ANXIETY AND WORKING MEMORY:
AN INVESTIGATION AND RECONCEPTUALISATION OF THE
PROCESSING EFFICIENCY THEORY

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This thesis is presented in partial fulfillment for the degree of Master of Psychology (Clinical) and Doctor of Philosophy at The University of Western Australia.

School of Psychology
December 2003
A dominant theory in the anxiety-working memory literature is the Processing Efficiency Theory (Eysenck & Calvo, 1992). According to this theory, worry - the cognitive component of state anxiety - pre-empts capacity in the central executive and phonological loop components within Baddeley and Hitch's (1974) fixed-capacity working memory system. Central to the Processing Efficiency Theory is the distinction between performance effectiveness (i.e. quality of performance) and processing efficiency (i.e. performance effectiveness divided by effort), with anxiety proposed to impair efficiency to a greater extent than it does effectiveness. The existing literature has provided support for this theory, although there exist factors that complicate the findings, including the nature of the working memory tasks utilised, comorbid depression, and the distinction between trait and state anxiety.

Clarification of the limiting factors in the anxiety-working memory literature was sought over a series of initial methodological studies. The first study was an initial step in addressing the issue of comorbid depression, identifying measures that maximised the distinction between anxiety and depression. The second study identified verbal and spatial span tasks suitable for examining the various working memory systems. The third study considered a possible role for somatic anxiety in the anxiety-working memory relationship, and additionally addressed the state/trait anxiety distinction. These three initial studies culminated in the fourth study which formally addressed the predictions of the Processing Efficiency Theory, and explored the cognitive/somatic anxiety distinction more fully. For the third and fourth studies, high and low trait anxious individuals underwent either cognitive (ego threat instruction) or somatic (anxious music) stress manipulations, and completed a series of span tasks assessing all components of the working memory system.

Unexpectedly, the fourth study yielded a notable absence of robust effects in support of the Processing Efficiency Theory. A consideration of the research into the fractionation of central executive processes, together with an examination of tasks utilised in the existing literature, suggested that anxiety might not affect all central executive processes equally. Specifically, the tasks utilised in this programme of research predominantly invoke the process of updating, and it has recently been suggested that anxiety may not actually impair this process (Dutke & Stöber, 2001). This queried whether the current conceptualisation of the central
executive component as a unified working memory system within the PET was adequate or if greater specification of this component was necessary. One central executive process identified as possibly mediating the anxiety-working memory relationship is that of inhibition, and the focus of the fifth study thus shifted to clarifying this more complex relationship. In addition to one of the verbal span tasks utilised in the third and fourth studies, the reading span task (Daneman & Carpenter, 1980) and a grammatical reasoning task (MacLeod & Donnellan, 1993) were also included. Inhibitory processing was measured using the directed ignoring task (Hopko, Ashcraft, Gute, Ruggerio, & Lewis, 1998). This study established that inhibition was affected by a cognitive stress manipulation and inhibition also played a part in the anxiety-working memory link. However other central executive processes were also implicated, suggesting a need for greater specification of the central executive component of working memory within the PET. A finding that also emerged from this, and the third and fourth studies, was that situational stress, rather than trait or state anxiety, was predominantly responsible for impairments in working memory.

Finally, a theoretical analysis placing the anxiety-working memory relationship within a wider context was pursued, specifically examining how the Processing Efficiency Theory is nested within other accounts examining the relationship between mood and working memory. In particular, similarities between the theoretical accounts of the relationships between anxiety and working memory, and depression and working memory, suggest the operation of similar mechanisms in the way each mood impacts on performance. Despite the similarities, potential distinctions between the impact each has on performance are identified, and recommendations for future research are made.
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I would like to thank several people for their support throughout this thesis.

First and foremost, I would like to thank my supervisor Murray Maybery, for his wisdom, humour, endless patience, and his boundless enthusiasm. I am also indebted to Matt Huitson and his programming expertise. I would also like to thank Andrew Page for his valuable comments on the final draft. To my family – your support throughout this process has been instrumental and very much appreciated. Finally, to my friends, thank you for your encouragement. Some of you have also provided valuable input while others have also been present on this journey, and I would like to say a heartfelt thank you for your support.
CHAPTER 1: LITERATURE REVIEW

1.1 Introduction

Working memory is implicated in the performance of a variety of tasks. These include simple everyday tasks such as remembering telephone numbers, what to buy while shopping for groceries, or how to get to a new destination. Working memory is also involved in more complex cognitive tasks like reasoning, learning, reading, and comprehension (Baddeley, 1996b). Indeed, it has been demonstrated that measures of reasoning ability and working memory capacity are highly correlated, with some studies reporting correlations upwards of .80 (Kyllonen & Christal, 1990). There are several factors that affect working memory performance, including age, cognitive disabilities (e.g. reading disability), and mood. The present thesis is concerned with a particular domain of mood – anxiety – and how it impacts on working memory performance.

Studies investigating the anxiety and working memory relationship have been predominantly premised on Baddeley and Hitch’s tripartite working memory model (Baddeley, 1992, 1996b; Baddeley & Hitch, 1974). A review of this model will now follow, thereby setting the context within which anxiety-linked impairments in working memory typically have been interpreted.

1.2 Working memory – the tripartite model

According to the tripartite model, working memory comprises two slave systems – the phonological loop (PL) and the visuospatial sketchpad (VSSP). These are governed by the modality-free central executive (CE) which functions as a controller of attention, co-ordinating information from the two slave systems. Each of these systems will be briefly reviewed.

The PL is responsible for the storage of verbal information, and comprises two components – a phonological store and a rehearsal process (Baddeley, 1986). The contents of the phonological store are limited temporally, and are retained in the system via the rehearsal process (Chincotta & Underwood, 1997). Investigations into

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1 A fourth component, the episodic buffer, has recently been added to this working memory model, however the functions ascribed to this component (see Baddeley, 2002) are not ones that would be expected to play a significant role in the anxiety-working memory link. Moreover the dominant theory accounting for the anxiety-working memory literature is premised on the tripartite model of working memory. Thus, the tripartite model of working memory forms the focus of the present research.
the PL have typically involved the recall of auditorily presented material (e.g. as in the assessment of digit span and word span). Visually-presented verbal material (e.g. printed letters) has also been employed, for such stimuli can be recoded phonologically (Morris, 1986). Four phenomena are presented as evidence in support of the structure of the PL – the phonological similarity effect, the word length effect, the irrelevant speech effect, and the effect of articulatory suppression (Baddeley, 1986; Logie, 1995). The phonological similarity effect refers to the poorer recall of sequences of verbal items that are phonologically similar (e.g. VCDG) compared to those that are phonologically dissimilar (e.g. HQLR). The poorer recall of the phonologically similar items is purportedly due to the greater confusability of their representations in the phonological store. The word length effect is premised on the notion that rehearsal is necessary to retain the contents held in the PL. A list of words of short spoken duration is recalled better than a list containing an identical number of words of longer spoken duration, and this is attributed to the faster rate of rehearsal permitted in the case of the former (Baddeley, Thomson, & Buchanan, 1975). A faster rate of list rehearsal is presumed to inoculate memory items against time-based decay. Irrelevant speech that the individual is instructed to ignore interferes with the recall of verbal material presumably because it has obligatory access to the phonological store (Salamé & Baddeley, 1982). Finally, articulatory suppression (e.g. repeating the word ‘the’) is argued to interfere with the rehearsal process, resulting in poorer performance. Altogether, these phenomena support the phonological nature of the PL.

The VSSP is responsible for the storage of visual and spatial information. As with the PL, rehearsal plays an important role in retaining information in the system (Bruyer & Scailquin, 1998). Studies of the VSSP employ tasks thought to involve visual or spatial coding, such as the Corsi Blocks task (Milner, 1971) or pattern recall. Performance on these tasks is markedly impaired under conditions of visual or spatial interference (e.g. tracking, tapping, or localising sound; Baddeley & Lieberman, 1980; Brooks, 1968; De Renzi & Nichelli, 1975; Farmer, Berman, & Fletcher, 1986; Logie, Zucco, & Baddeley, 1990; Morris, 1987), thereby supporting the visual-spatial nature of this system. It has been shown that there exists a visual similarity effect wherein poorer recall is found for visually similar materials (Avons & Mason, 1999; Logie, 1995). However, the VSSP should not be regarded as functionally analogous to the PL – there is contention surrounding whether irrelevant visual stimuli affect recall in a manner similar to the irrelevant speech effect (Andrade, Kemps, Werniers, May, & Szmalec, 2002; Toms, Morris, & Foley, 1994). It is also of note that there has been a
recent move towards the fractionation of the VSSP (Della Sala, Gray, Baddeley, Allamano, & Wilson, 1999; Pickering, Gathercole, Hall, & Lloyd, 2001). However, research on the VSSP is still in its infancy relative to the degree of investigation into the PL.

The CE is a modality-free system, and one of its primary functions is to co-ordinate the information held in the slave systems to arrive at an output. Other roles ascribed to the CE include activating representations held in long-term memory, focusing and switching attention, planning, and inhibition (Baddeley, 1992; Baddeley & Logie, 1999; refer to Chapter 6 for further discussion). Due to the complexity of its proposed functions, the CE is understood less well relative to the slave systems. However, a significant step in its conceptualisation borrows heavily from Norman and Shallice’s model of the Supervisory Attentional System (SAS; see Baddeley, 1986, for a discussion). According to the SAS model, most actions that an individual engages in are controlled by schemata and executed automatically. However, in instances where the individual is required to select between competing schemata, where there is a novel situation for which no existing schemata exist, where planning and decision-making is required, or where the inhibition of the activation of a schemata is required, the SAS comes into play. The CE, which is regarded as analogous to the SAS (Baddeley, 1986, 1996a), thus operates as a controller of attention. While there has been support for a CE system in working memory, it must be noted that this evidence rests primarily on its distinction from the PL and VSSP. That is, the CE is used to explain aspects of working memory that cannot be attributed to either of the slave systems.

At this point, it is important to acknowledge that the tripartite model is only one of a number of models of working memory and it is not without criticism (see Jones, 1999; Jones & Macken, 1993; Lovatt, Avons, & Masterson, 2000). Nevertheless, some of the key assumptions of the tripartite model, such as the division between verbal and visuospatial representational systems, are shared with many of the alternative models (see Miyake & Shah, 1999, for a review of alternative models of working memory), and no single alternative model has achieved the prominence of the tripartite model. Furthermore, it is the more basic separation of the three systems within the tripartite model that is fundamental to the dominant theory within the anxiety-working memory literature, the Processing Efficiency Theory (PET; see Section 1.4). For these reasons, and also because the majority of studies investigating the relationship between anxiety and working memory adopt the
tripartite model, this working memory model therefore forms the focus of the present program of research. What follows next is a review of evidence in support of the separation of the three systems of the tripartite model.

Evidence for the distinction between the three systems has been derived from several strands of research, including behavioural research, and studies of individuals with brain damage. Neuroimaging and event-related brain potentials (ERP) studies also provide some support for the tripartite distinction. The following review of the different forms of evidence is an illustrative one, and is not designed to provide an exhaustive appraisal. For more comprehensive reviews, refer to Baddeley (1996b), Kiss, Pisio, Francois, and Schopflocher (1998), and Smith and Jonides (1997).

