect of working memory capacity was also non-significant, $F(1, 81) = 0.24$, $p = .629$, $\eta_p^2 < .01$, *power* = .08. Examination of the two-way interaction between trait anxiety and situational stress found it to be non-significant, $F(1, 81) = 0.25$, $p = .616$, $\eta_p^2 < .01$, *power* = .08. The two-way interaction between trait anxiety and working memory capacity was non-significant, $F(1, 81) = 0.03$, $p = .80$, $\eta_p^2 < .01$, *power* = .05. The interaction between situational stress and working memory capacity was also found to be non-significant, $F(1, 81) = 0.06$, $p = .803$, $\eta_p^2 < .01$, *power* = .06. Likewise, the three-way interaction between all study variables was non-significant, $F(1, 81) = 1.37$ $p = .246$, $\eta_p^2 = .02$, *power* = .21.

Main Analysis, Standardised Forward Planning Efficiency

A three-way between-subjects 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 2 (working memory capacity; low vs. high) ANCOVA was performed. Standardised and scaled processing efficiency values, averaged across all levels of difficulty, were examined as the outcome variable. Levene's test for homogeneity of variance was found to not be met, $F(7, 82) = 2.98$, $p = .008$. However, ANOVA is robust to violations of this assumption when cell sizes are approximately equal (Tabachnick & Fidell, 2019). As such, analyses were continued without transformation of the data and results were interpreted with caution. Depression was entered as a covariate of the analysis but found to be non-significant at all levels of the analysis and was not interpreted further. Descriptive statistics of processing efficiency across all cells of the design are displayed in Table 23.

Table 23

Means and Standard Deviations of Standardised Processing Efficiency Values on Forward Planning Task Across All Trait Anxiety, Situational Stress, and Working Memory Capacity Groups

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	M **(*SD*)**	***M*** **(*SD*)**	***M*** **(*SD*)**	***M*** **(*SD*)**
Low Working Memory Capacity	0.95 (0.42)	1.09 (0.35)	1.04 (0.32)	0.84 (0.15)
High Working Memory Capacity	0.95 (0.26)	1.01 (0.32)	0.93 (0.80)	1.40 (0.34)

Results of the analyses found the main effect of trait anxiety to be non-significant, $F(1, 81) = 1.61$, $p = .208$, $\eta_p^2 = .02$, *power* = .24. The main effect of situational stress was also non-significant, $F(1, 81) = 0.35$, $p = .556$, $\eta_p^2 < .01$, *power* = .09. The main effect of working memory capacity was non-significant, $F(1, 81) = 1.19$, $p = .278$, $\eta_p^2 = .02$, *power* = .19. The two-way interaction between trait anxiety and situational stress was non-significant, $F(1, 81) = 0.05$, $p = .832$, $\eta_p^2 < .01$, *power* = .06. The interaction between trait anxiety and working memory capacity was non-significant, $F(1, 81) = 2.93$, $p = .091$, $\eta_p^2 = .04$, *power* = .39. The interaction between situational stress and working memory capacity was also non-significant, $F(1, 81) = 2.45$, $p = .122$, $\eta_p^2 = .03$, *power* = .34. However, the three-way interaction of trait anxiety × situational stress × working memory capacity was significant, $F(1, 81) = 4.84$, $p = .031$, $\eta_p^2 = .06$, *power* = .59. That is, relationship between trait anxiety and planning efficiency was found to vary as a function of both situational stress and working memory capacity. The interaction accounted for approximately 6% of variance in planning efficiency scores.

To unpack the three-way interaction, the data were first split by situational stress condition to examine the simple interaction of trait anxiety × working memory capacity at each level. This interaction is illustrated in Figure 29. Follow-up *F*-tests were calculated using the error term from the original omnibus test. At the level of the ego-safe condition, the interaction between trait anxiety and working memory capacity was non-significant, $F(1, 40) = 0.34$, $p = .564$, $\eta_p^2 = .01$, *power* = .09. However, at the level of the ego-threat condition, the two-way trait anxiety × working memory capacity was significant, $F(1, 40) = 6.42$, $p = .015$, $\eta_p^2 = .14$, *power* = .70. Further follow-up analyses found the simple effect of trait anxiety was non-significant at the level of low working memory capacity, $F(1, 21) = 3.19$, $p = .089$, $\eta_p^2 = .13$, *power* = .40. Similarly, at the level of high working memory capacity the simple effect of trait anxiety was also non-significant, $F(1, 18) = 3.67$, $p = .071$, $\eta_p^2 = .17$, *power* = .44. Though the simple effects were not found to be significant, the independence of the trait anxiety × working memory capacity interaction still suggested that for participants who underwent the ego-threat procedure, the trend of trait anxiety's influence on planning efficiency varied as a function of working memory capacity. The trend of results, as illustrated in Figure 29, demonstrated that at the level of low working memory capacity there was little difference in high and low trait anxiety groups. However, at high working memory capacity, those with high trait anxiety appeared to perform marginally better than those with low trait anxiety.

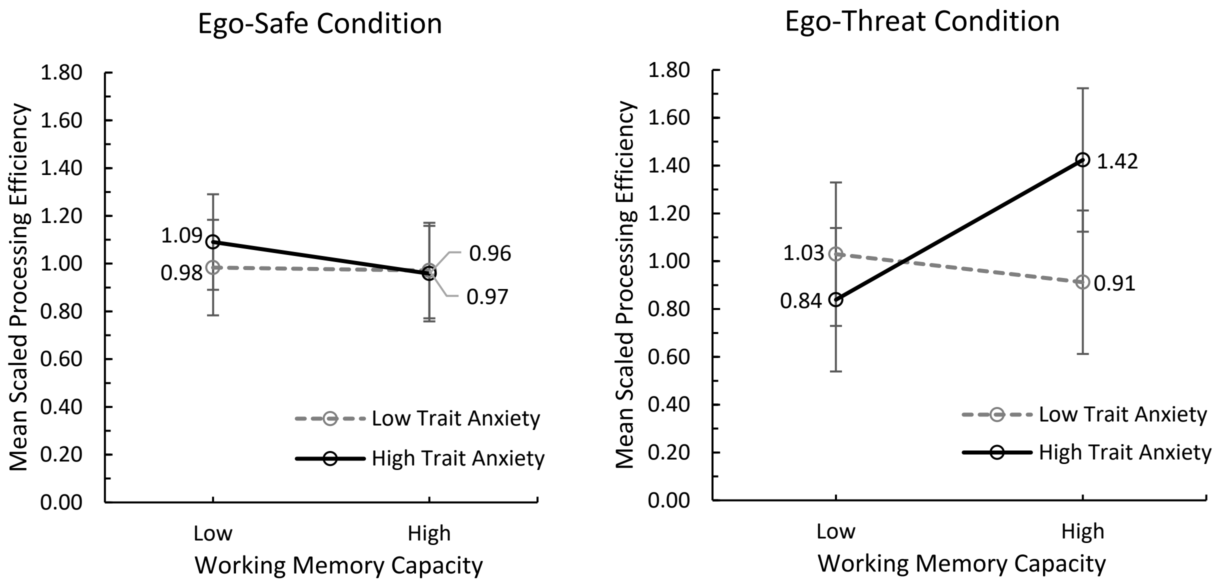

Figure 29. Three-way interaction of trait anxiety × situational stress × working memory capacity for forward planning processing efficiency.

Discussion: Trait Anxiety, Situational Stress, Working Memory Capacity, and Forward Planning

Study 5 aimed to assess the influence of trait anxiety, situational stress, and working memory capacity on planning ability assessed by use of a computerised *N*-puzzle task. While initially cognitive load was to be entered into the analyses, data restrictions led to the decision to simplify the analyses to focus only on trait anxiety, situational stress, and working memory capacity. Two outcome measures of planning ability were assessed including performance effectiveness (standardised accuracy) and processing efficiency (standardised accuracy and standardised RT ratio). A three-way interaction between trait anxiety, situational stress, and working memory capacity was hypothesised. Specifically, at the level of ego-threat, for participants with high working memory capacity, it was expected when compared to low trait anxiety participants, high trait anxiety participants would demonstrate greater performance effectiveness (i.e., higher standardised accuracy values) and lower processing efficiency (i.e., low scores on the processing efficiency ratio). Results found no support for the hypothesis regarding performance effectiveness data, as no significant findings were observed. However, partial support was found for processing efficiency data. While a difference was observed between high and low trait anxiety groups when evaluated at levels of the ego-threat condition and high working memory capacity, this difference was in the opposite direction to what was expected. That is, for participants who underwent the stress manipulation and demonstrated greater working memory capacity, those who self-reported higher trait anxiety performed with better efficiency than those with low trait anxiety.

The lack of difference for performance effectiveness is partially expected by theory. Attentional control theory suggests that high trait anxious participants have the ability, under the correct conditions, to perform at a level greater than or comparable to low trait anxious participants (Derakshan & Eysenck, 2009; Eysenck et al., 2007). This comparable performance is explained by the use of additional cognitive resources recruited through increased effort. The results are also in line with previous work that found no influence of trait anxiety or situational stress on planning effectiveness (Robinson, Vytal, et al., 2013; Van Tol et al., 2011). However, the findings contrast to the earlier Study 2 which also assessed planning ability. In Study 2, while no interactive effects were observed, situational stress was found to independently alter the performance effectiveness of participants. Specifically, participants who underwent the stress induction procedure displayed lower accuracy. The result was relatively robust, accounting for almost a quarter of the variance in accuracy scores. Changes to the trend of performance effectiveness results between studies may be due to different partitioning of variance. Specifically, the substitution of a cognitive load variable for working memory capacity. Alternatively, the differences may be attributable to the change in task. While the one-touch Tower of London task employed in Study 2 is almost functionally identical to the one-touch *N*-Puzzle, the tile configuration of the latter task might have increased the overall difficulty of the planning task. As such, this may have precluded advantages of accuracy in the ego-safe condition over the ego-threat condition.