Behavioural research typically employs a central task purported to engage one particular system, and requires the participants to perform interference tasks that are proposed to tap either the same, or an alternative, system. For example, the central task may involve remembering a series of digits (proposed to engage the PL), and interference can either be articulatory suppression (which is proposed to tap PL resources) or spatially-distributed tapping (which is proposed to engaged VSSP resources). If the systems are distinct, then where both the central and interference tasks engage the same system, performance is expected to be markedly worse than if the two tasks engage different systems. In the above example, distinct PL and VSSP systems would mean that remembering the series of digits would be more impaired by articulatory suppression than by spatially distributed tapping. An extension of this methodology is where a second central task is introduced to potentially provide evidence of a double dissociation. With the example, remembering a series of spatial locations might be introduced as a central task proposed to tap the VSSP. Evidence of a double dissociation would be where one central task is impaired to a greater extent by one interference task, whereas the other central task is affected to a greater adverse extent by the alternate interference task. Thus, articulatory suppression might be especially damaging to remembering the series of digits, whereas spatially-distributed tapping might be especially damaging to remembering the series of locations. This reversal of the relative impact of the two interfering tasks would represent convincing evidence of distinct PL and VSSP systems. If, however, working memory is a unitary system, then performance on either central task should be impaired by both of the interference tasks to the same extent.
Behavioural research has provided strong support for separate verbal and visual-spatial systems. Tasks that tap the PL are affected by verbal but not visual or spatial interference, whereas tasks that tap the VSSP are affected by visual/spatial but not verbal interference (Bruyer & Scailquin, 1998; Farmer et al., 1986; Logie et al., 1990; Morris, 1987). This double dissociation provides a cogent argument for the distinction between these two slave systems. Furthermore, Duff (2000) tested participants on visuospatial and verbal short-term memory tasks where these were performed independently or together in a dual-task format (where verbal material was presented in a spatial array) and found performance on the dual task to be equivalent to performance on the independent tasks, suggesting that the PL and VSSP are separable systems.

Behavioural research has also provided support for the existence of a distinct CE. This has been investigated using tasks that are typically complex in nature (e.g. syllogistic reasoning). For example, Gilhooly, Logie, Wetherick, & Wynn (1993) found that performance on a central task that engages the CE was affected by interference tasks expected to engage the CE (e.g. random number generation) but not by those expected to engage the slave systems (e.g. articulatory suppression, and spatially-distributed tapping). While this finding contrasts with those of Gilhooly, Logie, and Wynn (2002) who reported an effect on syllogistic reasoning of both random generation and articulatory suppression, the difference between the two studies is that the former involved the simultaneous presentation of premises in the reasoning task whereas the latter adopted a sequential presentation format. The sequential format would be expected to place greater demands on the PL as the premises would need to be retained in memory. This demand is lessened in the simultaneous presentation format, and it is apparent that performance is heavily contingent on CE resources in this format, thereby supporting the existence of this working memory system.

Although the Gilhooly et al. (1993, 2002) studies provide support for a distinct CE system, random generation tasks such as the ones employed in the Gilhooly et al. studies have been identified to additionally engage the slave systems (Vandierendonck, De Vooght, & Van der Goten, 1998). A more refined approach that reduces the involvement of the slave systems is the probe reaction time technique (Maybery, Bain, & Halford, 1986), which requires participants to monitor for tones presented at random intervals and to respond (either manually or vocally) when they hear one (i.e. to shadow the probes). This task is proposed to engage the CE as it
requires continued attention. Employing an interference design, Vandierendonck et al. found that performance on a more demanding version of a span task (i.e. backward letter span), but not on a less demanding version of a span task (i.e. simple forward letter span task) was affected by concurrent performance on the probe task (which they termed the random interval repetition task, RIR). It may be argued that the more demanding backward span task involves processing in addition to simple storage and, consequently, additionally engages the CE. It was demonstrated that performance on the simple forward span task was affected by articulatory suppression but not by concurrent performance of the RIR task, whereas both articulatory suppression and the RIR task affected performance on the backward letter span task. This dissociation shows that the effects of the RIR task are due to its effects on the CE, and that this is a system distinct from the PL and VSSP.

Neuropsychology studies also provide support for the tripartite model of working memory. Within this field, individuals with lesions localised in different brain regions are asked to perform a variety of tasks purported to tap the different working memory systems. Evidence of distinct systems stems from dissociations in task performance – that is, where performance on a task tapping one working memory system is adversely affected, but performance is intact on another task that taps a different system. For instance, De Renzi and Nichelli (1975) compared the performance of individuals with unilateral lesions of the right and left hemispheres, and demonstrated a clear link between left hemispheric lesions and impaired performance on verbal short-term memory tasks proposed to engage the PL. Similarly, Burgess and Shallice (1996) found that performance on a task requiring response initiation and inhibition (thought to engage the CE) was affected by frontal but not posterior lobe lesions, suggesting that the frontal lobes are involved in CE task performance. Evidence of a double dissociation – where performance on tasks tapping one system is intact but performance is impaired on tasks tapping another system for some individuals, but the converse is true for other individuals – further strengthens the argument for distinct working memory systems. Thus, while Hanley, Young, and Pearson (1991) found that right hemispheric damage was linked to impaired visuospatial task performance but intact verbal task performance, Vallar and Baddeley (1984) found that left hemispheric damage impaired verbal but not visuospatial task performance.
More recent approaches to fractionating working memory may be found in neuroimaging and evoked response potential (ERP) studies. The neuroimaging approach involves investigating brain activity (e.g. by examining regional cerebral blood flow in positron emission tomography, or oxygen uptake of the brain as in the case of functional magnetic resonance imaging) while individuals perform tasks presumed to engage different working memory subsystems. Along with the neuropsychology approach, neuroimaging and evoked response potential studies endeavour to demonstrate that the three subsystems of working memory have approximate architectural correlates in the brain – the PL being linked with the left temporal region, the VSSP with the right temporal region, and the CE with the frontal lobes (e.g. Lezak, 1995; Posner, Petersen, Fox, & Raichle, 1988; Smith & Jonides, 1997; Springer & Deutsch, 1985; Van der Linden et al., 1999; Walsh, 1987). While evidence for architectural correlates in the brain appears valid within neuropsychology research as outlined above, the division is not always apparent within neuroimaging and ERP studies, as will be evident in the following paragraphs.

One difficulty in attempting to demonstrate the fractionation of working memory using neuroimaging is that complex networks of activations are often observed (Jonides & Smith, 1997). In spite of this, it has been clearly demonstrated that tasks proposed to tap the PL corresponded with brain activity in the left hemisphere, and tasks purportedly tapping the CE corresponded with brain activity in the frontal areas of the brain (D’Esposito et al., 1995; Smith & Jonides, 1997; Smith, Jonides, & Koeppe, 1996). The picture is less clear regarding tasks proposed to tap the VSSP, for Smith and Jonides found that visual memory tasks engaged both the left and right hemispheres as did spatial memory tasks (although in the case of the spatial memory task, there was more activation in key regions in the right hemisphere which is consistent with the viewpoint that the right hemisphere is devoted to visuospatial processing). This contrasts with the prediction that the right hemisphere is devoted to processing visuospatial stimuli.

It has recently been suggested that lateralization of brain activation depends not so much on the nature of the stimuli (with the right hemisphere processing visuospatial information and the left hemisphere processing verbal information). Rather, it has been argued that the division is based on task requirements (McIntosh & Lobaugh, 2003; Stephan et al., 2003). To illustrate, Stephan et al. presented participants with words printed in predominantly black letters with one letter printed in red. Participants were asked to perform a letter decision task and a visuospatial decision
task using the same word set. The letter decision task required participants to ignore
the position of the red letter and indicate if the word contained the letter ‘A’, whereas
the visuospatial decision task required participants to judge whether the red letter
was to the left or right of the centre of the word. A dissociation in hemispheric
activations was evident, with letter decisions resulting in left hemispheric activation
and visuospatial decisions resulting in right hemispheric activation.

As with neuroimaging studies, ERP studies into the localization of function within the
brain also suffer from criticisms. It has been demonstrated that particular ERPs are
activated while performing tasks requiring the manipulation of stimuli (i.e. proposed to
engage the CE), but not during tasks that only require the maintenance of stimuli (i.e.
proposed to engage the slave systems). For example, the process of updating the
contents of working memory (which is argued to engage the CE) is proposed to elicit
the P300 component of the human ERP, whereas tasks that do not employ this
process do not elicit this ERP component (Kiss et al., 1998). However, it has also
been argued that the P300 component may reflect the operation of processes other
than updating working memory (see Verleger, 1988, for a review). Due to the lack of
clarity regarding what the P300 component measures, it becomes difficult to localize
functions such as updating within the brain.

What implications do the contradictory findings of the neuroimaging and ERP studies
hold for the tripartite model of working memory? First, it is important to note that
these two methodologies are relatively recent in their application to studying working
memory processes. Consequently, there is room for advancement and refinement
within this area. Presently, there is a growing shift away from localising function in
the brain towards considering interactions between the various brain regions in
performing a task (Carpenter, Just, & Reichle, 2000; McIntosh & Lobaugh, 2003;
Stephan et al., 2003; Veltman, Rombouts, & Dolan, 2003). It is with a greater focus
on these interactions that a clearer picture regarding working memory may be
obtained. For now, however, the support that the neuroimaging and ERP studies
provide for the tripartite working memory model needs to be interpreted cautiously.

Altogether, the above review of behavioural, neuropsychological and, to a limited
extent, neuroimaging and ERP research, provides support for the tripartite model of
working memory. It was previously acknowledged that there is evidence to question
the model (see Jones, 1999; Jones & Macken, 1993; Lovatt et al., 2000). To
reiterate, however, some of the key assumptions of the tripartite model are found in
other models of working memory (cf. Miyake & Shah, 1999), and furthermore that most studies in the anxiety-working memory literature, along with the PET, utilise this working memory model. Thus, the present thesis adopts this theoretical framework. The following section presents a review of some studies within the anxiety-working memory literature that utilise Baddeley and Hitch’s (1974) tripartite working memory model.

1.3 Anxiety and working memory – empirical studies

Most studies that have evaluated the impact of anxiety on working memory have done so with reference to the three systems delineated by Baddeley (1992, 1996b; Baddeley & Hitch, 1974). A brief overview of these studies is provided in Table 1.1. This summary of the studies includes certain factors – such as the state/trait anxiety distinction, and the nature of the working memory tasks employed – that need to be addressed in construing the anxiety-working memory link, and these will be considered subsequently (see Section 1.6). What follows is an overall interpretation of these findings in relation to the tripartite model of working memory.

Anxiety, on the whole, does not appear to impair performance on tasks that tap the VSSP (Ikeda, Iwanaga, & Seiwa, 1996; Markham & Darke, 1991; refer to Table 1.1). There are some instances where anxiety-linked impairments in performance have been associated with tasks that utilise visuospatial material (e.g. Leon & Revelle, 1985; Tohill & Holyoak, 2000), however it is important to note that these tasks also place heavy demands on the CE and hence anxiety may impair performance via this route.

There has been mixed support for the impact of anxiety on the PL. Darke (1988a) found that accuracy on a digit span task was impaired for high anxious participants relative to low anxious participants, suggesting that the PL is affected by elevated levels of anxiety. To the contrary, Markham and Darke (1991) found no evidence of an anxiety-related difference using the same task. On a similar span task (i.e. using words rather than digits), no effect of anxiety was evident (Sorg & Whitney, 1992) which is consistent with Markham and Darke’s findings. However, on a verbal recognition task, anxiety was found to impact on reaction time but not task accuracy (Ikeda et al., 1996). Thus, the evidence in support for an impact of anxiety on the PL appears to be inconclusive.
The strongest argument for a link between anxiety and working memory has been evident in studies utilising tasks that make heavy demands on the CE. Due to the difficulties associated with studying the CE in isolation as it is purportedly modality-free, it has been necessary to investigate its operation using either verbal or visuospatial material. There has been some evidence suggesting that anxiety impacts adversely on the performance of CE tasks that utilise visuospatial material (Leon & Revelle, 1985; Tohill & Holyoak, 2000; but note Markham & Darke, 1991, in which there was no effect of anxiety on the performance of a CE task that utilised visuospatial material). However, most of the studies reporting anxiety-linked performance deficits on tasks that tap the CE have employed verbal material (e.g. Darke, 1988b; Derakshan & Eysenck, 1998; Elliman, Green, Rogers, & Finch, 1997; C. MacLeod & Donnellan, 1993; Richards, French, Keogh, & Carter, 2000; Zarantonello, Slaymaker, Johnson, & Petzel, 1984; refer to Table 1.1).