The processing efficiency results demonstrated that when undergoing stressful situations, high trait anxiety individuals could outperform their low trait anxiety counterparts, but only when demonstrating greater working memory capacity. The results are in opposition to what was expected by theory and literature (Eysenck et al., 2007; Robinson, Vytal, et al., 2013; Van Tol et al., 2011). The findings suggested working memory capacity buffered the impact of trait anxiety on performance, particularly under stressful conditions where greater demand is placed on the individual. The possession of a larger working memory capacity possibly allowed for a greater amount of compensatory cognitive resources to be used in enhancing the efficiency of responses (Gilhooly et al., 2002; Owen et al., 1990; Phillips, 1999; St Clair-Thompson, 2011). Seemingly, not only were these high trait anxiety participants able to elevate their performance effectiveness to a level comparable with the low trait anxiety group, but they were also able to demonstrate faster RTs. This conclusion is made given that no differences in performance effectiveness were found. As such, it is likely the key difference contributing to changes in processing efficiency ratios was the inclusion of RT[45]. The results go beyond the suggestion of attentional control theory that processing

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[45]*Forward planning efficiency* = $\left(\frac{\text{Standardised scaled accuracy}}{\text{Standardised scaled RT}}\right)$

efficiency must be sacrificed for performance effectiveness. Instead, maintenance and improvement of both accuracy and RT was observed, undermining the supposed reliance of these outcome measures.

Overall, the results of the current study suggest trait anxiety, situational stress, and working memory capacity combine to determine the processing efficiency of the planning executive function. Specifically, greater working memory capacity buffers the interactive effects of trait anxiety and situational stress. With greater working memory capacity, under conditions of increased stress higher trait anxious individuals can outperform their low trait anxious peers. It is likely the additional cognitive resources available in combination with the elevated activity of trait anxious individuals that allows them to perform to a higher standard. To date, no work has examined the executive function of planning ability under such intricate conditions. The currents study suggests emotionality can alter complex executive functions like planning. Further, the study also highlights individual differences in working memory capacity can explain facilitated performance in complex tasks of executive function.

Study 6: Trait Anxiety, Situational Stress, Working Memory Capacity, and Hot Decision-Making

Study 6 examined how differences of trait anxiety, situational stress, and working memory capacity might alter trends of decision-making. The study examined the hot-variant of the executive function, that is, decision-making reliant on heuristics and expressive feedback. Both performance effectiveness and processing efficiency outcomes were measured. A brief summary of Study 6's methodology is provided prior to the study results.

Participants and Group Allocation

Participants consisted of 90 undergraduate university students ranging in age from 18 to 56 years (M_{age} = 24.40, *SD* = 8.56). The sample was comprised predominantly of females (68 female, 22 male). Based on arrival to the testing lab, participants were allocated between situational stress conditions. Of the sample, 46 participants were allocated to the ego-threat condition and 44 participants were allocated to the ego-safe condition. When collapsed across all other groups, there was no significant difference in the number of females and males between situational stress conditions, $\chi^2(1) = 0.14$, $p = .905$. There was also no significant difference of age between the ego-threat (*M* = 23.20, *SD* = 7.79) and ego-safe (*M* = 25.73, *SD* = 9.21) conditions, $t(88) = 1.41$, $p = .162$.

High and low trait anxiety groups were decided by a median split procedure. The median value of trait cognitive anxiety amongst the sample was 18.00. Participants who scored below the median were allocated to the low trait anxiety group, while those who scored above the median were allocated to the high trait anxiety group. Eleven participants scored the exact median, however to maintain approximately equal group sizes these participants were allocated to the low trait anxiety group (DeCoster et al., 2011). Ultimately, the low trait anxiety group (*M* = 15.19, *SD* = 2.49) consisted of 47 participants, and the high trait anxiety group (*M* = 23.11, *SD* = 5.42) consisted of 43 participants. There was no significant difference in the number of males and females allocated between trait anxiety groups, $\chi^2(1) = 2.98$, $p = .085$. Further, there was no significant difference in age between the two groups, $t(88) = 0.93$, $p = .356$.

High and low working memory capacity groups were also determined by the use of a median split procedure. The median AOSPAN score for the sample was 42.00. Participants who scored below the median were allocated to the low working memory capacity group, and those who scored above were allocated to the high working memory capacity group. Three participants scored the exact median, though to maintain approximately equal group sizes these participants were allocated to the low working memory capacity group (DeCoster et al., 2011). Forty-six participants were therefore assigned to the low working memory capacity group ($M = 30.00$, $SD = 7.98$), while 44 participants were allocated to the high working memory capacity group ($M = 58.39$, $SD = 7.33$). Analyses found no significant difference in the number of males and females between groups, $\chi^2(1) = 0.37$, $p = .541$. Also, no significant difference in age was found between the groups, $t(88) = 0.42$, $p = .677$. A summary of the sample's demographic information split by each cell of the design is presented in Table 24 (overleaf).

Table 24

Demographics for Cells of Situational Stress (Ego-Safe vs. Ego-Threat) × Trait Anxiety (High vs. Low) × Working memory Capacity (High vs. Low) for Hot Decision-Making Study

	Ego-Safe				**Ego-Threat**			
	Low Trait Anxiety		**High Trait Anxiety**		**Low Trait Anxiety**		**High Trait Anxiety**	
	Low WMC	**High WMC**	**Low WMC**	**High WMC**	**Low WMC**	**High WMC**	**Low WMC**	**High WMC**
	n = 12	*n* = 11	*n* = 11	*n* = 10	*n* = 14	*n* = 10	*n* = 9	*n* = 13
M_{Age} (*SD*)	29.00 (8.21)	21.91 (4.11)	23.09 (9.70)	28.90 (12.16)	24.79 (9.58)	25.00 (11.40)	21.33 (3.64)	21.38 (3.12)
Females	9	7	11	8	10	6	8	11
Males	3	4	2	3	4	4	1	2

Note. WMC = Working Memory Capacity

Materials

Questionnaires. Participants were provided with a battery of questionnaires to complete, inclusive of the STICSA[46] (Ree et al., 2008), the DASS-21[47] (Lovibond & Lovibond, 1995), and the Stress Rating Questionnaire (Edwards, Edwards, et al., 2015). Scores derived from the STICSA's trait-cognitive subscale were used to determine allocation to high/low trait anxiety groupings. The STICA's state-cognitive subscale was used in the manipulation check of the study's situational stress induction (described below). Scores from the Stress Rating Questionnaire was also used in the manipulation check. The depression subscale of the DASS-21 was included to isolate depression symptomatology as a possible covariate of results. Further detail regarding measurement descriptions, including scoring procedures and psychometric properties, is provided in Chapter Three.

[46] State-Trait Inventory of Cognitive and Somatic Anxiety
[47] Depression Anxiety Stress Scale – 21 Items

Modified Iowa Gambling Task (IGT). Hot decision-making was evaluated using the IGT. A modified, computerised version (devised by Cauffman et al., 2010) was chosen that allowed for exhaustive sampling of all decision-making options and one-touch responding. Participants were presented four digital card decks, each resulting in either a financial-based gain or loss. Decks A and B were disadvantageous and produced a net loss over repeated play. Decks C and D were advantageous and produced a net profit over repeated play. At the start of each trial, an arrow appeared randomly over one of the four decks. Participants could then decide to play the deck, or pass. If the deck was played, participants received feedback indicating the amount won or lost. Further details regarding the task protocol, payoff variations of each individual deck, and example task layout are presented in Chapter Six.

Automatic Operation Span (AOSPAN; Unsworth et al., 2005). The AOSPAN is a cognitive task designed to assess working memory capacity. The computerised task is a complex-span measure, in that it is comprised of both a primary memory task and secondary distraction task. The AOSPAN used in the current work used a letter-based serial recall task as its primary memory task. The secondary task required the mental calculation of mathematic problems. Greater scores on the AOSPAN are indicative of greater working memory capacity. Full details of the task protocol and procedure are presented in Chapter Six.

Experimental Setup

Task stimuli were presented on a 19-inch LCD desktop screen. Responses to the IGT and AOSPAN were made using mouse and keyboard. Participants were tested individually.

Procedure

At the commencement of the study, participants were provided an explanatory statement and consent form. Following this, participants were screened for depression symptomatology using the DASS-21. No participants demonstrated scores ≥ 28 (i.e., "extremely severe) and so all were able to continue. For the retained participants, all continued to complete the STICSA, the Stress Rating Questionnaire, and the AOSPAN. Based on arrival order, participants were -allocated alternately to either the ego-safe (control condition) or ego-threat condition (situational stress manipulation) to maintain balanced groups. Participants in the ego-safe condition received task-relevant information. Participants in the ego-threat condition were informed they were completing a test of intelligence. Ego-threat participants were also informed their performance on the AOSPAN appeared worse compared to prior participants. Following the situational stress induction, participants completed the Stress Rating Questionnaire again. All participants continued to complete the IGT. At the completion of the study, participants were debriefed and released.

Situational Stress Manipulation

Evaluation of the situational stress manipulation was conducted using a mixed-design 2 (time; baseline vs. post-manipulation) × 2 (group; ego-threat vs. ego safe) ANOVA. Total Stress Rating Questionnaire values were the dependent variable. The main effect of time was found to be significant, $F(1, 88) = 27.66$, $p < .001$, $\eta^2_p = .24$, *power* = .99. The main effect of group was non-significant, $F(1, 88) = 0.63$, $p = .428$, $\eta^2_p = .01$, *power* = .12. Results demonstrated the two-way time × group interaction was non-significant, $F(1, 88) = 0.85$, $p = .360$, $\eta^2_p = .01$, *power* = .15. That is, the change in Stress Rating Questionnaire scores from the baseline to post-manipulation time points was comparable for both ego-safe and ego-threat conditions. Averaged across groups, Stress Rating Questionnaire scores were higher at the post-manipulation time point ($M = 16.17$, $SD = 7.51$) compared to the baseline ($M = 12.61$, $SD = 5.35$). Mean Stress Rating Questionnaire scores for each group at both baseline and post-manipulation are displayed in Figure 30. Both ego-safe and ego-threat conditions showed a comparable increase in Stress Rating Questionnaire scores across time.

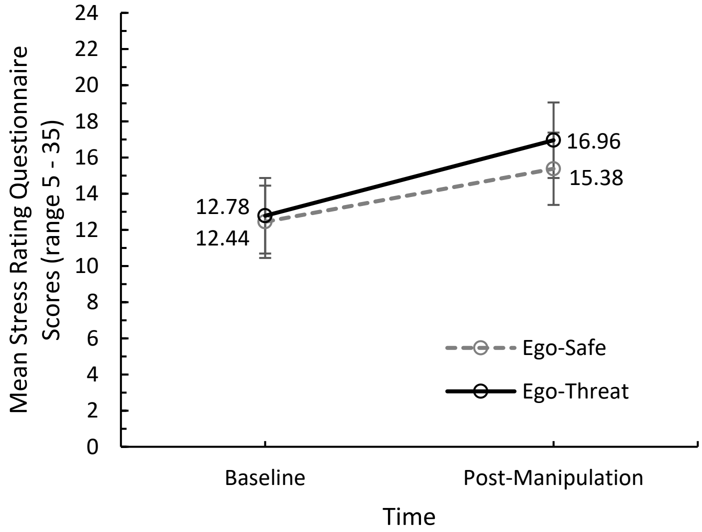

Figure 30. Linear trend of time at each level of situational stress condition for Stress Rating Questionnaire scores during the hot decision-making task. Error bars represent 95% confidence intervals.

Results

Measurement of Hot Decision-Making

Hot decision-making effectiveness. Prior literature has suggested IGT performance from trial 41 onward is the best representation of the executive function qualities of the task, while the initial 40 trials operate as a learning/practice phase (Gansler et al., 2011). As such, calculation of hot decision-making effectiveness incorporated only scores from trials 41 to 120. Hot decision-making effectiveness was operationalised as the preference to select advantageous choices over disadvantageous distractors. The sum of advantages selections (decks C and D) was subtracted from the sum of disadvantageous selections (decks A and B). Higher values were indicative of more advantageous (and risk-aversive) decision-making:

Hot decision-making effectiveness = (decks *C* + *D*) – (decks *A* + *B*)

Following this calculation, scores were transformed into *z*-scores before being translated into a positive range by an increase of +3.00 units. This additional scaling was used to aid interpretability.

Hot decision-making efficiency. Hot decision-making efficiency values were operationalised as a ratio between performance effectiveness and RT. RT data were standardised and scaled in the same manner as effectiveness scores. Standardised and scaled performance effectiveness scores were divided by the standardised and scaled RTs, as per the following calculation:

$$\textit{Hot decision-making efficiency} = \left(\frac{\text{Standardised scaled decision-ratio}}{\text{Standardised scaled RT}}\right)$$

Data Diagnostics

Data were first cleaned at the level of individual trials. Trials with RTs less than 200ms (considered anticipatory) ± 3.00 *SD*s from the participant's mean were removed prior to analyses. This constituted < 1% of trials. Univariate outliers were screened for as *z*-scores with values ±3.00. No univariate outliers were identified, nor were any multivariate outliers via calculation of Mahalanobis' Distance.

The assumption of normality was assessed using the Shapiro-Wilk test. Results found the assumption of normality to be violated within the low working memory capacity/ego-safe/high anxiety cell for the performance effectiveness outcome. The normality assumption was also not met in the high working memory capacity/ego-threat/low trait anxiety cell for performance effectiveness data. There was a final violation of normality in the high working memory capacity/ego-threat/high trait anxiety cell for the processing efficiency outcome. All other cells met the assumption of normality for both performance effectiveness and processing efficiency outcome variables. Despite the few violations, as ANOVA is robust to violations of normality no transformation was conducted on the data (Tabachnick & Fidell, 2019). Missing data analyses found no cases of missing values for either accuracy or RT data. Analyses were conducted using SPSS version 26 and an applied significance level of $\alpha \leq .050$ for all findings.

Main Analysis, Standardised Hot Decision-Making Effectiveness

A between-subjects 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 2 (working memory capacity; low vs. high) three-way ANCOVA was run, with the dependent variable as decision-making effectiveness. The depression covariate was non-significant at all levels of the analysis and was not interpreted further. Levene's test for homogeneity of variance was found to be met, $F(7, 82) = 0.42$, $p = .890$. Descriptive statistics for performance effectiveness values across all groups are displayed in Table 25.

Table 25

Means and Standard Deviations of Standardised Performance Effectiveness Values on Hot Decision-Making Task Across All Trait Anxiety, Situational Stress, and Working Memory Capacity Groups

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
Low Working Memory Capacity	3.05 (0.91)	2.81 (1.26)	3.59 (0.91)	3.05 (1.08)
High Working Memory Capacity	2.73 (1.05)	2.85 (1.16)	2.92 (0.57)	2.84 (0.97)

Analyses demonstrated the main effect of trait anxiety to be non-significant, $F(1, 81) = 0.14$, $p = .714$, $\eta_p^2 < .01$, *power* = .07. The main effect of situational stress was non-significant, $F(1, 81) = 1.33$, $p = .252$, $\eta_p^2 = .02$, *power* = .21. The main effect of working memory capacity was also non-significant, $F(1, 81) = 1.32$, $p = .254$, $\eta_p^2 = .02$, *power* = .21.

Likewise, the trait anxiety × situational stress interaction was non-significant, $F(1, 80) = 0.41$, $p = .525$, $\eta_p^2 = .01$, *power* = .10. The interaction between trait anxiety and working memory capacity was non-significant, $F(1, 81) = 1.40$, $p = .240$, $\eta_p^2 = .02$, *power* = .22. Similarly, the situational stress × working memory capacity interaction was non-significant, $F(1, 81) = 0.72$, $p = .401$, $\eta_p^2 = .01$, *power* = .13. Finally, the three-way interaction between all study variables was non-significant as well, $F(1, 81) < 0.01$, $p = .951$, $\eta_p^2 < .01$, *power* = .05.

Main Analysis, Standardised Hot Decision-Making Efficiency

A three-way between-subjects 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 2 (working memory capacity; low vs. high) ANCOVA was conducted. Decision-making efficiency scores were entered as the dependent variable. The depression covariate was non-significant at all levels of the analysis. The assumption of homogeneity of variance was found to be met for the analysis as Levene's test was non-significant, $F(7, 82) = 0.68$, $p = .684$. Descriptive statistics for efficiency values across all groups are displayed in Table 26.

Table 26

Means and Standard Deviations of Standardised Processing Efficiency Values on Hot Decision-Making Task Across All Trait Anxiety, Situational Stress, and Working Memory Capacity Groups

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
Low Working Memory Capacity	1.17 (0.47)	1.10 (0.48)	1.21 (0.52)	0.97 (0.37)
High Working Memory Capacity	0.88 (0.37)	1.17 (0.72)	1.14 (0.54)	1.17 (0.55)

Results found the main effect of trait anxiety was non-significant, $F(1, 81) < 0.01$, $p = .955$, $\eta_p^2 < .01$, *power* = .05. The main effect of situational stress was also found to be non-significant, $F(1, 81) = 0.12$, $p = .729$, $\eta_p^2 < .01$, *power* = .06. The main effect of working memory capacity was non-significant, $F(1, 81) = 0.06$, $p = .806$, $\eta_p^2 < .01$, *power* = .06. The trait anxiety × situational stress interaction was found to be non-significant, $F(1, 81) = 0.91$, $p = .342$, $\eta_p^2 = .01$, *power* = .16. The trait anxiety × working memory capacity was also non-significant, $F(1, 81) = 1.90$, $p = .172$, $\eta_p^2 = .02$, *power* = .28. The situational stress × working memory capacity interaction was non-significant, $F(1, 81) = 0.74$, $p = .392$, $\eta_p^2 = .01$, *power* = .14. The three-way interaction between trait anxiety, situational stress, and working memory capacity was also found to be non-significant, $F(1, 81) = 0.05$, $p = .829$, $\eta_p^2 < .01$, *power* = .06.

Discussion: Trait Anxiety, Situational Stress, Working Memory Capacity, and Hot Decision-Making

Study 6 examined the influence – independently and interactively – of trait anxiety, situational stress, and working memory capacity on the performance of a hot decision-making task. The IGT[48] was used to operationalise hot decision-making, with two outcome measures were assessed including performance effectiveness and processing efficiency. The IGT does not offer an estimate of accuracy. Therefore, performance effectiveness was indexed as the difference between advantageous and disadvantageous decision-making. A more advantageous, or risk-avoidant, decision-style was interpreted to be indicative of greater performance effectiveness. Processing efficiency was assessed as the ratio of performance effectiveness and RT[49]. A three-way interaction between all study variables (trait anxiety, situational stress, working memory capacity) was expected for both performance effectiveness and processing efficiency. Specifically, at the level of the ego-threat condition, at higher levels of working memory capacity, higher trait anxiety participants were predicted to shower greater performance effectiveness but lower processing efficiency compared to low trait anxiety participants. The results did not support either the performance effectiveness or processing efficiency hypotheses, as no significant results were observed in Study 6.

The results contrast with the predictions of attentional control theory regarding the influence of trait anxiety and situational stress on tasks reliant on the central executive. However, the predictions of attentional control theory ultimately rely on accuracy-based

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[48] Iowa gambling task

[49] Hot decision-making efficiency = $\left(\frac{\text{Standardised scaled decision-ratio}}{\text{Standardised scaled RT}}\right)$. The greater the proclivity to choose advantageous decisions, the higher the decision ratio entered as the ratio numerator. As such, greater scores of processing efficiency remain indicative of greater performance effectiveness combined with lower RTs, even in the absence of more traditional accuracy-based effectiveness values.

measures of performance effectiveness. As such, the decision-preference outcome produced by the IGT might have been an incompatible choice. This limitation is based more so in a critique of the general hot decision-making literature, as no accuracy-based alternative task was readily available (see Table 4 of Chapter Two). Alternatively, the findings of the current research could represent a true null result.

The lack of significant results was in contrast with prior work that had found significant associations between hot decision-making preferences and trait anxiety (Giorgetta et al., 2012; Heilman et al., 2010; Maner et al., 2007; Miu et al., 2008) as well as working memory capacity (Bagneux et al., 2013; Bechara & Martin, 2004). The lack of cohesion with prior work may be due to operational differences. For example, the work of Maner et al. (2007) used the BART[50] to assess hot decision-making. Unlike the IGT which offers a series of card decks to select from, the BART does not promote choices between competing options. However, other works like Miu et al. (2008) and Zhang et al. (2015) found a significant association between trait anxiety and decision-preference when also using the IGT in sub-clinical samples. Of note though, both works used variations of the IGT that rely on participant-guided selection rather than randomised computer selection. That is, while Miu et al. used a manual task and Zhang et al. used a computer-based task, both studies allowed the participants to select which decks to sample. A limitation of this approach is that participants may not sample every deck, continuing to choose a single option without exploring the alternate options. As such, the decision-making process is incomplete and individual participants operate on different ruleset formations. In the current study, participants were exposed to all possible deck choices in a randomised order. Perhaps in such circumstances where participant-driven biases are not allowed to develop fully, the risk-avoidant/approach

[50] Balloon analogue risk task

preferences are lost. Comparison of processing efficiency results cannot be made, as prior work did not include RT measures.