It is important to note that the distinction between tasks that tap the slave systems, and tasks that engage the CE but also utilise verbal or visuospatial material, lies in the CE tasks requiring the manipulation of information rather than merely its passive retention (cf. Baddeley, 1986). An example of this demarcation can be found in Sorg and Whitney's (1992) study investigating the impact of anxiety on the performances of word span and reading span tasks. In the word span task, participants are required to recall series of words of increasing series length. In the reading span task, participants are presented with sentences and required to read each sentence for the purpose of comprehension in addition to remembering the last word of each sentence. Thus, while the word span task requires the retention of stimuli, the reading span task additionally requires the individual to engage in processing in order to complete the comprehension task.

Tasks tapping the CE on which anxiety-linked deficits in performance are evident are varied in form. These include the reading span task discussed above (Darke, 1988a; Sorg & Whitney, 1992; but note Calvo, Eysenck, Ramos, & Jiménez, 1994), the grammatical reasoning task (Derakshan & Eysenck, 1998; C. MacLeod & Donnellan, 1993), syllogistic reasoning (Darke, 1988b; Richards et al., 2000; Markham & Darke, 1991), solving anagrams (Zarantonello et al., 1994), and even reading for the purposes of comprehension (Calvo et al., 1994; for a review of all these tasks, refer to Table 1.1). These different tasks are likely to engage a variety of CE processes (this will be further elaborated in Chapter 6), but the commonality is that they require the manipulation, rather than solely the retention, of material.
Table 1.1. Summary of some studies in the anxiety-working memory literature.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Participants</th>
<th>Mood measures</th>
<th>Mood Induction</th>
<th>Tasks</th>
<th>Main findings</th>
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</thead>
<tbody>
<tr>
<td>Zarantonello, Slaymaker, Johnson, &amp; Petzel (1984)</td>
<td>24 Control 24 High trait anxious 24 Depressed-high trait anxious</td>
<td>• STAI-trait • Beck Depression Inventory (BDI) • Ratings of cognitive interference, subjective evaluation of performance, administered post tasks</td>
<td>None</td>
<td>Anagrams.</td>
<td>• No differences between depressed-high anxious and high anxious participants in accuracy on anagram task, ratings of cognitive interference, or subjective evaluations of performance. Compared to controls, the other two groups were less accurate on the anagram task, endorsed a greater amount of cognitive interference, and had more negative subjective evaluations of performance. Further analyses attribute this to the anxiety factor common to both the depressed-high anxious and high anxious participants.</td>
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<tr>
<td>Leon &amp; Revelle (1985)</td>
<td>102 participants Median splits on both trait and state anxiety measures to yield: 51 high trait anxious 51 low trait anxious as well as: 51 high state anxious 51 low state anxious</td>
<td>• State-Trait Anxiety Inventory (STAI), trait and state versions. State measure administered before, halfway through, and after task.</td>
<td>Participants randomly allocated into stressed (ego threatening) and relaxed (non ego threatening) conditions.</td>
<td>Geometric analogy task.</td>
<td>• In the relaxed condition, high state anxious participants were less accurate and slower than low state anxious participants. In the stressed condition, it appears that the two state anxiety groups responded differently to stress (i.e. the groups engaged in different speed-accuracy trade-off strategies). There was no clear performance decrement for high anxious participants in the stressed condition.</td>
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<tr>
<td>Author(s)</td>
<td>Participants</td>
<td>Mood measures</td>
<td>Mood Induction</td>
<td>Tasks</td>
<td>Main findings</td>
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<td>Darke (1988a)</td>
<td><strong>Experiment 1</strong></td>
<td>• Test Anxiety Scale (TAS). This is a trait measure.</td>
<td>All participants received ego threatening instructions.</td>
<td><strong>Digit span task</strong>. Participants recalled sequences of digits of increasing sequence length.</td>
<td>• High anxious participants had lower digit span scores than low anxious participants.</td>
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<td>16 High test anxious</td>
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<td>16 Low test anxious</td>
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<td><strong>Experiment 2</strong></td>
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<td><strong>Reading span task</strong>. Participants read sequences of sentences of increasing sequence length for the purpose of comprehension, while recalling the last word of each sentence in each sequence.</td>
<td>• High anxious participants had lower reading span scores than low anxious participants.</td>
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<td>16 High test anxious</td>
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<td>16 Low test anxious</td>
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<tr>
<td>Darke (1988b)</td>
<td><strong>Experiment 1</strong></td>
<td>• TAS</td>
<td>All participants received ego threatening instructions.</td>
<td><strong>Verbal reasoning task</strong>. Verifying anaphoric references, which is argued to be an automatic (i.e. not a controlled) process and not one that places great demands on working memory.</td>
<td>• No effect of anxiety on reaction times or error rates.</td>
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<td>16 High test anxious</td>
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<td>16 Low test anxious</td>
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<td><strong>Experiment 2</strong></td>
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<td><strong>Verbal reasoning task</strong>. Verifying non-anaphoric references, which is argued to be a controlled process that places demands on working memory.</td>
<td>• High anxious participants had longer verification times than low anxious participants. This was not affected by memory load (number of sentences in verification task). There was no difference in error rates between anxiety groups.</td>
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<td>16 High test anxious</td>
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<td>16 Low test anxious</td>
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<td><strong>Experiment 3</strong></td>
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<td><strong>Verbal reasoning task</strong>. Verifying relational sentences (e.g. Tim is taller than Bill, Bill is taller than Bob. Bob is taller than Tim. True/False?)</td>
<td>• High anxious participants had longer verification times than low anxious participants. There was no difference in error rates between anxiety groups.</td>
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</table>
Table 1.1. (continued)

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Participants</th>
<th>Mood measures</th>
<th>Mood Induction</th>
<th>Tasks</th>
<th>Main findings</th>
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</thead>
<tbody>
<tr>
<td>Markham &amp; Darke (1991)</td>
<td>18 High test anxious 18 Low test anxious</td>
<td>TAS</td>
<td>All participants subjected to ego threatening instructions.</td>
<td>• Digit span task (see Darke, 1988a, for description).</td>
<td>• Digit and spatial span tasks. No effect of anxiety on memory span scores.</td>
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<td>• Spatial span task (Corsi task). Participants recalled sequences of</td>
<td>• Spatial reasoning task. No effect of anxiety on accuracy or reaction times.</td>
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<td>locations of increasing sequence lengths.</td>
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<td>• Verbal reasoning task.</td>
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<td>• Spatial reasoning task. Excerpts from Minnesota Paper Form Board test.</td>
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<td>Sorg &amp; Whitney (1992)</td>
<td>15 High trait anxious 15 Low trait anxious</td>
<td>STAI-trait</td>
<td>Tasks performed after both stressful (i.e. competition) and non-stressful</td>
<td>• Word span task. Participants recalled sequences of words of</td>
<td>• Word span task. No effects involving anxiety or stress.</td>
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<td>(non-competitive) conditions.</td>
<td>increasing sequence length.</td>
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<td>• Reading span task. See Darke (1988a, Experiment 2) for a description.</td>
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<td>MacLeod &amp; Donnellan (1993)</td>
<td>24 High trait anxious 24 Low trait anxious</td>
<td>STAI, trait and state versions</td>
<td>None</td>
<td>Grammatical reasoning task. Participants retained a string of</td>
<td>• Digit string memory task. No effect of anxiety on either accuracy or latency.</td>
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<td>digits while performing a reasoning task. The string of digits either</td>
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<td>imposed a high memory load (a string of six random digits) or a low</td>
<td>• Reading task. No effect of anxiety on accuracy. High anxious</td>
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<td>memory load (all digits were 0s).</td>
<td>participants exhibited longer latencies, and this was more pronounced</td>
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<td>under a high memory load. Furthermore, this was attributable to STAI</td>
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<td></td>
<td>trait anxiety scores, rather than STAI state anxiety or BDI scores.</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Participants</td>
<td>Mood measures</td>
<td>Mood Induction</td>
<td>Tasks</td>
<td>Main findings</td>
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</tbody>
</table>
| Calvo, Eysenck, Ramos, & Jiménez (1994) | **Experiment 1**  
18 High anxious  
18 Low anxious |  
- Test Anxiety Inventory (this is a trait measure)  
- STAI, state version. Used here to measure state anxiety under actual stress conditions to compose participants into groups. Also administered after text reading in Experiments 1 to 4. In these instances, high anxious participants endorsed higher state anxiety ratings than did low anxious participants. | All participants received ego threatening instructions. A video camera was also placed in front of them. | Text reading. Self-paced reading of texts for the purpose of comprehension, performed either without interference, with concurrent speech, or with articulatory suppression. Experiments 1 & 2 differed only in text lengths (longer texts in Experiment 2). |  
- No effect of anxiety on reading speed, comprehension times or accuracy scores, or on vocal and subvocal utterances engaged in during the reading process. |
|  
**Experiment 2**  
18 High anxious  
18 Low anxious |  
Text reading. Identical experimental design to Experiments 1 & 2, only using texts presented in a self-paced, sentence-by-sentence format. |  |  |  
- High anxious participants had slower reading speed and longer comprehension times than low anxious participants. No effect of anxiety on comprehension scores, or vocal and subvocal utterances. |
|  
**Experiment 3**  
18 High anxious  
18 Low anxious | Note: The composition of high and low anxious groups in all five experiments was such that high anxious groups differed from low anxious groups on both trait and state anxiety scores. | No ego threatening instructions, and video camera removed. | Text reading. Same as for Experiment 3, only no articulatory suppression. |  
- No effect of anxiety on vocal or subvocal utterances, nor on comprehension scores. High anxious participants read slower, and made more regressions to previous sentences compared to low anxious participants. |
|  
**Experiment 4**  
Same participants as for Experiment 3 |  |  |  |  
- Under conditions of no stress, high anxious participants took longer to read in order to attain the same comprehension accuracy. Under conditions of stress, high anxious individuals tended to perform poorer when comparing the ratio of comprehension accuracy to the number of regressions made during text comprehension, while low trait anxious participants exhibited the opposite pattern. Results from Experiments 3 & 4 suggest that most effects of anxiety occur under stressful conditions. |
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Participants</th>
<th>Mood measures</th>
<th>Mood Induction</th>
<th>Tasks</th>
<th>Main findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calvo et al. (1994; cont'd)</td>
<td>Experiment 5</td>
<td>Same as for Experiments 1-4.</td>
<td>No ego threatening instructions, and video camera removed.</td>
<td>• General vocabulary test from Primary Mental Abilities test.</td>
<td>• General vocabulary test. No anxiety-linked effects.</td>
</tr>
<tr>
<td></td>
<td>Same participants as for Experiments 3 &amp; 4</td>
<td></td>
<td></td>
<td>• Reading span task. Refer to Darke (1988a) for description.</td>
<td>• Reading span task. No difference between anxiety groups on reading span scores.</td>
</tr>
<tr>
<td>Ikeda, Iwanaga, &amp; Seiwa (1996)</td>
<td>17 High trait anxious</td>
<td>• Reactions to Tests (RTT). This is a trait measure.</td>
<td>All participants received ego threatening instructions. A video camera was also placed in front of them.</td>
<td>• Verbal memory task. Recognition test utilising Japanese hiragana letters.</td>
<td>• Verbal memory task. No effect of anxiety group on accuracy, but high anxious participants had longer reaction times.</td>
</tr>
<tr>
<td></td>
<td>19 Low trait anxious</td>
<td>• Worry and cognitive self-concern scales. Measure worry and self-concern experienced while completing the tasks.</td>
<td></td>
<td>• Spatial memory task. Recognition test using line drawings.</td>
<td>• Spatial memory task. No effect of anxiety on accuracy or reaction times.</td>
</tr>
<tr>
<td>Elliman, Green, Rogers, &amp; Finch (1997)</td>
<td>24 Low anxious</td>
<td>• Hospital Anxiety and Depression Scale (HADS; a state measure of anxiety). Participants composed into groups based on this measure.</td>
<td>None</td>
<td>• BAKAN sustained attention task. Participants monitor a stream of digits and indicate when three consecutive odd or even numbers are present.</td>
<td>• BAKAN task. No impact of anxiety on accuracy. No main effect of anxiety on reaction time, but times increased as task progressed for high anxious participants only, while remaining unchanged for low and medium anxious participants.</td>
</tr>
<tr>
<td></td>
<td>24 Medium anxious</td>
<td>• RTT</td>
<td></td>
<td>• Reaction time task. Pressing the keyboard (spacebar) as quickly as possible in response to target stimulus.</td>
<td>• Reaction time task. No effect of anxiety.</td>
</tr>
<tr>
<td></td>
<td>24 High anxious</td>
<td></td>
<td></td>
<td>• Motor speed task. Tapping at the same location.</td>
<td>• Motor speed task. No effect of anxiety.</td>
</tr>
<tr>
<td>Author(s)</td>
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<td>Mood Induction</td>
<td>Tasks</td>
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</table>
| Derakshan & Eysenck (1998) | 20 Low trait anxious 19 Repressors 24 High trait anxious 16 Defensive high-anxious | • STAI-trait  • Marlowe-Crowne Social Desirability Scale | All participants received ego threatening instructions. | Grammatical reasoning task. See C. MacLeod and Donnellan (1993) for a description. This task comprises two components - a digit string memory task, and a reasoning task. | • Digit string memory task: No effect of anxiety on accuracy. However, the high anxious participants had longer reaction times than the low anxious participants when memory load was high but not when it was low (i.e. anxiety x load interaction).  
• Reasoning task: No effect of anxiety on accuracy. High anxious participants had longer reaction times than low anxious participants and this was more pronounced under high memory load than under low memory load. |
| Richards, French, Keogh, & Carter (2000) | 17 High test anxious 19 Low test anxious | • TAS  • STAI-state  • STAI-trait | None | Verbal reasoning task. Similar to Darke (1988b; Experiments 1 & 2). This task consists of verifying both non-anaphoric and anaphoric references. Verifying anaphoric sentences is argued to not place great demands on working memory. Verifying non-anaphoric sentences is argued to place demands on working memory. The task was performed concurrently with a *digit string memory task* that imposed either a low memory load (2 digits) or a high memory load (6 digits). | • Digit string memory task: High anxious participants took longer to study memory items than low anxious participants, and this was attributed to test anxiety rather than state or trait anxiety. No effects of anxiety on accuracy were observed.  
• Reasoning task: Accuracy was greater for low than for high anxious participants. Reaction times were also faster for low than for high anxious participants. The time taken to verify anaphoric and non-anaphoric sentences was equivalent for the low anxious participants, but the high anxious participants took longer to verify non-anaphoric sentences than anaphoric sentences. Accuracy and reaction time differences were attributed to test anxiety rather than to state or trait anxiety. |
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Participants</th>
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<th>Mood Induction</th>
<th>Tasks</th>
<th>Main findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tohill &amp; Holyoak (2000)</td>
<td>Experiment 1&lt;br&gt;11 High state anxious&lt;br&gt;11 Low state anxious</td>
<td>• STAI-state, administered after completion of task</td>
<td>Participants divided into anxiety groups on basis of allocation to stressful (subtraction task) or non-stressful tasks.</td>
<td>Analogical reasoning task. Pictorial analogies. Solution achieved either by mapping attributes of individual objects (which makes low resource demands) or mapping the relations between objects (greater resource demands). In Experiment 2, participants were instructed to use relational mapping.</td>
<td>• High anxious participants engaged in significantly fewer relational mappings (which tax working memory resources) than did low anxious participants.</td>
</tr>
<tr>
<td></td>
<td>Experiment 2&lt;br&gt;11 High state anxious&lt;br&gt;11 Low state anxious</td>
<td></td>
<td></td>
<td></td>
<td>• High anxious participants still produced fewer relational mappings than did low anxious participants despite explicit instruction. Interestingly, there was no significant difference in response times.</td>
</tr>
</tbody>
</table>
| A.M. Williams, Vickers, & Rodrigues (2002) | 10 table tennis players | • Competitive Sport Anxiety Inventory (CSAI-2). A state measure of cognitive anxiety. | Participants underwent both stressful (competition conditions with prize money) and non-stressful (practice) conditions. | Modified table tennis task. Participants performed a table tennis task that imposed either a low memory load (returning a shot into one of three circles) or a high memory load (returning a shot according to a set of complex rules determining where the shot could be returned). | • Participants reported expending more mental effort under the stressful than non-stressful condition. The stressful condition also elicited greater cognitive anxiety ratings than did the non-stressful condition.  
• Modified table tennis task. Greater accuracy was observed under non-stressful than stressful conditions.  
• Probe reaction task. Longer probe reaction times were observed under stressful than non-stressful conditions. |
Table 1.1. (continued)