It is unclear why the current study was unable to replicate previous findings that found an association between hot decision-making and working memory capacity. In work by Bagneux et al. (2013), the same modified IGT task was used as the current study. However, Bagneux and colleagues estimated working memory capacity by use of three complex-span measures that were subsequently standardised into a single outcome variable. Potentially the different operationalisation of working memory capacity contributed to the difference. While the use of multiple complex-span tasks has been suggested to provide a stronger estimate of working memory (Conway et al., 2005) use of only the AOSPAN in the current work was chosen for feasibility. In defence, the AOSPAN alone demonstrates sound psychometrics (Redick, Unsworth, et al., 2012; Unsworth et al., 2005). Alternatively, while Bagneux and colleagues only examined working memory capacity and trial sequence, the current work included trait anxiety, situational stress, and depression. Changes to the variance within the ANOVA model might have precluded working memory capacity from being flagged as significant. Bagneux et al. did not measure RT of participants, limiting comparison of processing efficiency findings.

Ultimately, the current study found variations of trait anxiety, situational stress, and working memory capacity did not alter the performance effectiveness or processing efficiency of hot decision-making. The incompatibility with prior literature may have possibly been due to inconsistency of measures. Alternatively, there might be no influence of trait anxiety, situational stress, or working memory capacity on hot decision-making when the function is evaluated using the specific form of effectiveness and efficiency measures selected for the research. However, no comparison could be made to prior literature regarding processing efficiency estimates. Most literature examining hot decision-making emphasised the decision-preference over the efficiency of responses. As such, many do not measure RT information. Future research could extend the current work to examine if the findings of the current work pertaining to processing efficiency are replicable. Finally, a key issue with Study 6 which might have also contributed to the pattern of results was the inefficacy of the situational stress manipulation. For both the ego-safe and ego-threat conditions, participants reported a significant increase in situational stress. As such, levels of the manipulated variable were more likely to be analogous. Future work may wish to extend the current study with the use of an alternate situational stress manipulation.

Study 7: Trait Anxiety, Situational Stress, Working Memory Capacity, and Sustained Attention

Study 7 focused on sustained attention, indexed using a continuous performance task. The study examined how variations of trait anxiety, situational stress, and working memory capacity might disrupt performance effectiveness and processing efficiency outcome measures. A brief summary of Study 7's methodology is provided before detailing the study's results.

Participants and Group Allocation

Participants consisted of 90 undergraduate students. The sample was predominantly female (69 female, 21 male) and ranged in age from 18 to 56 years (M_{Age} = 24.51, *SD* = 1.23). Based on arrival to the testing lab, participants were assigned to one of two situational stress conditions. Forty-five individuals were allocated to the ego-safe condition, and 45 were allocated to the ego-threat condition. Collapsed across all other groups, there was an equal allocation of both males and females between situational stress conditions, $\chi^2(1) = 0.00$, $p = 1.00$. There was also no significant difference of age between the ego-safe (*M* = 25.18, *SD* = 9.06) and ego-threat conditions (*M* = 23.44, *SD* = 7.36), $t(88) = 1.00$, $p = .322$.

To determine high and low trait anxiety groups, a median split procedure was used. The median of the trait cognitive anxiety variable was found to be 18.00. As such, participants who scored below 18 were allocated to the low trait anxiety group, and those who scored 19 or above were allocated to the high trait anxiety group. Participants who had scored the median were assigned to the low trait anxiety group to maintain approximately equal group sizes (DeCoster et al., 2011). Overall, 48 participants were assigned to the low trait anxiety group (*M* = 15.23, *SD* = 2.48) and 42 participants were assigned to the high trait anxiety group (*M* = 23.13, *SD* = 4.89). Collapsed across all over groups, there was found to be no significant difference in the number of males or females allocated between trait anxiety groups, $\chi^2(1) = 1.03$, $p = .310$. Further, there was no significant difference of age between the low ($M = 24.53$, $SD = 7.68$) and high trait anxiety groups ($M = 24.09$, $SD = 8.86$), $t(88) = 0.25$, $p = .800$.

High and low working memory capacity groups were also created using a median split process. The median of AOSPAN scores was 42.00. Participants scoring below the median were allocated to the low working memory capacity group and those scoring above were allocated to the high working memory capacity group. Participants who scored the median value ($n = 3$) were allocated to the low working memory capacity group. Overall, 44 participants were assigned to the low working memory capacity group ($M = 28.66$, $SD = 8.11$) and 46 to the high working memory capacity group ($M = 57.43$, $SD = 8.55$). When collapsed across all other variables, there was found to be no significant difference in the number of males or females allocated to each condition, $\chi^2(1) = 0.54$, $p = 463$. No significant difference of age was found between the low ($M = 24.91$, $SD = 8.67$) and high working memory capacity groups ($M = 23.65$, $SD = 7.82$), $t(88) = 0.72$, $p = .471$. A summary of the demographic information of the sample across each cell of the study design is presented in Table 27.

Table 27

Demographics for Cells of Situational Stress (Ego-Safe vs. Ego-Threat) × Trait Anxiety (High vs. Low) × Working memory Capacity (High vs. Low) for Sustained Attention Study

	Ego-Safe				**Ego-Threat**			
	Low Trait Anxiety		**High Trait Anxiety**		**Low Trait Anxiety**		**High Trait Anxiety**	
	Low WMC	**High WMC**	**Low WMC**	**High WMC**	**Low WMC**	**High WMC**	**Low WMC**	**High WMC**
	n = 13	*n* = 10	*n* = 12	*n* = 11	*n* = 13	*n* = 12	*n* = 9	*n* = 10
M_{Age} (*SD*)	26.08 (6.84)	24.20 (8.30)	26.08 (11.38)	25.82 (10.69)	25.08 (9.90)	25.00 (8.97)	20.44 (1.81)	21.80 (3.36)
Females	10	7	10	8	10	8	8	8
Males	3	3	2	3	3	4	1	2

Note. WMC = Working Memory Capacity

Materials

Questionnaires. Participants completed a series of questionnaires that included the STICSA[51] (Ree et al., 2008), DASS-21[52] (Lovibond & Lovibond, 1995), and the Stress Rating Questionnaire (Edwards, Edwards, et al., 2015). Scores derived from the STICSA's trait-cognitive subscale were used to determine the assignment of participants to high/low trait anxiety groups. The STICA's state-cognitive subscale was included in the manipulation check of the study's situational stress induction (described below). Scores from the Stress Rating Questionnaire were also included in the manipulation check. The DASS-21 depression subscale was used to isolate depression symptomatology as a possible covariate during analyses. Further information on measurement descriptions, scoring procedures, and psychometric properties is provided in Chapter Three.

[51] State-Trait Inventory of Cognitive and Somatic Anxiety
[52] Depression Anxiety Stress Scale – 21 Items

Test of Variables of Attention (TOVA). Sustained attention was evaluated in the current work by use of the TOVA. The TOVA is a continuous performance task, requiring participants to observe an uninterrupted sequence of visual stimuli. Participants are required to discriminate between two visual stimuli, one representing a target and the other a distractor. Participants are instructed to give a button-press response when they identify the target on-screen. When distractor stimuli are presented, participants are told to withhold their response. The TOVA consists of one block of 640 trials, comprised of 320 targets and 320 distractors. The first half of the task features frequent distractors and infrequent targets, while the second half presents infrequent distractors and frequent targets. Task duration is approximately 23 minutes and includes no rest-periods. Further details of the TOVA protocol and example stimuli are provided in Chapter Six.

Automatic Operation Span (AOSPAN; Unsworth et al., 2005). The AOSPAN is a computerised cognitive task designed to measure working memory capacity. The task is a complex-span measure, comprised of both a primary memory task and secondary distraction task. The AOSPAN used in the current work employed a letter-based serial recall task as its primary memory task. The secondary task required mental calculation of mathematic problems. Greater scores on the AOSPAN are indicative of greater working memory capacity. Full details of the task protocol and procedure are presented in Chapter Six.

Experimental Setup

Task stimuli were presented on a 19-inch LCD desktop screen. Responses to the TOVA were made using a keyboard. Responses to the AOSPAN were made using both a mouse and keyboard. Participants were tested individually.

Procedure

At the beginning of the study, participants were provided with an explanatory statement and consent form. Following this, participants were asked to complete the DASS-21. No participants demonstrated scores ≥ 28 (i.e., “extremely severe) on the depression subscale, therefore no participants were excluded. For the remaining participants, all completed the STICSA, Stress Rating Questionnaire, and the AOSPAN. Based on arrival, participants were allocated alternately to either the ego-safe (control condition) or ego-threat condition (situational stress manipulation). Participants in the ego-safe condition received task-relevant information. Participants in the ego-threat condition were informed they were completing a test of intelligence. Ego-threat participants were also told their performance on the AOSPAN was poor compared to prior participants. Following the ego-threat or task-relevant instruction, participants completed the Stress Rating Questionnaire again. All participants continued to complete the TOVA. At the completion of the study, participants were debriefed and thanked for their time.

Situational Stress Manipulation

The situational stress manipulation was assessed using a 2 (time; baseline vs. post-manipulation) × 2 (group; ego-threat vs. ego safe) mixed-design ANOVA. Total Stress Rating Questionnaire values were entered as the dependent variable. The main effect of time was found to be significant, $F(1, 88) = 24.71$, $p < .001$, $\eta_p^2 = .22$, *power* => 1.00. The main effect of group was non-significant, $F(1, 88) = 1.84$, $p = .179$, $\eta_p^2 = .02$, *power* = .27. Results also demonstrated the time × group interaction was significant, $F(1, 88) = 4.41$, $p = .039$, $\eta_p^2 = .05$, *power* = .55. Follow-up within-subject contrasts demonstrated the linear trend of time varied as a function of group (ego-safe vs. ego-threat). Average Stress Rating Questionnaire scores for both groups at baseline and post-manipulation time points are displayed in Figure

31. For the ego-threat condition, 95% CIs showed no overlap suggesting a significant increase in Stress Rating Questionnaire values across time. However, for the ego-safe group the 95% CIs demonstrated overlap, indicating the slight increase in Stress Rating Questionnaire scores over time was non-significant.