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Participants</th>
<th>Mood measures</th>
<th>Mood Induction</th>
<th>Tasks</th>
<th>Main findings</th>
</tr>
</thead>
</table>
| Murray & Janelle (2003) | 14 Low trait anxious 14 High trait anxious | • STAI-trait  • CSAI-2 | Participants underwent both stressful (ego-involving instructions plus prize) and non-stressful (no prize and no ego-involving instructions) conditions. The non-stressful session always preceded the stressful session. | • Driving task. Driving simulation task. Racecourse projected onto screen, participants used analogue steering wheel, brake, and accelerator foot pedals to navigate the course.  
• Response-time task. Performed concurrently with driving task. Participants identified, by pressing one of two buttons, which one of four lights presented on either side of the screen was illuminated. | • State cognitive anxiety ratings were higher for the stressful than for the non-stressful conditions, and this was more pronounced for the high than low trait anxious individuals. Also, high trait anxious individuals had higher state cognitive anxiety ratings than low trait anxious individuals.  
• Driving task. No effect of anxiety on lap speed.  
• Response-time task. Response times for low trait anxious individuals decreased from the non-stressful to the stressful conditions, whereas the high trait anxious individuals showed an increase in response times over the same period. |
1.4 Anxiety and working memory – the Processing Efficiency Theory

One theory that has been put forward to account for anxiety-linked deficits in working memory performance is the Processing Efficiency Theory (PET). Proposed by Eysenck and Calvo (1992), the PET draws on both Sarason’s (1984) attentional interference theory and Humphreys and Revelle’s (1984) theory linking personality, motivation, and performance. The pertinent aspects of these two theories will now be discussed prior to an examination of the PET.

According to Sarason’s (1984) attentional interference theory, threatening situations engender stress. Part of this stress reaction includes thoughts that pertain to the task at hand (e.g. in solving the problem), as well as thoughts that are not related to the task at hand (e.g. worrying about performance and abilities). Thoughts that are not relevant to the task consume attention, leaving fewer resources available for task performance. Thus, where thoughts that are not focused on attaining the goal of the task predominate, performance on the task is likely to be impaired due to fewer resources being allocated to the task.

Humphreys and Revelle’s (1984) personality, motivation, and performance theory views motivation as the critical factor determining performance, suggesting it is intimately linked with the level of effort an individual expends on a given task. Motivation is proposed to affect performance via two routes. First, it affects performance via the allocation of resources. Where there are two tasks that the individual performs simultaneously, the tradeoff in the allocation of resources to each task is contingent on the motivation to succeed at one task over the other. Where there is only one task, motivation affects whether resources are allocated: (a) to one facet of task performance over another (e.g. accuracy may be favoured over speed); (b) to either an experimenter-defined task (i.e. the task that the individual is presented with) or a participant-defined task (e.g. worrying about performance); (c) or not allocated, as is the case in instances where resource allocation comes at a cost, and a ‘saturation point’ occurs where the benefits resulting from additional resource allocation is equivalent to the cost of resource allocation. At this point, no further resources are likely to be allocated.
The second route via which motivation affects performance is via the availability of resources. Drawing on Kahneman’s (1973) theory of attention and effort, Humphreys and Revelle (1984) suggest that heightened motivation may actually increase the amount of available resources, rather than simply influence the reallocation of resources (either from one task to another, or from an unused pool of resources to a task at hand). Alternatively, increased motivation may serve to decrease the costs associated with resource allocation such that more resources may be allocated to the task presently, with the cost deferred until a later time. An example of this may be additional effort that is put into running a race, at the expense of a significantly decreased level of effort post-race.

The PET draws on both Sarason’s (1984) and Humphreys and Revelle’s (1984) theories. From Sarason’s theory, Eysenck and Calvo (1992) view anxiety to affect attention, though, in light of Humphreys and Revelle’s theory, motivation also plays an important role in the anxiety-performance relationship. However, unlike Humphreys and Revelle, Eysenck and Calvo suggest that where avoidance is not possible (e.g. test situation) or where it results in negative consequences (e.g. failing), anxious individuals are motivated to circumvent the negative consequences of poor performance. That is, Eysenck and Calvo advocate an active, rather than passive, role for anxious individuals. Specifically, anxious individuals have the ability to recruit strategies or to increase effort in order to overcome deficits they may experience in performance. Thus, the PET draws a distinction between performance effectiveness and processing efficiency. Effectiveness refers to the quality of performance. Efficiency is more difficult to define, however Eysenck and Calvo suggest that this may be operationalised as effectiveness divided by effort. Anxiety is proposed to affect efficiency to a greater extent than it does effectiveness. For instance, equivalent levels of performance may be observed between anxious and non-anxious individuals. However, as the working memory capacity of high anxious individuals is limited due to worry consuming resources, they expend more effort to attain the same level of effectiveness and, hence, efficiency is lowered.

1.4.1 Assumptions of the PET

Prior to a more detailed examination of the PET, the assumptions of this theory will be reviewed. First, worry is the component of anxiety deemed responsible for the deleterious impact anxiety has on performance. Worry is viewed as the cognitive component of state anxiety, with state – rather than trait – anxiety responsible for
any observed effects. However, it should be noted that Eysenck and Calvo (1992) regard state anxiety to be determined interactively by trait anxiety and situational stress, and view state and trait anxiety to be difficult to distinguish empirically.

Second, the PET is premised on the tripartite working memory model (Baddeley & Hitch, 1974) which conceptualises working memory as having both storage and processing functions, with a division in the storage functions along the nature of the material each system processes (i.e. verbal or visuospatial). In adopting the Baddeley and Hitch model of working memory, Eysenck and Calvo (1992) embrace the CE as being an attention-based system. The PET proposes that worry concerning task performance pre-empts capacity within the working memory system, predominantly affecting the CE and, to a lesser extent, the PL (due to the verbal nature of worry; Eysenck & Calvo, 1992). It is noteworthy that the working memory capacity of high and low anxious individuals is proposed to be equivalent.

Third, worry is proposed to impair working memory performance by consuming attentional resources. However, worry also has a beneficial role to counter its adverse effects, and this is mediated by a self-regulatory system that is proposed to be housed within the working memory system (Eysenck & Calvo, 1992). This system is responsive to feedback that indicates that performance is below a desired level, and reacts to counter the negative impact of worry either by (a) directly reducing the amount of worry, thereby freeing up working memory resources; or (b) applying additional effort or recruiting additional processing strategies. Thus, the impetus for applying extra effort or engaging strategies is contingent on the discrepancy between expected and actual performance.