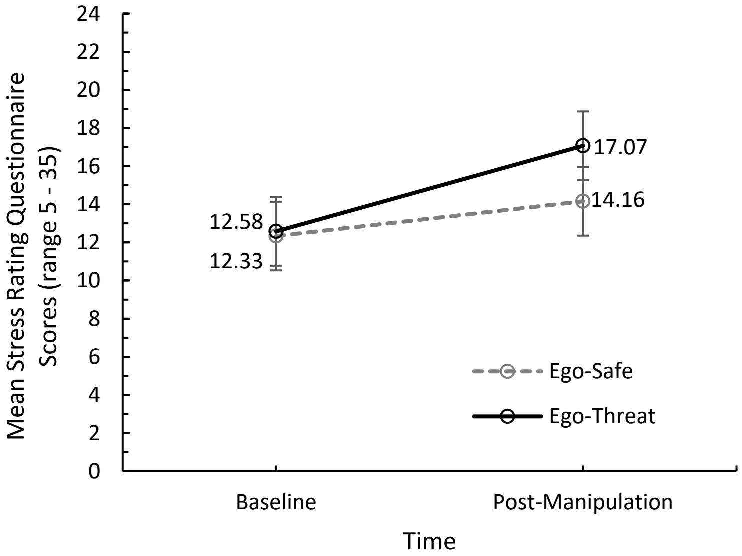

Figure 31. Linear trend of time at each level of situational stress condition for Stress Rating Questionnaire scores during the sustained attention task. Error bars represent 95% confidence intervals.

Results

Measurement of Sustained Attention

Sustained attention effectiveness.

Performance effectiveness scores of the sustained attention task were derived using the sensitivity index *d'*. The calculation is a measure of sensitivity and is derived from signal detection theory (see Pastore & Scheirer, 1974). The measure evaluates the differences of correct signal identification (hit, correct rejection) and noise-related errors (false alarm, miss; Stanislaw & Todorov, 1999). Calculation of *d'* was carried out in accordance with the

TOVA's professional manual (Leark et al., 2007). Though intermediary steps are not reproduced here, ultimately the calculation of *d'* may be summarised as:

Sustained attention effectiveness = *z*(Hit) - *z*(False Alarm)

Values of *d'* were subsequently standardised and scaled into a positive range by the addition of 3.00 units.

Sustained attention efficiency. Processing efficiency values of sustained attention were calculated as the ratio between performance effectiveness (*d'*) and RT variability. The TOVA emphasises RT variability as a more informative index of sustained attention performance compared to average RT (Leark et al., 2007). RT variability values were standardised and scaled by the addition of 3.00 units. The final processing efficiency values were determined using the following ratio calculation:

$$\textit{Sustained attention efficiency} = \left(\frac{\text{Standardised scaled } d'}{\text{Standardised scaled RT variability}}\right)$$

Data Diagnostics

The dataset was cleaned first at the level of individual trials. Trials with RTs less than 200ms or ± 3.00 *SD*s from the participant's mean were removed before the main analyses. Overall, this comprised < 1% of trials. Once data were collated, univariate outliers were screened for by calculation of *z*-scores. Values ± 3.00 were considered to be extreme outliers, however no cases met this criterion. Further, calculation of Mahalanobis' Distance did not identify any multivariate outliers.

The assumption of normality was assessed by use of the Shapiro-Wilk test. The assumption of normality was found to be met at all cells of the design. Missing data analyses found no cases of missing values for either accuracy or RT data. All analyses were conducted using SPSS version 26. An α-level of ≤ .050 was set to determine significance for all findings.

Main Analysis, Standardised Sustained Attention Effectiveness

A three-way mixed-design 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 2 (working memory capacity; low vs. high) ANCOVA was conducted on sustained attention performance effectiveness values. The depression covariate was found to be non-significant and was not interpreted further. The assumption of homogeneity of variance was found not to be met by Levene's test, $F(7, 82) = 2.68$, $p = .015$. However, given that ANOVA is robust to violations of this assumption when cell sizes are approximately equal, analyses were continued without transformation of data (Tabachnick & Fidell, 2019). Descriptive statistics for performance effectiveness values across all groups are summarised in Table 28.

Table 28

Means and Standard Deviations of Standardised Performance Effectiveness Values on Sustained Attention Task Across All Trait Anxiety, Situational Stress, and Working Memory Capacity Groups

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	M **(*SD*)**	***M*** **(*SD*)**	***M*** **(*SD*)**	***M*** **(*SD*)**
Low Working Memory Capacity	2.88 (1.25)	2.78 (1.24)	3.16 (0.89)	2.49 (1.16)
High Working Memory Capacity	3.19 (0.55)	2.94 (0.84)	2.81 (0.72)	3.76 (0.91)

Results demonstrated the main effect of trait anxiety to be non-significant, $F(1, 81) = 0.03$, $p = .874$, $\eta_p^2 < .01$, *power* = .05. The main effect of situational stress was also found to be non-significant, $F(1, 81) = 0.28$, $p = .601$, $\eta_p^2 < .01$, *power* = .08. The main effect of working memory capacity was also non-significant, $F(1, 81) = 2.99$, $p = .087$, $\eta_p^2 = .04$, *power*

= .40. The two-way interaction between trait anxiety and situational stress was not significant, $F(1, 81) = 0.51$, $p = .478$, $\eta_p^2 = .01$, *power* = .11. Similarly, the interaction between trait anxiety and working memory capacity was found to be non-significant, $F(1, 81) = 3.27$, $p = .074$, $\eta_p^2 = .04$, *power* = .43. The interaction between situational stress and working memory capacity was also not significant, $F(1, 81) = 0.20$, $p = .660$, $\eta_p^2 < .01$, *power* = .07. The three-way interaction between trait anxiety, situational stress, and working memory capacity was however found to be significant, $F(1, 81) = 4.27$, $p = .042$, $\eta_p^2 = .05$, *power* = .53. The interaction between all three study variables accounted for approximately 5% of the variance in performance effectiveness scores.

To follow-up the three-way interaction (illustrated in Figure 32), the data were first split by situational stress. At the level of the ego-safe condition, the simple interaction between trait anxiety and working memory capacity was non-significant, $F(1, 81) = 0.06$, $p = .802$, $\eta_p^2 < .01$, *power* = .06. However at the level of the ego-threat condition, the two-way interaction was significant, $F(1, 81) = 8.68$, $p = .005$, $\eta_p^2 = .18$, *power* = .82. Further follow-ups at the ego-threat condition found the simple effect of trait anxiety was non-significant at the level of low working memory capacity, $F(1, 81) = 1.49$, $p = .237$, $\eta_p^2 = .07$, *power* = .21. However, the simple effect of trait anxiety was significant at the level of high working memory capacity, $F(1, 81) = 4.53$, $p = .047$, $\eta_p^2 = .19$, *power* = .52. Specifically, for participants undergoing the ego-threat procedure who demonstrated greater working memory capacity, those in the high anxiety group demonstrated better target sensitivity ($M = 3.76$, $SD = 0.91$) compared to the low trait anxiety group ($M = 2.81$, $SD = 0.72$). This trend of results can be seen in the illustration of the interaction presented in Figure 32 (overleaf).

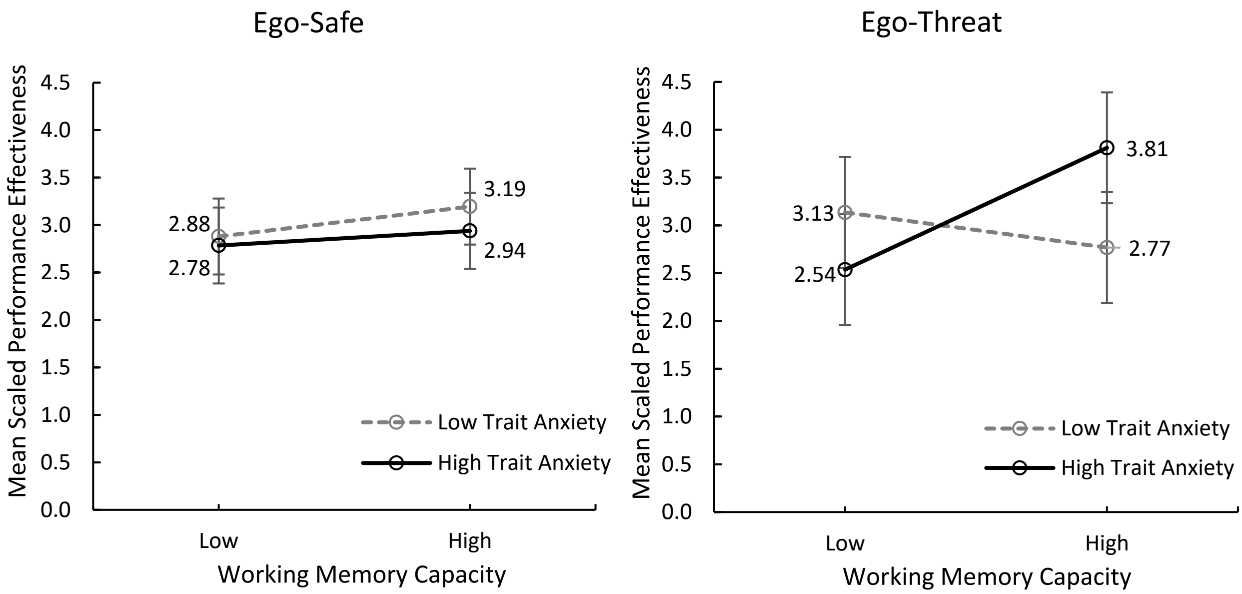

Figure 32. Three-way interaction of trait anxiety × situational stress × working memory capacity for sustained attention performance effectiveness.

Main Analysis, Standardised Sustained Attention Efficiency

A three-way 2 (trait anxiety; low vs. high) × 2 (situational stress; ego-safe vs. ego-threat) × 2 (working memory capacity; low vs. high) between-subjects ANCOVA was conducted with sustained attention processing efficiency values as the dependent variable. The addition of the depression covariate was found to be non-significant and was not interpreted further. Levene's test found the assumption of homogeneity of variance not to be met, $F(7, 82) = 1.23$, $p = .295$. Descriptive statistics for processing efficiency values across all groups are displayed in Table 29.