The self-regulation system is likely to be activated with greater frequency in anxious than non-anxious individuals for several reasons (Eysenck & Calvo, 1992). Eysenck and Calvo hypothesise that anxious individuals typically hold unrealistically high expectations of their own performance, thus a discrepancy between expected and actual performance is more likely to occur. Anxious individuals also generally engage in a greater amount of worry than non-anxious individuals. For them, the available capacity that can be devoted to task performance is restricted to a greater extent. Consequently, the discrepancy between expected and actual performance is more pronounced. Furthermore, biases in attention towards threatening stimuli (C. MacLeod, Mathews, & Tata, 1986), mean that high anxious individuals are faster at detecting threatening situations. Thus, anxious individuals are faster to respond
to the discrepancy between expected and actual performance, thereby activating the self-regulatory system. In all, while worry serves to reduce the amount of capacity that can be allocated towards a task, it can also, via the self-regulatory system, mitigate the adverse effect of anxiety.

A diagrammatic representation of Eysenck and Calvo’s (1992) PET is provided in Figure 1.1. This is not one specified by the authors, but rather an interpretation based on the theory’s assumptions. Consequently, there are several aspects of the diagrammatic representation that necessitate clarification:

1. State anxiety is determined interactively by trait anxiety and situational stress and it comprises two components – cognitive and somatic anxiety. It is worry, an aspect of cognitive state anxiety, that is critical within the PET.

2. Worry has two effects, as indicated by the two arrows. First, it consumes capacity predominantly in the CE and, to a lesser extent, the PL. The dashed line indicates that the effect of worry on the PL is weaker than that on the CE.

3. The second arrow concerns Eysenck and Calvo’s (1992) prediction that worry serves a motivational function via a control system. The control system is housed within the working memory system and, while not explicit stated by Eysenck and Calvo, it may be equated with the CE for both appear to serve very similar functions. The notion of a control system is not dissimilar to that of the CE (indeed, Baddeley, 1986, views it as an overall controller) which, amongst other functions, includes strategy selection (i.e. the processing activation that Eysenck and Calvo refer to), integrating information from several sources (it is not unrealistic to suggest that it is capable of integrating performance feedback), and is called upon in situations judged to be dangerous (i.e. threatening, as in the case of potential failure). The arrow linking worry with the control system is bidirectional for reasons that will be elucidated later in this section. For now, it is sufficient to state that the control system is triggered by motivational influences.
Figure 1.1 A diagrammatic representation of Eysenck and Calvo’s (1992) Processing Efficiency Theory.
4. Worry – either by the consumption of capacity or by motivation – impacts on the working memory system and, consequently, on both performance effectiveness and processing efficiency. The greater impact is proposed to be on performance efficiency (hence the solid arrow), with a lesser impact on performance effectiveness (dashed arrow).

5. The control system is responsive to feedback regarding performance. This feedback may come in the form of performance effectiveness (e.g. less than optimal accuracy) or efficiency (e.g. taking longer than expected to complete a task). From this feedback, the control system is able to (a) initiate the application of additional effort or initiate processing activities that compensate for impaired performance, and (b) directly cope with worry by decreasing the amount of worry and consequently increasing the capacity of working memory (hence the bidirectional arrow between worry and the control system). Eysenck and Calvo (1992) suggest that the control system is responsive to performance feedback that indicates failure. However, it is not unreasonable to suggest that the control system and the strategies (i.e. effort/processing activities) may also be triggered in the first instance prior to initiation of the task – that is, not merely in response to feedback from performance. This is likely to occur when the individual is motivated to perform well prior to commencing the task, and may already have considered the best way of tackling the task (i.e. motivation has triggered processing activities even prior to commencing the task, therefore the feedback loop that encompasses performance has not yet been engaged).

6. There is a potential alternative route via which motivation may affect working memory performance (denoted in green in Figure 1.1). Eysenck (1985) demonstrated that monetary incentive interacted with trait anxiety to affect performance, and suggested that since this did not serve to elevate state anxiety levels, it presumably does not engender worry. While this route is deserving of further investigation in order to clarify the relationship, the focus of the present programme of research is firmly on the first route – that is, the one in which state anxiety, and worry, play a role in affecting working memory performance.
1.4.2 Predictions of the PET

There are two central predictions to the PET. The first is that processing efficiency is impaired by anxiety to a greater extent than is effectiveness. The second is that this impairment is more pronounced under increasing demands on working memory capacity. Under each of these, Eysenck and Calvo (1992) delineate precise predictions regarding the relationship between anxiety and working memory. Table 1.2 provides a brief summary of these predictions as outlined by Eysenck and Calvo.

Table 1.2. Predictions of the Processing Efficiency Theory

<table>
<thead>
<tr>
<th>Prediction 1</th>
<th>Processing efficiency is affected by anxiety to a greater extent than is effectiveness.</th>
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<tbody>
<tr>
<td></td>
<td>Where performance effectiveness is equated, a direct comparison between high and low anxious individuals is possible, with the expectation that the former will expend more effort and therefore exhibit poorer processing efficiency.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Prediction 1.1</th>
<th>Where performance effectiveness is equivalent, high anxious participants should report expending more effort.</th>
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<tbody>
<tr>
<td></td>
<td>Where performance effectiveness is equated, high anxious individuals are expected to have expended more effort to counter the negative effects of worry, and this should be reflected in subjective reports. It should be noted that while high anxious individuals may be inclined to exaggerate the amount of effort spent, this alone does not provide a complete account of the data (Eysenck &amp; Calvo, 1992).</td>
</tr>
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<tr>
<th>Prediction 1.2</th>
<th>Anxiety typically impairs secondary task performance</th>
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<td></td>
<td>In performing a central task, the remaining available resources are inversely related to the effort expended by the individual. This may be investigated using a secondary task, with the expectation that where central-task performance is comparable between high and low anxious individuals, the former are already expending more effort on the primary task and therefore have less remaining resources to devote to the secondary task. Consequently, anxiety is proposed to result in poorer secondary task performance.</td>
</tr>
</tbody>
</table>
| Prediction 1.3 | Anxiety limits the amount of residual capacity during task performance, and this can be assessed using the probe technique. 

This technique requires participants to perform a central task to the best of their ability, and also to respond as quickly as possible to a series of occasional probes (i.e. to shadow the probes). The greater the available capacity remaining from performing the central task, the better the performance on the probe task will be. As high anxious individuals are already expending more effort on the central task and have less remaining capacity as a result, they are expected to exhibit longer probe response times. It is noted that this prediction has similarities with Prediction 1.2. |
| Prediction 1.4 | Enhancing motivation serves to increase effort which, in turn, improves performance. Low anxious individuals benefit from this to a greater extent than do high anxious individuals. 

High anxious individuals already expend more effort than their low anxious counterparts to achieve the same level of effectiveness. Thus, conditions that enhance motivation (e.g. ego involvement instructions, monetary incentives) benefit low anxious individuals to a lesser extent than they do high anxious individuals. |
| Prediction 1.5 | Where an additional load is imposed, impairments in performance on a central task will be more pronounced for high anxious than low anxious individuals. 

If a secondary task – which imposes an additional load – must be performed to a particular level of effectiveness, it is assumed that high anxious individuals have already expended more effort to attain this level. Consequently, high anxious individual would have fewer remaining resources available for the central task than would their low anxious counterparts. This prediction has similarities with Predictions 1.2 and 1.3. |
| Prediction 1.6 | Where performance effectiveness is comparable between high and low anxious individuals, lower processing efficiency in the former may be observed in longer processing times. 

If the time taken to process information is regarded as a measure of efficiency (as is assumed by Eysenck and Calvo, 1992), then high anxious individuals may overcome the negative effects of worry by taking a longer period of time to achieve the same level of effectiveness as low anxious individuals. |
| Prediction 1.7 | Anxiety-linked impairments on efficiency may be observed psychophysiological. 

On tasks on which a psychophysiological component is involved, high anxious individuals have been found to expend more energy (an index of effort) to achieve an equivalent level of effectiveness compared to low anxious individuals. |
Table 1.2. (cont’d)

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Prediction 2</strong></td>
<td>With increasing demands on working memory capacity, the negative impact of anxiety on performance becomes more pronounced.</td>
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<tr>
<td></td>
<td>Anxiety engenders worry, and worry pre-empts capacity in the CE and PL. High anxious individuals therefore have less residual working memory resources to devote to the task at hand. If a task is relatively simple and can be successfully performed with the remaining available resources, then additional effort need not be applied. If, however, the demands of the task exceed the remaining available resources, then high anxious individuals need to expend more effort to attain an equivalent level of performance (and processing efficiency is thus lowered). Impairments are proposed to be observed only where the task itself taps either the CE or the PL, with deficits most pronounced on tasks that tap both these systems.</td>
</tr>
<tr>
<td><strong>Prediction 2.1</strong></td>
<td>The degree of anxiety-linked impairments is contingent on the demands the task makes on working memory resources (as evaluated by its susceptibility to interference from a concurrent load).</td>
</tr>
<tr>
<td></td>
<td>Anxiety-linked impairments are more pronounced on tasks that make heavy demands on working memory resources. The degree to which a task is demanding of resources may be evaluated by how resistant it is to a concurrent load, with greater susceptibility found with increasingly demanding tasks.</td>
</tr>
<tr>
<td><strong>Prediction 2.2</strong></td>
<td>Anxiety limits the available storage capacity.</td>
</tr>
<tr>
<td></td>
<td>Worry, a component of state anxiety, pre-empts capacity in the PL, which is a system specialising in the storage of verbal information. Thus, high anxious individuals should exhibit lower scores on verbal storage tasks such as the digit span task.</td>
</tr>
<tr>
<td><strong>Prediction 2.3</strong></td>
<td>Anxiety-linked impairments in performance will be most pronounced on tasks with heavy storage and processing demands.</td>
</tr>
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<td></td>
<td>Tasks that tap both the CE and PL are expected to reveal greater anxiety-linked decrements in performance than tasks that tap only one of these systems, for worry is proposed to affect these two working memory systems.</td>
</tr>
<tr>
<td><strong>Prediction 2.4</strong></td>
<td>Anxiety-linked impairments are not typically observed on tasks that tap neither the CE nor PL.</td>
</tr>
<tr>
<td></td>
<td>The performance of high and low anxious individuals is not expected to differ on tasks that make demands on the VSSP alone (i.e. not involving the PL or the CE) for worry is not proposed to affect this working memory system.</td>
</tr>
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</table>
1.5 Accounting for the anxiety-working memory findings

Studies of anxiety and working memory have generally supported the predictions of the PET. Specifically, most of the tasks on which anxiety-linked impairments in performance have been evident tend to be CE tasks that utilise verbal stimuli (Predictions 2.3 and 2.4). These include the grammatical reasoning task, reading span task, syllogistic reasoning task, and anagram solution task. There is mixed support for an impact of anxiety on verbal storage capacity (Prediction 2.2; Darke, 1988a; Markham & Darke, 1991).

More importantly, in some instances where anxiety did not adversely affect indices of performance effectiveness such as accuracy, the differences have been evident on reaction times (Prediction 1.6; Calvo et al., 1994, Experiments 2 & 3; Darke, 1988b, Experiments 2 & 3; Derakshan & Eysenck, 1998; Elliman et al., 1997; Ikeda et al., 1996; C. MacLeod & Donnellan, 1993; Markham & Darke, 1991). This dissociation in the effects of anxiety on various indices of performance supports the distinction the PET makes between effectiveness and efficiency (Prediction 1). It is important to note that these differences between anxiety groups on reaction times, which are predicted by the PET, are often interpreted in terms of processing efficiency within the anxiety-working memory literature. However, in the broader cognition literature, accuracy and reaction time are commonly interpreted as alternative indices of task difficulty over which the participant typically has some control through adopting a particular speed-accuracy trade-off (e.g. Allen Osman et al., 2000\(^2\)). Thus instruction (e.g. to emphasise speed) could potentially shift effects from reaction time to accuracy, and this has implications for conceptualisations of the relationship between anxiety and working memory.

Studies of anxiety and working memory performance have demonstrated that differences in performance between high anxious and low anxious individuals are more pronounced with increasing task demands on working memory resources (Prediction 2.1; Derakshan & Eysenck, 1998; C. MacLeod & Donnellan, 1993).

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\(^2\) There are two studies cited in this thesis wherein the primary author is an A. Osman, however in the absence of any middle initials to differentiate between the two, the full first names of both A. Osmans will be utilised.
One aspect of the PET that is weakly translated into its predictions is the role of strategies in the anxiety-working memory performance relationship. It is specified in the theory that the control system reacts to indications of impoverished performance either by the application of extra effort or the utilisation of strategies to counter performance deficits. However, predictions involving strategy application do not feature prominently in empirical evaluations of the PET (refer to Table 1.2). Rather, the research examines more closely the notion of additional effort and focuses on measures expected to be sensitive to this construct (e.g. reaction times; Prediction 1.6). Two studies reviewed in Table 1.1 suggest that anxiety does affect strategy selection. In one study, by Calvo et al. (1994, Experiment 3), participants were required to read sentences for the purpose of comprehension. These sentences were presented individually, with regressions to previous sentences permitted. While comprehension accuracy did not differ between high and low anxious individuals, the former made more regressions to previous sentences than did their low anxious counterparts.

In another study, conducted by Tohill and Holyoak (2000), participants were presented with a pictorial analogical reasoning task. The solution to each problem in the task was attainable either by mapping the attributes of individual objects (attributitional mapping) or by mapping the relations between objects (relational mapping), with the latter proposed to be more taxing on CE resources (Gentner, 1983). For example, one picture may portray a man with a dog breaking away from its leash to chase a cat, while a second picture may show a dog tied to a tree, breaking away from its leash to chase a man. If the task involved relating an object in the second picture to the man in the first picture, an attributitional mapping would yield the response of the man in the second picture (i.e. mapping based on the physical characteristics), whereas a relational mapping would yield the response of the tree as something the dog is breaking away from (i.e. akin to the dog breaking away from the man). High anxious participants were found to utilise significantly less relational mappings than low anxious participants (Experiment 1). Even when both groups were instructed to employ relational mappings (Experiment 2), high anxious individuals still produced fewer relational mappings than did low anxious individuals, suggesting that the former relied on strategies that made less demands on CE resources. Interestingly, no significant group differences were evident in response times in Experiment 2. This hints at the possibility that employing
strategies that are less demanding on CE resources may help the individual preserve efficiency (i.e. through expending less effort).

Altogether, studies of the anxiety-working memory relationship have generally supported the various predictions of the PET. Where the PET has been particularly influential in research examining the relationship between anxiety and working memory is in the adoption of different indices of performance. Where once there was an over-reliance on measures of accuracy in indexing performance, the PET has encouraged a broader perspective (e.g. additionally utilising reaction times and strategy selection). In doing so, a more comprehensive picture of the impact of anxiety on working memory may be constructed.

1.6 Difficulties in the interpretation of the literature

While the relationship between anxiety and working memory appears to be relatively straightforward, several factors complicate the existing findings. These relate specifically to: (a) suitability of tasks evaluating the working memory systems; (b) comorbid depression; (c) state versus trait anxiety; and (d) cognitive versus somatic anxiety. Each of these factors is outlined in the following sections. It is important to outline these factors as, prior to a test of the PET, the next few chapters comprise an initial series of methodological studies addressing the limiting factors present in the anxiety-working memory literature.

1.6.1 Suitability of tasks evaluating the working memory systems

Part of the difficulty in interpreting the anxiety-working memory relationship stems from the tasks utilised to assess the three different working memory systems. Ideally, such tasks would be identical in their requirements save for the process of interest. Thus, when comparing the slave systems, the tasks should differ only in the modality of the stimuli. Likewise, the difference between tasks employed to evaluate the CE and one of the slave systems should only be the necessity to manipulate the information (as in the case of the CE task), as opposed to the mere maintenance of information (as in the case of the slave system task). In this way, differences in performance on the various tasks reflect the cognitive process being investigated, and any interpretation is not complicated by potential executive control, sensory, and motor differences (Fiez, 2001).
Several studies focus only on one working memory system (typically the CE, Derakshan & Eysenck, 1998; C. MacLeod & Donnellan, 1993; Tohill & Holyoak, 2000; Zarontonello et al., 1984), and thus differences in task demands are perhaps a moot point concerning these findings. While this focus is undoubtedly the product of research suggesting that these systems are most susceptible to anxiety, it nevertheless does not – in one experiment – evaluate the impact of anxiety on all three systems within working memory.

For those studies that endeavour to compare performance on two or more working memory systems, the issue of task congruence arises, and this is most evident in comparisons between the slave systems and the CE. For example, Markham and Darke (1991) utilised a digit span task to assess the PL, and a verbal reasoning task (syllogisms) to assess the CE. The digit span task requires participants to recall sequences of numbers of increasing sequence length. In the syllogisms task, participants are presented with a series of premises (e.g. ‘Bob is heavier than Sam, Sam is lighter than John, John is lighter than Simon’), followed by a conclusion (e.g. ‘Simon is heavier than Sam’), and are required to verify the conclusion as being true or false. The difficulty with utilising these vastly different tasks is that where anxiety is deemed to affect one task but not another, it becomes unclear as to which critical aspect of the affected task is responsible. For example, Markham and Darke suggest that since anxiety affected performance on the syllogistic task but not performance on digit span task, it appears that anxiety-linked impairment in performance are evident on CE but not PL tasks. However, an alternative explanation may be that the syllogistic task makes heavier demands on the PL than does the digit span task – via the imposition of a heavier memory load – and that this may contribute to the observed pattern of results.

Greater congruency in the tasks used to examine the CE and one of the slave systems was achieved by Sorg and Whitney (1992). These authors utilised a word span task to assess PL functioning, and a reading span task to assess CE functioning. The word span task is identical to the digit span task, save for the utilisation of words rather than digits. The reading span task presents participants with sequences of sentences of increasing sequence length, with the requirement that participants process the content
of the sentences for the purpose of a comprehension task, while recalling the last word of each sentence in the current sequence. Using these two tasks, the number of words to be recalled by participants may be equated, therefore differences in performance on the two tasks heavily reflect the processing component of the reading span task. However, although these two tasks engage CE and PL resources while retaining task congruence, difficulties arise where the study of all three working memory systems is desired. Specifically, the difficulty stems from finding nonverbal tasks to parallel the word and reading span tasks. Establishing such tasks is desirable, for it provides an opportunity to obtain a comprehensive picture of the impact of anxiety on working memory performance.

The way towards establishing congruence between tasks that tap all three working memory systems may be to adapt the tasks utilised by Markham and Darke (1991) to evaluate the slave systems, extending these tasks to assess CE functioning. In Markham and Darke’s study, the digit span task was employed to study the PL, and the Corsi blocks task was employed to study the VSSP. In the Corsi task, participants are presented with an array of haphazardly-arranged blocks and required to recall series of highlighted blocks of increasing length. The digit span and Corsi tasks may be equated on most dimensions (e.g. the number of trials at each given series length, the series length at which the task commences, the conditions determining termination of the task, and presentation rate), thereby forming parallel tools for assessing the slave systems. With only the nature of the stimuli presented (verbal versus visuospatial) and the method of response (vocal versus motor) differing between the two tasks, differences in performance are less likely to be attributable to task characteristics.

The capacity to equate several task dimensions of the digit span and Corsi tasks, thereby permitting comparisons between the PL and VSSP, may be extended to derive tasks to evaluate the CE. These are inevitably variations of the tasks for the slave systems that additionally invoke CE processes. One such variation is the running memory task (Pollack, Johnson, & Knaft, 1959) wherein the participant is presented with a sequence of items of unknown length, and is then asked to recall a particular number of the most recent items. The manner in which this engages the CE may be conceptualised as follows. Say the participant is required to recall, sequentially, the last x items in the series of items. The first x items presented are held in memory, and
subsequent items require the participant to update the contents of the memory set by (a) dropping the item that was first presented; (b) adding the most recent item to the set; and (c) reassigning the order of elements – thus, the second element of the initial x items becomes the first element when x + 1 items are presented (Morris & Jones, 1990).

Another variation is the n-back task (e.g. Awh et al, 1996), which has been described as a running memory task that utilises recognition rather than recall (Kusak, Grune, Hagendorf, & Metz, 2000). Participants are presented with a sequence of stimuli followed by a target, and required to indicate if the target corresponds to the item presented n items ago. The CE is engaged such that, as in the running memory task, the order of elements in the series must be continually reassigned with each additional element added to the series. Say, the first n items are presented. The first of these is assigned the serial position n-back, the next, assigned the serial position (n-1) back, and so on. When an additional item is presented, the first item is then dropped from the memory set, and the item that was previously (n-1) back is now assigned the serial position n-back.

Earlier, it was noted that studying the functioning of the CE alone is difficult due to its modality-free nature and the necessity to utilise either verbal or visuospatial stimuli, which engages the PL and VSSP (respectively). An appropriate question that may arise, therefore, is whether there is a substantial contribution of the CE to the performance of any cognitive task that is above and beyond what the slave systems can account for. It appears that performance on the CE tasks described above is indeed contingent on CE and not slave system resources. For example, Lehto (1996) found that performance on an updating task utilising digits did not correlate with performance on a simple digit span task, suggesting that the process of updating commands resources that are not restricted to simple storage. In a more rigorous test, Morris and Jones (1990) independently manipulated verbal interference and also the number of updates required. While each of these had an effect on recall, an absence of interaction of these two factors suggests that the act of updating is not governed by the PL slave system. Morris and Jones therefore concluded that performance on a verbal updating task was such that the updating was governed by CE processes, and serial recall by PL processes.
Neuroimaging and ERP studies (Awh et al., 1996; Kiss et al., 1998; Kusak et al., 2000; Smith & Jonides, 1997; Van der Linden et al., 1999) also demonstrate that the n-back and updating tasks tap CE processes, as indexed by activity in the prefrontal cortex. In contrast, performance on the corresponding slave system task was not characterised by activity in the same area. It is noted that the neuroimaging and ERP studies need to be interpreted cautiously for there is contention within the working memory literature regarding the localisation of function in the brain (see Carpenter et al., 2000; McIntosh & Lobaugh, 2003; Veltman et al., 2003).

In summary, many studies investigating the impact of anxiety on working memory employ tasks that vary on several dimensions in addition to the process of interest. However, Markham and Darke’s (1991) utilisation of the digit span and Corsi tasks, along with research into the n-back and running memory tasks, ideally provide a way forward to invoke the involvement of the three working memory systems while controlling other critical task aspects. Chapter 3 endeavours to further minimise differences inherent in the different span tasks, with a focus on equating the mode of stimuli presentation and method of response between tasks designed to tap the VSSP and PL. In doing so, differences in performance on tasks that assess the different working memory systems may be attributed to the differential influence of anxiety across the working memory systems, rather than to task characteristics.

### 1.6.2 Comorbid depression

A factor complicating the anxiety-working memory relationship is that of depression. Measures of anxiety and depression have been reported to correlate between .40 and .70 (L.A. Clark & Watson, 1991a). The difficulty with this is that depression itself has been found to affect working memory performance. While research in the area of depression and working memory is sparse relative to that of anxiety and working memory, the literature suggests a relationship involving depression that is akin to that accorded to anxiety, with elevated mood levels serving to impair performance. Specifically, performance on VSSP and PL tasks has been reported to be comparable between depressed and non-depressed individuals, with differences between the two groups pronounced on a variety of tasks tapping the CE (Baker & Channon, 1995; Channon, 1996; Channon & Baker, 1996). Furthermore, similar to Tohill and Holyoak’s
(2000) study of anxiety and working memory, depressed individuals were found to be more reliant on strategies that were less taxing on effortful processing resources (i.e. that engaged the CE to a lesser degree; Channon & Baker, 1994).