Table 29

Means and Standard Deviations of Standardised Processing Efficiency Values on Sustained Attention Task Across All Trait Anxiety, Situational Stress, and Working Memory Capacity Groups

	Ego-Safe		**Ego-Threat**	
	Low Trait Anxiety	**High Trait Anxiety**	**Low Trait Anxiety**	**High Trait Anxiety**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
Low Working Memory Capacity	0.97 (0.49)	0.97 (0.43)	1.15 (0.38)	0.83 (0.58)
High Working Memory Capacity	1.28 (0.49)	0.94 (0.34)	1.06 (0.29)	1.65 (0.62)

Results found the main effect of trait anxiety to be non-significant, $F(1, 81) = 0.07$, $p = .787$, $\eta_p^2 < .01$, *power* = .06. The main effect of situational stress was also non-significant, $F(1, 81) = 1.88$, $p = .174$, $\eta_p^2 = .02$, *power* = .27. The main effect of working memory capacity was found to be significant, $F(1, 81) = 7.41$, $p = .008$, $\eta_p^2 = .08$, *power* = .77. Participants from the high working memory capacity group demonstrated greater processing efficiency scores ($M = 1.22$, $SD = 0.50$) compared to the low working memory capacity group ($M = 0.99$, $SD = 0.47$). The two-way trait anxiety × situational stress interaction was not significant, $F(1, 81) = 2.18$, $p = .143$, $\eta_p^2 = .03$, *power* = .31. Likewise, the trait anxiety × working memory capacity interaction was also non-significant, $F(1, 81) = 2.50$, $p = .118$, $\eta_p^2 = .03$, *power* = .35. The situational stress × working memory capacity interaction was also non-significant, $F(1, 81) = 0.91$, $p = .344$, $\eta_p^2 = .01$, *power* = .16. The three-way trait anxiety × situational stress × working memory capacity interaction was found to be significant, *F*(1,

81) = 9.88, p = .002, η_p^2 = .11, *power* = .87. The three-way interaction between all study variables accounted for approximately 11% of variance in processing efficiency scores.

Follow-up analyses of the three-way interaction (as shown in Figure 33) began with splitting the data by situational stress. For the ego-safe condition, the simple two-way interaction between trait anxiety and working memory capacity was non-significant, $F(1, 81) = 1.40$, p = .244, η_p^2 = .03, *power* = .21. In contrast, at the level of the ego-threat condition the trait anxiety × working memory capacity interaction was significant, $F(1, 81) = 10.35$, p = .003, η_p^2 = .21, *power* = .88. Additional follow-up analyses within the ego-threat condition found at the level of low working memory capacity the simple effect of trait anxiety was non-significant, $F(1, 81) = 1.54$, p = .229, η_p^2 = .08, *power* = .22. At the level of high working memory capacity, the simple effect of trait anxiety was significant, $F(1, 81) = 6.22$, p = .022, η_p^2 = .25, *power* = .66. This trend of results can be seen in the illustration of the three-way interaction presented in Figure 33. For participants undergoing the ego-threat procedure, and who demonstrated greater working memory capacity by allocation to the high working memory capacity group, those allocated to the high anxiety group demonstrated better processing efficiency on the sustained attention task (M = 1.65, SD = 0.62) compared to the low trait anxiety group (M = 1.06, SD = 0.29).

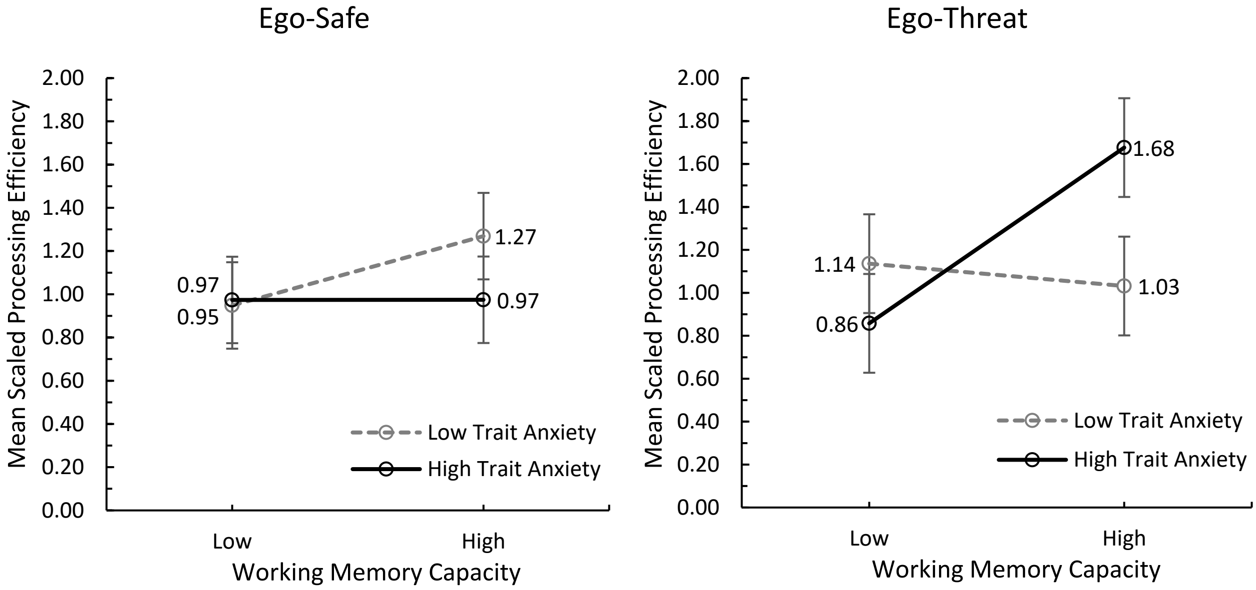

Figure 33. Three-way interaction of trait anxiety × situational stress × working memory capacity for sustained attention processing efficiency.

Discussion: Trait Anxiety, Situational Stress, Working Memory Capacity, and Sustained Attention

Study 7 sought to address methodological concerns raised in the prior Study 4. Issues with the chosen task, such as overly complex sequential stimuli, were suggested to have contributed to a floor effect. It was also suggested the task had been potentially an inappropriate length to evaluate sustained attention (Leark et al., 2007). To rectify these limits an alternative task of sustained attention, the TOVA, was chosen for subsequent investigation as it utilised simplified visual stimuli and was of extended duration (approx. 20 minutes). Further, Study 7 aimed to examine the impact of trait anxiety, situational stress, and working memory capacity on sustained attention performance. Outcome measures included performance effectiveness indexed as *d'* a sensitivity measure of target/noise discrimination, and processing efficiency indexed as a ratio of *d'* and RT variability. In accordance with the chosen theory, it was predicted that a three-way interaction between trait anxiety × situational stress × working memory capacity would be observed for both performance effectiveness and processing efficiency measures. It was expected at the levels of the ego-threat condition and high working memory capacity, high trait anxiety participants would outperform low trait anxiety participants on the performance effectiveness measure. Under these same conditions, high trait anxiety participants were expected to exhibit poorer processing efficiency scores. Results supported the performance effectiveness hypothesis, observing the predicted three-way interaction in the expected direction. However, results for the processing efficiency hypothesis were in opposition to what was expected. While a three-way interaction was also observed for processing efficiency, it was found that within the ego-threat condition, at the level of high working memory capacity, the high trait anxiety participants demonstrated better processing efficiency than the low trait anxiety participants.

For sustained attention effectiveness, indexed as the outcome measure *d*', it was found that for participants who underwent the ego-threat manipulation, those who exhibited greater WMC and were high in trait anxiety performed with improved sustained attention effectiveness compared to low trait anxious participants. That is, such individuals showed improved sensitivity towards identifying target stimuli amongst distractors over a prolonged period of time. The improved *d'* index, or performance effectiveness, demonstrated by these participants may have come about due to a greater proportion of hits and correct rejections, lower proportion of false alarms and misses, or a combination of both. Of note, at the level of low working memory capacity, there was no difference in the performance of either low or high trait anxiety participants when undergoing situational stress. Low working memory capacity may therefore not be a risk factor for further performance impairment, but it does not offer the same protective and somewhat facilitative influence as high working memory capacity. Although research evaluating the exact combination of variables as the current study is limited, thus restricting comparison, the findings of the current study are partially compatible with literature that identified sustained attention was influenced by trait anxiety and situational stress (Elliman et al., 1997; Geen, 1985; Robinson, Krimsky, et al., 2013). Further, the facilitating influence of high working memory capacity is in line with the predominant view of research (Barrett et al., 2004; Brewin & Beaton, 2002; Brewin & Smart, 2005; McVay & Kane, 2009; 2012a).

The findings align with attentional control theory. From this view, it can be suggested in situations of increased stress, higher trait anxious participants are under increased cognitive load, placing strain on their ability to modulate attention focus, amend behavioural strategies, and monitor internal and external feedback. If these trait anxious individuals possess a higher working memory capacity, they have access to the necessary resources to maintain vigilance, and as such, forgo behavioural detriments.

Like sustained attention effectiveness, a three-way interaction of trait anxiety, situational stress, and working memory capacity was also observed for processing efficiency. The data demonstrated that for participants who underwent the ego-threat manipulation and were also allocated to the high working memory capacity group, those who were high trait anxiety performed with better processing efficiency than the low trait anxious group. Given the nature of the processing efficiency ratio, it is unclear if these participants demonstrated greater performance effectiveness and comparable RT variability to the low trait anxiety participants, or if they exhibited greater performance effectiveness and lower RT variability (i.e., greater consistency of response). Regardless, the current findings suggested greater working memory capacity allowed for high trait anxiety individuals to improve not only their effectiveness (i.e., accuracy) but also their efficiency (i.e., RT) under the correct circumstances. The contingent trade-off proposed by attentional control theory was therefore not found in the present work. Rather, the measures of performance effectiveness and processing efficiency, though sharing overlap, demonstrated the same trend of results. This is akin to the findings observed in Study 5 for planning ability. Regardless, the processing efficiency findings contrast with work which had found trait anxiety and situational stress to be unrelated to reports of sustained attention efficiency (Righi et al., 2009; Robinson, Krimsky, et al., 2013). However, this discrepancy was possibly due to the use of simple RT measures, rather than an efficiency ratio incorporating effectiveness scores. The current study is in line with work which had associated greater working memory capacity with reduced RT variance and thus improved processing efficiency (McVay & Kane, 2009).

Overall, in the current study working memory capacity appeared to demonstrate an ability to buffer the detrimental interaction of trait anxiety and situational stress. An interpretation of results may be that successful maintenance of sustained attention (a critical executive function which underlies almost all on-task behaviours) can be improved for highly trait anxious individuals in stressful environments if they possess enough capacity of working memory to draw on for maintenance of performance effectiveness and processing efficiency.

Chapter Eight: Summary of Dissertation

The sequence of experimental studies presented in the current dissertation aimed to investigate the association between trait anxiety and a limited series of executive functions. In particular, the interactive influences of situational stress, cognitive load, and working memory capacity were also examined. The cognitive interference model of attentional control theory was used as the theoretical framework for the current work. As such, two key outcomes of interest were evaluated for all selected executive functions. This included performance effectiveness (the overall quality and task performance) and processing efficiency (the relationship between performance effectiveness and the cognitive resources invested). In the first phase of research, experimental variables consisted of trait anxiety, situational stress, and cognitive load, with an additional covariate of depression recorded. Both the independent and interactive influence of variables were investigated. Outcome variables included task performance of mental rotation, forward planning ability, cold decision-making and sustained attention. In the second phase of research, the executive functions of concern were forward planning ability, hot decision-making, and sustained attention. Cognitive load was swapped for evaluation of working memory capacity as an alternate buffer to trait anxiety and situational stress.

In Chapter One, an introduction to the dissertation topic was provided. The key constructs of anxiety and executive functioning were detailed, in addition to providing a brief overview of their general association. A review of executive functioning literature summarised the transition from initially viewing the construct as a unitary process, to the modern acceptance of executive functioning’s diversity comprised of separable processes. In addition to trait anxiety, further sources of disruption to executive functions were reviewed, inclusive of situational stress and cognitive load. Common theories that integrate executive functions into their framework were reviewed, with emphasis placed on cognitive interference models. Attentional control theory (Eysenck et al., 2007) was set as the theoretical framework of the dissertation. Its predictions and operationalisations were summarised.

In Chapter Two, the chosen executive functions to be examined in the current dissertation were identified and defined. Selected functions included mental rotation, forward planning, decision-making, and sustained attention. The chapter reviewed existing literature that detailed trait anxiety and the series of executive functions. The available research detailing anxiety-related detriments of complex executive functions was found to be scarce. This lacking literature was attributed partially to variations in operational definitions surrounding executive functioning. Key methodological limitations were identified amongst existing literature. These limits included improper measures of processing efficiency, little consideration of the interactive effects of trait anxiety and situational stress, and lack of controls for potentially comorbid depression. These issues were addressed in the subsequent study series detailed in Chapter Three and Chapter Four.

In Chapter Three, the general methodology of the first phase of research was provided. In Chapter Four, analyses for each of the first phase's studies were detailed. These analyses involved factorial ANCOVAs examining the influence of trait anxiety, situational stress, and cognitive load on the performance effectiveness and processing efficiency of discrete executive function tasks. Specifically, mental rotation (Study 1), forward planning (Study 2), cold decision-making (Study 3), and sustained attention (Study 4). The independent and interactive effects of the independent variables were reviewed. Brief discussions for each study were provided throughout Chapter Four. These discussions evaluated the findings of each separable study and compared the current work to trends observed in prior literature and predicted by attention control theory.

Chapter Five served to link the first and second phases of research. In this chapter, the construct of working memory capacity was introduced in more detail. Literature associating working memory capacity with the chosen executive functions (planning, decision-making, and sustained attention) was reviewed. Justification for new approaches in the second phase of research was provided.

In Chapter Six, the general methodology for the second phase of research was presented. In Chapter Seven, analyses for the studies of the second research phase were reported. Analyses used factorial ANCOVAs to evaluate the influence of trait anxiety, situational stress, and working memory capacity on performance effectiveness and processing efficiency outcomes of discrete executive function tasks. Specifically, forward planning (Study 5), hot decision-making (Study 6), and sustained attention (Study 7). Independent and interactive effects of the independent variables were examined. Discussions for each study were provided throughout Chapter Seven. These sections evaluated the findings of each study and compared results of the current work to trends in prior literature and theory.

Ultimately, the current dissertation proposed a need to better understand how sources of cognitive interference can impair the performance of executive functions. With the adoption of attentional control theory, an emphasis was placed on detriments observed in a sub-clinical sample. That is, how the negative emotionality of individuals not reaching the threshold of clinical diagnosis may still contribute to cognitive deficits in functions reliant on coordination and maintenance properties. Limited research was available examining these associations beyond the boundaries of popular models (e.g., Miyake et al., 2000; inhibition, shifting, updating). As such, very little information was available on how trait anxiety might influence other, more complex executive functions. Even less was known about the interactive influence of additional sources of interference (e.g., stress, cognitive load). The current research therefore aimed to evaluate the influence of cognitive interference, both internal and external, on the effectiveness and efficiency of separable, less researched executive functions lacking in literature. Specifically, the influence of trait anxiety, situational stress, and cognitive load was evaluated in the first phase of research. In addition, the second phase of research introduced the aim of evaluating the possible protective influence of working memory capacity. The current chapter provides a summary of the general trends identified over the course of the seven experiments conducted during this project. The findings of the current program are related to theory where applicable. Practical implications of the research, limitations, and directions for future research are also presented.

Trait Anxiety and Situational Stress Interact to Impair Complex Executive Functions

Attentional control theory assumes anxiety to be determined interactively by trait anxiety and situational stress, and that it is this combination that induces poorer processing efficiency and, in some cases, poorer performance effectiveness. Results from four of the seven experiments in the current research show trait anxiety and situational stress to interact in determining outcomes on tasks of separable executive functions. Specifically, this included mental rotation (Study 1), planning ability (Study 2 and Study 5), as well as sustained attention (Study 7). While both trait anxiety and situational stress were found to influence cold decision-making performance effectiveness (Study 3), these effects were independent of one another and not interactive. The lack of interaction between trait anxiety and situational stress in Study 4 (RVIP, sustained attention) and Study 6 (IGT; hot decision-making) were contributed to limitations of the selected tasks.

Cognitive Load Does Not Reliably Buffer Trait Anxiety and Situational Stress in Complex Executive Functions

Attentional control theory proposes that the detriments of anxiety worsen at higher levels of cognitive load. Vice versa, behavioural detriments may be minimised at lower levels of cognitive load where it is easier to recruit additional cognitive resources to compensate performance. The first phase of research (Study 1, Study 2, Study 3, Study 4) evaluated cognitive load as both an independent and interactive variable. With only the exception of Study 1, none of the studies showed a significant influence of cognitive load. For Study 1 examining mental rotation, the effect of cognitive load was embedded within a three-way interaction with trait anxiety and situational stress. Mental rotation effectiveness and efficiency were found to be improved in the ego condition, for high trait anxiety participants over low trait anxiety participants, only at the higher cognitive load level of 90°[53]. This finding may be attributable to the mental rotation task's relative simplicity in comparison to the other functions under investigation. Mental rotation does not require the same integration of sub-processes as executive functions like planning or decision-making (Chan et al., 2008; Khooshabeh et al., 2013). This might have allowed for the effect of cognitive load to be more visible. In the remaining studies of planning (Study 2), cold decision-making (Study 3), and sustained attention (Study 4), cognitive load exerted no influence on performance. Where Study 4 may have been limited by task selection, Study 2 and Study 3 nonetheless suggest cognitive load is not a reliable moderator of trait anxiety nor situational stress.

While cognitive load had been observed to influence executive functions in prior work (Eysenck et al., 2007), the majority of research examine relatively simple tasks of inhibition, shifting, and updating. In comparison, for more multifaceted tasks like those used to assess the processing planning, decision-making, and sustained attention, it was suggested the demand of increasing cognitive load was less impactful. Rather, the underlying amount of resources available to be drawn upon (i.e., working memory capacity) was suggested to be more important.

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[53] Rotation angles examined included 0°, 45°, 90°, 135°, and 180°. Some consider the 90° rotation to be one of the most difficult rotations (Bilge & Taylor, 2016).

Trait Anxiety and Situational Stress Influence Planning Ability

Study 2 and Study 5 demonstrated trait anxiety and situational stress interacted to alter the processing efficiency of planning ability, as measured by two separate tasks (the Tower of London and *N*-Puzzle, respectively). In Study 2, the trend of the interaction suggested that when placed under additional situational stress, high trait anxious participants response with poorer planning efficiency than low trait anxious participants. For Study 5, this interaction was further moderated by working memory capacity. All trends were found while controlling for depression. The current work is the first to evaluate the interactive effect of trait anxiety and situational stress on planning ability, as well as further third-variable moderators.

Trait Anxiety and Situational Stress Influence Some Variations of Decision-Making

Both cold (Study 3) and hot decision-making (Study 5) were examined in the current dissertation. In Study 3, cold decision-making was found to be influenced by both trait anxiety and situational stress. Specifically, the low trait anxiety participants performed with poorer performance effectiveness (i.e., accuracy) compared to the high trait anxiety participants. As well, participants allocated to the ego-threat condition who underwent a stress induction process showed lower performance effectiveness compared to the ego-safe condition. This study did not show the expected interactive effect predicted by attentional control theory. Nonetheless, the results were a novel contribution to an under-researched area, suggesting that the accuracy of cold decision-making, specifically decisions reliant on criteria comparison, may be influenced by the trait- or state-based emotionality of an individual. Further work is necessary to replicate this trend, given the severe lack of literature examining non-risk-based decision models.

In Study 5, no influence of trait anxiety or situational stress was observed. While this may indicate the hot variant of decision-making is unrelated to variation in trait anxiety or changes in situational stress, this finding remained in contrast to the majority of prior literature. Most previous works have reported at least trait anxiety to alter decision-preferences on hot decision-making tasks. It was suggested the null results might have been due to the use of a modified IGT that restricted participants choices more so than prior work. Further, the situational stress manipulation was noted to be ineffective in this study, which likely contributed to a null difference between ego-safe and ego-threat groups. Further work is needed to address the weaknesses of this study.

Trait Anxiety and Situational Stress Influence Sustained Attention

Study 7 found a significant interaction between trait anxiety and situational stress for both performance effectiveness (target sensitivity) and processing efficiency (target sensitivity/RT ratio) outcomes of a sustained attention task. This two-way interaction was embedded within a three-way interaction that included the addition of working memory capacity. The finding was complementary to prior research and theory. Study 4 found no influence of trait anxiety and situational stress, however, the null results were suggested to be attributable to the limits with the task selection.

Working Memory Capacity Buffers the Influence of Trait Anxiety and Situational Stress in Complex Executive Functions

The second phase of research (Study 5, Study 6, Study 7) evaluated the role of working memory capacity as a possible moderator to the influence of trait anxiety and situational stress on tasks of executive functions. From a theoretical standpoint, though not explicitly mentioned in attentional control theory’s key predictions, working memory capacity forms the foundation of all the theory’s hypotheses pertaining to cognitive load and resources. This makes working memory capacity an ideal construct of consideration when extending attentional control theory to more intricate executive functions like those examined in the current work. It was proposed that the influence of cognitive load changes within tasks was of less importance amongst already difficulty and multifaceted tasks of more complex executive functions. That is, additional demands from the task of inherent executive function under examination were inconsequential if the individual did not have the necessary capacity of resources to be drawn upon. The second phase of research did not manipulate working memory capacity, but rather allowed the construct to vary freely so as to assess inherent individual differences. As such, the emphasis of the current work was on a trait-variant of working memory capacity.