It is particularly noteworthy that one of the dominant theories proposed to explain depression-linked impairments in working memory is similar to the PET. The Resource Allocation Model (RAM; Ellis & Ashbrook, 1988) is premised on the assumption that working memory capacity is fixed and at any given time, only a finite amount may be allocated to a task at hand. Depression is proposed to affect performance by restricting the amount of available resources that may be allocated to the task. This arises either due to depression directly diminishing the size of the available pool of resources, or through the experience of depression occupying working memory resources reflecting depressed individuals thinking about their depressed state. While it may be difficult to empirically test the first possibility, the second possibility – that such irrelevant thoughts pre-empt working memory capacity – has been empirically supported (Seibert & Ellis, 1991). The extent to which depression debilitates performance is determined, in part, by the demands of the task, with a greater depression-linked decrement in performance attributable to higher demands placed by the task on available resources (for a more detailed description of the RAM and its assumptions, refer to Ellis & Ashbrook, 1988).

Certainly, the similarities between the RAM and the PET are striking, and this is acknowledged by the authors of the PET (Eysenck & Calvo, 1992). Both theories contend that the amount of working memory capacity allocated to task performance is diminished by task-irrelevant thoughts, and both theories pinpoint the CE as the working memory system that is most impaired. A further complicating factor is the role of psychomotor retardation – which encompasses gross motor speed as well as simple reaction time – that is characteristic of depression (Byrne, 1976). The implication of this is that slowed performance exhibited in studies of anxiety and working memory, in which depression is typically confounded, may reflect either impaired processing

Note: A task in this context refers to one that requires effortful processing (see Ellis & Ashbrook, 1988), not an automatic one that is presumed to be able to be completed without engaging working memory resources.

Although see Oaksford, Morris, Grainger, and J.M.G. Williams (1996) who suggest that positive mood states can also affect performance in a similar manner.
efficiency (as proposed by the PET), or it may reflect psychomotor retardation linked with depression. It should be noted, however, that psychomotor retardation has only been studied in clinically depressed individuals and not subclinically depressed individuals, and consequently this point is only speculative in nature.

Caution may be required when interpreting the studies of depression and working memory. While research in the area of anxiety and working memory suffers from a lack of clarity because depression has generally not been controlled for, the converse is also true. That is, studies of depression and working memory do not attempt to isolate the contributions of anxiety to any observed deficits in performance.

In summary, the depression-working memory relationship appears to be similar to the anxiety-working memory relationship. The moderate to high correlations between anxiety and depression, however, is only an empirical indicator of how intimately linked the two are, with conceptual analyses highlighting the complexity of their relationship. Indeed, the difficulty in differentiating between the two stems from the large degree of overlap between the two constructs. At the core of this is the significant overlap in the symptoms that constitute the two disorders (Gotlib & Cane, 1989). These symptoms include irritability, agitation, concentration difficulties, fatigue, and insomnia. Consequently, a significant proportion of individuals meeting the diagnostic criteria for one disorder also meet the criteria for the other (Frances et al., 1992; Rouillon, 1999; Sartorius, Üstün, Lecrubier, & Wittchen, 1996). Also, self-report measures such as the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970) and the Beck Depression Inventory (BDI; A.T. Beck & Steer, 1987), which were developed to capture the symptoms of anxiety and depression, exhibit poor discriminant validity (Gotlib & Cane, 1989; Watson & Kendall, 1989). The first step forward in isolating the contribution of anxiety to working memory performance, therefore, is to utilise self-report measures that maximise the distinction between anxiety and depression when identifying high and low anxious individuals. An in-depth exploration of this issue is presented in Chapter 2, and a more detailed discussion of the relationship between anxiety and depression may be found in Chapter 7.
1.6.3 State versus trait anxiety

According to the PET, elevated levels of state anxiety is the cause of anxiety-linked deficits in performance, and furthermore, state anxiety is determined interactively by trait anxiety and situational stress (Eysenck & Calvo, 1992). However, Eysenck and Calvo concede that state and trait anxiety are difficult to distinguish empirically in light of the high correlations between them (.70 or greater). Certainly, for several studies investigating the relationship between anxiety and working memory (e.g. Darke, 1988a,b; Ikeda et al., 1996; Tohill & Holyoak, 2000), the distinction between the effects of state and trait anxiety is not clearly made, thus it is difficult at times to attribute impairments in performance to the effects of elevated levels of state anxiety alone.

Part of the difficulty in discriminating state and trait anxiety within the literature lies in the piecemeal approach that many studies adopt in assessing whether it is state or trait anxiety, or even situational stress, that accounts for impairments in performance. One approach adopted by several studies is to divide participants into high and low trait anxiety groups and to experimentally manipulate mood, however state anxiety levels are often not measured following the mood induction. This makes it difficult to establish that state anxiety levels altered in response to the mood induction in the desired direction. Often, situational stress is not a factor that is the focus of examination – in some studies, none of the participants undergo stressful situations (e.g. C. MacLeod & Donnellan, 1993; A. Richards et al., 2000), while in other studies all participants undergo stressful situations (e.g. Darke, 1988a,b; Derakshan & Eysenck, 1998; Ikeda et al., 1996; Markham & Darke, 1991). One study that did include situational stress as a factor found a trait anxiety x stressor interaction effect on performance (Sorg & Whitney, 1992). While this suggests that impairments are attributable to state anxiety, the authors relied on skin temperature, rather than a self-report measure, as an index of state anxiety levels.

In some studies, researchers endeavoured to experimentally manipulate state anxiety levels by subjecting participants to conditions of stress or no stress (e.g. Tohill & Holyoak, 2000; A.M. Williams et al., 2002). However while state anxiety levels were measured, trait anxiety levels were not, thereby making it difficult to identify the contribution of trait anxiety in these studies.
The closest that studies have come to isolating the effects of trait or state anxiety in the anxiety-working memory performance relationship is in the form of research conducted by C. MacLeod and Donnellan (1993), Calvo et al. (1994), and Murray and Janelle (2003). In C. MacLeod and Donnellan’s study, participants were composed into high and low anxiety groups on the basis of their trait anxiety scores. While situational stress was not manipulated, the authors measured state anxiety and, employing partial correlation analyses, they found that impaired working memory performance reflected elevations in trait, rather than state, anxiety. Calvo et al. (1994) examined the effect of evaluative stress on high and low anxious individuals who were composed into groups on the basis of their trait anxiety score as well as their state anxiety scores. That is, high anxious individuals were those who endorsed high trait anxiety scores as well as high state anxiety scores under actual stress conditions (performing a reasoning task in the classroom under test instructions). Conversely, low anxious individuals were those who endorsed both low trait anxiety scores, and low state anxiety scores under actual stress conditions. Participants in the two groups underwent both ego threat and no ego threat conditions. Calvo et al.’s findings indicated that while anxiety-linked performance impairments were evident under conditions of stress (ego threat), most of these were ameliorated under non-stressful conditions (no ego threat). Thus, it appears that situational stress is a critical mediating factor. State anxiety scores were not obtained during the testing session, thus it is inconclusive as to whether impairments in performance are attributable to situational stress or the interaction between trait anxiety and situational stress (i.e. elevated levels of state anxiety).

Perhaps the most thorough study conducted to address the state/trait distinction is that conducted by Murray and Janelle (2003), who examined dual task performance using a simulated driving task and probe reaction time task. Participants were composed into high and low trait anxiety groups, and all participants underwent both stressful (competition conditions plus prize money) and non-stressful conditions (no competition conditions, no prize money). The non-stressful condition always preceded the stressful condition. State anxiety levels were assessed following mood induction, prior to the commencement of the driving and probe reaction time tasks. Consistent with the predictions of the PET that state anxiety is determined interactively by trait anxiety and stress, a trait anxiety x stress interaction was observed on state anxiety scores such that while the stressful condition elicited significantly elevated state anxiety scores
compared to the non-stressful conditions, this difference was greater for the high trait anxious individuals than their low trait anxious counterparts. A corresponding trait anxiety x stress interaction was observed on reaction times on the probe task, suggesting anxiety-linked effects may be attributable to state anxiety. Here, low trait anxious individuals exhibited a decrease in reaction times from the non-stressful to the stressful conditions, whereas the high trait anxious individuals exhibited an increase in reaction times over the same period.

A clear strength of Murray and Janelle’s (2003) study is the use of a within-subjects design that minimises error variance due to subject characteristics. However, this design makes it difficult to interpret the decrease in reaction time on the probe task for the low trait anxious individuals. Specifically, it may reflect practice effects carrying over from the first non-stressful testing session, a real effect of stress that enhances performance thereby resulting in shortened reaction times, or a combination of the two. A between-subjects design may therefore be more suitable in this instance. Another manner in which Murray and Janelle’s study could be enhanced is by the inclusion of state anxiety measures administered following the completion of the task to examine if the effects of the stress manipulation endured throughout the experimental task. These limitations aside, Murray and Janelle’s study provides a way forward to systematically examining the state/trait distinction.

In summary, Eysenck and Calvo (1992) attribute impaired working memory performance to state anxiety, moreover that state anxiety is determined interactively by trait anxiety and situational stress. While some studies support this contention (e.g. Calvo et al., 1994; Darke, 1988a,b; Markham & Darke, 1991), these are restricted by methodological limitations. Furthermore, some studies suggest that trait anxiety is the critical factor (e.g. C. MacLeod & Donnellan, 1993; Richards et al., 2000), while others argue for the role of situational stress per se (e.g. Tohill & Holyoak, 2000; A.M. Williams et al., 2002). Certainly, a more rigorous approach to evaluating the state/trait distinction is necessary in order to obtain a clearer picture of the anxiety-working memory performance link, and Murray and Janelle’s (2003) study provides a way forward. The state/trait distinction is addressed in Chapters 4, 5, and 6.
1.6.4 Cognitive versus somatic anxiety

Researchers have delineated separable cognitive and somatic components under the rubric of anxiety (e.g. Barlow, 1985; Steptoe & Kearsley, 1990). In the more specific area of test anxiety research – from which our understanding of the relationship between anxiety and working memory has been significantly advanced – this division has been identified as one between worry and emotionality respectively (Liebert & Morris, 1967). Since Liebert and Morris’ identification of worry as the critical component in the effect of anxiety on performance, research in this area has flourished. As outlined earlier, Eysenck and Calvo’s (1992) theory conceptualises worry as serving two distinct purposes. First, it preempts capacity in the working memory system, thereby reducing the available capacity that can be devoted to the task at hand. Second, it motivates the individual to engage in processes (e.g. the application of additional effort, the recruitment of strategies) to mitigate the negative impact of worry.

Of lesser note has been the area of research into the relationship between emotionality (or somatic anxiety) and working memory. Studies examining the impact on performance of non-cognitive induction of other mood states (e.g. elation) have shown some support for deficits in working memory performance. These deficits have been evident using mood induction techniques such as viewing film clips designed to induce different mood states (elated, neutral, or depressed; Palfai & Salovey, 1993-4), pictures designed to induce different mood states (Meinhardt & Pekrun, 2003), guided imagery (Hudetz, Hudetz, & Klayman, 2000), and the Velten procedure – wherein participants read a series of statements designed to put them in a particular mood – in combination with music (Spies, Hesse, & Hummitzsch, 1996). These different mood induction techniques are likely to yield varying levels of worry, thus the question arises as to how all of these procedures affect working memory performance.