All studies in the second phase of research demonstrated a moderating influence of working memory capacity, with the exception of hot decision-making (Study 5) potentially due to task limits. In planning ability (Study 4), higher working memory capacity was found to improve the processing efficiency of high trait anxiety participants (compared to low trait participants) undergoing situational stress. Likewise, higher working memory capacity also improved both the performance effectiveness and processing efficiency of high trait anxiety participants (compared to low trait participants) undergoing the ego-threat procedure. Not only did working memory capacity buffer against performance detriments commonly linked to trait- and state-based variations of negative affect, but rather facilitated performance of an at-risk group. Results suggest that when concerned with more intricate executive functions, working memory capacity is a better moderator of performance compared to cognitive load. Findings also suggest the performance effectiveness and processing efficiency trade-off cited by attentional control theory is not guaranteed. That is, under the correct circumstances, high trait anxious participants can improve both their effectiveness and efficiency compared to the low trait anxious peers.

Practical Implications

The current dissertation was designed to evaluate a gap in the literature of trait anxiety and executive functioning. While the influence of negative emotionality had been investigated in some executive functions, the current body of literature had stagnated and seemed unable to extend beyond a select trio of functions overemphasised in literature. Despite the prevalence of anxiety-related conditions amongst the Australian population (Australian Bureau of Statistics, 2018), little work had been done to examine how this common mental-health concern may disrupt daily living by impairment of executive functions. This was concerning given the ubiquity of such functions in daily living. As executive functions are also associated with areas of academic achievement, self-care, and general wellbeing (Anderson et al., 1999; Pessoa, 2009; Best et al., 2011), it is imperative risk factors which may undermine this performance continue to be identified. Further to this, the moderating effects of additional circumstantial variables were also evaluated. The research program was framed by attentional control theory, focusing on a sub-clinical sample. Further, the work identified key predictions originally intended for more simple functions that could be extended to more intricate executive functions.

A key finding of the current work highlighted the critical role working memory capacity plays in buffering executive functions from emotional interference. Individuals who experience greater anxiety, heightened situational stress, or a combination of both cannot rely only on changes to difficulty levels when engaging in multifaceted executive functions. Consideration must be given to the resource capacity inherent to each individual through assessment of their working memory capacity limits. This is particularly relevant for clinical interventions which seek to improve the cognitive abilities of anxious individuals. The suggestion that an individual’s ability to overcome anxious symptomatology is determined by a fixed construct appears disheartening and could be interpreted as undermining perceptions of autonomy. However, despite its more rigid nature when compared to mental effort, one could speculate how working memory capacity might be improved. Increases in working memory capacity have been tentatively found in response to repeated use/training of working memory tasks (e.g., Constantinidis & Klingberg, 2016; Klingberg, 2010). Further, reduction of cognitive interference by self-related thoughts consuming attentional resources has been shown in applications of cognitive-behavioural therapy (Hadwin & Richards, 2016), training of self-directed attention (Chiesa, Calati, & Serretti, 2011; Quach, Mano, & Alexander, 2016), reframing interpretations of task difficulty (Autin & Coizet, 2012), and expressive writing programs (Klein & Boals, 2001). The use of such interventions, however, are only relevant if the proposed beneficial changes to working memory capacity are able to be executed on command in real-world settings when required. In-depth evaluation of the efficacy of these individual programs is beyond the scope of the current dissertation, though this may be a direction for future research.

Limitations and Future Research

Despite the methodological strengths of the present dissertation, limitations of the project are also considered to guide future research directions. Firstly, recruitment for the experimental studies relied on the participant pool made available at the tertiary institution where the research was conducted, Bond University. Participants, therefore, were comprised of only undergraduate university students. Although somewhat limited in scope, the samples were complementary to the project's theoretical basis. Attentional control theory places a focus on the individual differences of anxiety amongst sub-clinical populations. However, it is not yet determined whether the trend of results reported in the current project can be applied to clinical populations. Such populations might include individuals with a diagnosis of generalised anxiety disorder, obsessive-compulsive disorder, post-traumatic stress disorder, and other anxious conditions with symptomatology that exceeds sub-clinical norms. Any variation in the performance of executive functions between clinical and sub-clinical populations would define boundaries of impairment and further inform considerations of psychological interventions. Future research may wish to replicate the investigation of trait anxiety, situational stress, working memory, and the selected executive functions amongst a sample of clinical participants.

A further issue seen in the sampling of the current research was the imbalance between male and female participants. Female participants comprised the majority of sample in all individual studies, ranging from 76% of the entire sample (Study 6) to 86% (Study 2). As such, the dissertation's results may be a better representation of the association between emotion and cognition amongst a female population. This limit may be addressed in future research by the recruitment of balanced groups or by exploration of possible gender differences.

Another potential limitation of the research project is its evaluation of only cognitive symptoms of trait anxiety. The focus on this dimension of anxiety was driven by use of cognitive interference models like attentional control theory. These models placed emphasis on the verbal component of anxiety, such as worrisome thoughts and variations of internal self-monitoring, as being the cause of disruption to the central executive. These symptoms are more prevalent within the cognitive dimension of anxiety. However, the experience of somatic symptomatology might also be relevant given the experience of autonomic changes (e.g., increased heart-rate, sweating palms, "butterflies" of the stomach) might still draw attention away from task-relevant processing. This is also relevant to the chosen situational stress induction. The current ego-threat procedure can be considered as cognitively-oriented, intending to increase internal narration by promoting worrisome thoughts and self-doubt. It would be of interest to examine if the same pattern of behavioural responses observed in the current research extends to use of somatic stressors, such as threat of shock or a cold pressor stress test. In future research, the somatic dimension of trait anxiety might also be recorded, and the ego-threat procedure substituted with a somatic-oriented situational stress induction.

Summary and Conclusion

The current research established several key conclusions. These include (1) trait anxiety and situational stress can impair executive functions that are complex and multifaceted, (2) trait anxiety and situational stress interact to determine planning efficiency, and at times planning effectiveness, (3) trait anxiety and situational stress can influence some forms of decision-making effectiveness but not efficiency, (4) trait anxiety and situational stress interact to determine sustained attention effectiveness when defined by a sensitivity index, as well as sustained attention efficiency, (5) cognitive load does not reliably moderate the influence of trait anxiety and situational stress on complex executive functions, and (6) working memory capacity can buffer the influence of trait anxiety and situational stress on complex executive functions, as well as provide facilitating effects in the right circumstances.

Overall, laboratory-based experimental research like the current work has contributed substantially to understanding the influence of anxiety on simple cognitive functions. Further work must be done to extend our knowledge of relatively simple processes to more ecologically valid complex processes such as the executive functions of planning, decision-making, and sustained attention. The current dissertation has contributed to several shortcomings of the literature and strengthened the foundation on which further research can be built. It is hoped that future research will continue to identify and investigate additional constructs and processes underlying the relationship between anxiety and higher-order cognition.

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Appendix A

Participant Explanatory Sheet

Project Title: Effectiveness and Efficiency of Executive Processing in Anxiety
Project #: RO-0000015579

Effectiveness and Efficiency of Executive Processing in Anxiety

My name is Katarina Needham and I am currently undertaking a Doctor of Philosophy (PhD) at Bond University under the supervision of Dr Mark Edwards. I am conducting a research investigation into the relationship between anxiety and performance. As part of this study, I will invite you to complete some questionnaires and a number of computer tasks. The study will take about 90 minutes to complete. Any data that you provide is anonymous. The experiment may involve procedures that could temporarily elevate your stress levels.

Participation in this study is completely voluntary and you may withdraw at any time without risking any negative consequences. If you choose to withdraw your participation in this study, the information you have provided will be immediately destroyed. All the data collected in this study will be treated with complete confidentiality and not made accessible to any person outside of the researchers working on this project. Data will be stored in a secure location at Bond University for a period of five years in accordance with the guidelines set out by the Bond University Human Research Ethics Committee.

If you would like to discuss your participation in the study, or be informed of the aggregate research findings, please contact the student researcher Katarina Needham at kneedham@bond.edu.au.

It is unlikely that you will be adversely affected by participating in this study. However, if at any time you experience feelings of distress or discomfort, you may wish to contact Lifeline on 13 13 14 or Beyond Blue on 1300 224 636 for confidential support and assistance.

Should you have any complaints concerning the manner in which this research is being conducted please make contact with:
Bond University Human Research Ethics Committee,
Bond University Office of Research Services.
Bond University, Gold Coast, 4229, Australia
Tel: +61 7 5595 4194 Fax: +61 7 5595 1120 email: ethics@bond.edu.au

Thank you for taking time to assist us with this research.

Yours sincerely,

Katarina Needham
PhD Candidate

Appendix B

Consent Form

RESEARCH CONSENT

Project Title: Effectiveness and Efficiency of Executive Processing in Anxiety
Project #: RO-0000015579

Today I am volunteering to participate in a research study which will involve the completion of questionnaires and computer tasks that assess cognitive abilities. I acknowledge the research may also include a procedure that could temporarily elevate my stress levels.

I understand that any data I provide will be held as totally confidential and that I am free to withdraw from the experiment at any time without risking negative consequences. If I choose to withdraw from this study, the information provided will be immediately destroyed. All data collected in this study will be treated with complete confidentiality and not made accessible to any person outside of the researchers working on this project. Data will be stored in a secure location at Bond University for a period of five years before being destroyed in accordance with the guidelines set out by the Bond University Human Research Ethics Committee.

This study has been approved by the Bond University Human Research Ethics Committee (BUHREC) in accordance with the National Health and Medical Research Council's guidelines. If you would like more information on this study or would like to be informed of the complete research findings, please contact Katarina Needham at kneedham@bond.edu.au.

I have read the Explanatory Statement and I agree to participate in Bond University Research Project Number RO-0000015579, *Effectiveness and Efficiency of Executive Processing in Anxiety*.

____________________ Signature

____________________ Print Name

____________________ Student Number

____________________ Date

Appendix C

Depression Anxiety Stress Scale – 21 Item Version

(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 (e.g., 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 (e.g., 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 (e.g., 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 D

State and Trait Inventory of Cognitive and Somatic Anxiety – Trait Subscale

(Ree et al., 2008)

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.**

		Not at All	A Little	Moderately	Very Much So
		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 E

State and Trait Inventory of Cognitive and Somatic Anxiety – State Subscale

(Ree et al., 2008)

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
	Right now...				
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 F

State Rating Questionnaire

(Edwards, Edwards, et al., 2015)

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**