One model proposed to account for the effects of mood (of a more general nature) on working memory is the RAM (Ellis & Ashbrook, 1988; see Section 1.6.2). Adopting this framework, it has been suggested that emotions themselves, and also the process of mood repair (which the individual is motivated to engage in, particularly when the mood is negative in nature, Spies et al., 1996), consumes attentional resources and leaves less resources available to devote to the task at hand (Krohne, Pieper, Knoll, & Breimer, 2002; Meinhardt & Pekrun, 2003). It is noteworthy that the mechanism via
which emotions affect working memory outlined in the RAM bears striking similarities with Sarason’s (1984) attentional interference theory, on which the PET is based. While the RAM itself has not been subjected to extensive empirical scrutiny, it nevertheless provides a point of interest pertaining to how less cognitive forms of mood, particularly somatic anxiety, may impact on working memory performance. Specifically, it suggests that anxiety may affect working memory performance via a route other than worry, and thus it remains a point of interest to investigate a role for somatic anxiety in the anxiety-working memory relationship. A preliminary exploration for a role of somatic anxiety is presented in Chapter 4, while Chapters 5 and 6 document a more in-depth investigation into the cognitive/somatic anxiety distinction.

1.7 The present programme of research

The selective review outlined above points to limitations in the existing anxiety-working memory literature. These relate specifically to (a) the nature of the tasks utilised to assess which working memory systems are affected by anxiety; (b) the issue of comorbid depression; (c) whether it is state or trait anxiety – or situational stress – that is responsible for the observed deficits in performance; and (d) whether somatic anxiety plays a role in the anxiety-working memory performance link. These issues form the focus of the next few chapters. To foreshadow, Chapter 2 focuses on identifying measures that maximise the distinction between anxiety and depression, whereas Chapter 3 is devoted to identifying comparable working memory tasks that minimise differences in characteristics across tasks assessing the different working memory systems. Chapter 4 investigates a potential role for somatic anxiety in the anxiety-working memory relationship, and also addresses the state/trait anxiety distinction. Studies in subsequent chapters (Chapters 5 and 6), which are more focused on cognitive anxiety, provide a more direct test of the PET.
CHAPTER 2: TRAIT ANXIETY AND DEPRESSION – MAXIMISING THE DISTINCTION

2.1 Introduction

It was identified in Chapter 1 (Section 1.6.2) that there exists a significant overlap in the symptoms that constitute anxiety and depression, including irritability, agitation, concentration problems, as well as insomnia (Gotib & Cane, 1989). One ramification of this is that measures of anxiety and depression may have limited discriminant validity (Watson & Kendall, 1989). Consequently, it may be difficult to isolate the effects of anxiety on working memory performance if measures of anxiety also measure depressive symptoms to some extent. This chapter is motivated by the search for self-report measures that maximise the distinction between anxiety and depression. An issue pertinent to the focus of this chapter concerns the state/trait anxiety distinction raised in Section 1.6.3. To refresh, that section argued for greater rigour in examining whether it is state anxiety, trait anxiety, or situational stress that is responsible for anxiety-linked impairments in working memory performance. As Eysenck and Calvo (1992) view state anxiety to be determined interactively by trait anxiety and situational stress, an ideal starting point would be to focus on clarifying the anxiety and depression distinction at the trait level. To foreshadow the present study, the factor structure of two well-established measures of trait anxiety and depression (STAI, Spielberger et al., 1970; and the Beck Depression Inventory, BDI-2, A.T. Beck, Steer, & G.K. Brown, 1996) that have been employed in the anxiety and working memory research (e.g. Leon & Revelle, 1985; C. MacLeod & Donnellan, 1993; Murray & Janelle, 2003; Sorg & Whitney, 1992) was compared with the factor structure of the Depression, Anxiety, Stress Scale (DASS; S.H. Lovibond & P.F. Lovibond, 1995), a measure designed to maximally differentiate between trait anxiety and depression. It was expected that the DASS scales would discriminate between trait anxiety and depression to a greater extent than would the STAI and BDI-2.

2.2 State-Trait Anxiety Inventory (STAI) and Beck Depression Inventory-2 (BDI-2)

The STAI comprises both state and trait versions, however this chapter is concerned only with the latter (henceforth referred to simply as the STAI). The STAI comprises 20 items and requires respondents to indicate how applicable items such as “I feel rested”, ...
“I feel nervous and restless”, and “I have disturbing thoughts” are in terms of how the respondent generally feels. Items for the STAI are presented in Table 2.1. Test-retest reliability is sound (rs ranging from .73 to .84 for college students over periods of 1 hour to 104 days; Spielberger, 1983), and the STAI has very high internal consistency (coefficient alphas around .90; Spielberger, 1983).

The STAI has been criticised regarding its ‘purity’ in measuring anxiety symptoms, particularly in relation to items such as failure, disappointment, and unhappiness, which have been argued to be more characteristic of depression (Watson et al., 1995a). The lack of specificity of the STAI was investigated by Gotlib and Cane (1989), who examined the degree to which measures of anxiety and depression tap the constructs they were designed to (according to DSM-III-R criteria). In their analysis of the STAI, only 20% of the items measured symptoms specific to anxiety. In contrast, 25% of the items measured symptoms specific to depression, while 20% of the items were common to both anxiety and depression (35% of the items were identified as being unrelated to DSM-III-R diagnoses of anxiety and depression). Consistent with this, Bieling, Antony, and Swinson (1998) also identified general negative affect, anxiety, and depression factors within the STAI. The STAI-depression and STAI-anxiety factors showed similar correlations with scores on the BDI, from which the BDI-2 evolved, suggesting that the STAI does not assess merely anxiety symptoms (Bieling et al., 1998).

The BDI-2 is a 21-item questionnaire (see Table 2.1) that requires respondents to indicate how they have been feeling in several content areas (e.g. sadness, pessimism, loss of interest) in the past two weeks. The BDI-2 evolved from the original version of the scale, the BDI. The BDI also has 21 items and an identical response scale, although four items (weight loss, body image change, somatic preoccupation, and work difficulty) from this scale were altered to form the BDI-2. Another difference between the BDI and BDI-2 is that the former adopts a shorter time frame of the preceding week.

Test-retest reliability estimates of the BDI-2 are very high (rs of .93, .96), however these estimates were obtained over periods of between one to twelve days (A.T. Beck et al., 1996; Sprinkle et al., 2002). Research into the test-retest reliability of the BDI-2 over a longer time-frame is sparse, although A.T. Beck, Steer, and Garbin (1988) reviewed the
stability of the first version of the scale, the BDI, and found that test-retest reliabilities ranged from .62 to .90 in non-psychiatric populations over periods of between three weeks and four months. It is noted that the time-frame specified by the BDI-2 is longer than that specified by the BDI. Internal consistency estimates of the BDI-2 are very high (coefficient alphas around .90; Augustine Osman et al., 1997; Steer, Ball, Ranieri, & A.T. Beck, 1997; Steer & D.A. Clark, 1997; Whisman, Perez, & Ramel, 2000).

Relative to the STAI, there has been less research regarding the ‘purity’ of the BDI-2 – that is, the extent to which it measures depressive symptoms only. Instead, the focus has been on the factor structure of the BDI-2, specifically delineating cognitive and somatic factors (Endler, A. Rutherford, & Denisoff, 1999; Steer, Ball, Ranieri, & A.T. Beck, 1999; Steer & D.A. Clark, 1997; Whisman et al., 2000). However, critiques of the predecessor of the BDI-2, the BDI, suggest that this measure may not assess just depressive symptoms. The BDI has been argued to tap symptoms common to both anxiety and depression (irritability, poor concentration, indecisiveness, insomnia, and fatigue; L.A. Clark & Watson, 1991a), while Gotlib and Cane (1989) found that 57.1% of the items measured depression and 4.7% measured anxiety, but that 19.0% measured symptoms common to both anxiety and depression (according to DSM-III-R criteria). Furthermore, while the BDI has been shown to demonstrate sound discriminant validity with the Beck Anxiety Inventory (BAI), it has been argued that this is due to the high content specificity of the latter instrument (L.A. Clark & Watson, 1991b). It is noted that the four BDI items altered to form the BDI-2 relate to weight loss, body image, somatic preoccupation, and work difficulty, and are not items of the BDI that comprise symptoms that L.A. Clark and Watson (1991a) identified as common to both anxiety and depression. Thus, it is possible that the BDI-2 may also suffer from ‘impurity’ criticisms.

2.3 Depression, Anxiety, Stress Scales (DASS)

The DASS (S.H. Lovibond & P.F. Lovibond, 1995) attempts to maximise the distinction between anxiety and depression, while retaining the core symptoms of each. It is designed to measure depression, anxiety, and stress, with each scale comprising 14 items. Factor analytic studies have replicated the factor structure originally reported by S.H. Lovibond and P.F. Lovibond (T.A. Brown, Chorpita, Korotitsch, & Barlow, 1997).
As the distinction between anxiety and depression forms the focus of the present programme of research, only the anxiety and depression scales will be utilised. The Depression scale assesses hopelessness, self-deprecation, anhedonia, and lack of interest. Items comprising this scale include “I felt downhearted and blue”, “I felt I wasn’t worth much as a person”, and “I felt that life was meaningless”. The Anxiety scale assesses skeletal muscle effects, situational anxiety, autonomic arousal, and the subjective experience of anxious affect. Items on this scale include, “I was aware of dryness of my mouth”, “I experienced trembling”, and “I felt scared without any good reason” (items for both scales are presented in Table 2.2).

The DASS requires respondents to indicate the extent to which they have experienced varying emotional states “in the past week”. This version of the DASS has very sound internal consistency (coefficient alphas upwards of .90 for the Depression scale, and upwards of .84 for the Anxiety scale; Antony, Bieling, Cox, Enns, & Swinson, 1998; T.A. Brown et al., 1997; S.H. Lovibond & P.F. Lovibond, 1995). Concurrent validity of the Depression scale with the BDI ranges from .74 to .77. Similarly, the Anxiety scale exhibits good concurrent validity with the BAI (rs ranging from .81 to .84). Furthermore, both the DASS Depression and Anxiety scales are more highly correlated with their Beck Inventory counterparts, than with the inventories measuring the opposing construct (rs upwards of .73 for scales measuring the same construct, and rs between .42 and .58 for scales measuring opposing constructs; Antony et al., 1998; S.H. Lovibond & P.F. Lovibond, 1995). However, Antony et al. found the Anxiety scale correlated poorly with the STAI-trait (r = .44), with a higher correlation evident between the Anxiety scale and the BDI (r = .57). This is consistent with observations that the STAI-trait contains items that tap depressive symptoms (Bieling et al., 1998; Gotlib & Cane, 1989). Correlations between the DASS Depression and Anxiety scales range from .44 to .54 (Antony et al., 1998; T.A. Brown et al., 1997; P.F. Lovibond & S.H. Lovibond, 1995).

An alternative version of the DASS with instructions to assay trait mood (“in a typical week in the past 12 months”) has also been utilised, and it is this version that will be utilised in the present study. Test-retest reliability estimates for this version are adequate given the long periods over which it has been assessed, ranging between .19 to .47 for the Depression scale, and between .37 and .46 for the Anxiety scale, over a
period of 3-8 years (P.F. Lovibond, 1998). It is not unreasonable to expect that this version of the instrument possesses similar psychometric properties to the version employing “over the past week” instructions.

The DASS is also available in a short form comprising 21 items (7 from each scale; DASS-21). Regarding psychometric properties of the DASS-21, both the Anxiety and Depression scales have good internal consistency (coefficient alphas upwards of .81 for the Depression scale, and upwards of .73 for the Anxiety scale; Antony et al., 1998; S.H. Lovibond & P.F. Lovibond, 1995). As indicated in the preceding paragraph, test-retest reliability estimates employing the 42-item version demonstrated stability over the 3-8 year period, and one of the authors of the DASS expects similar stability for the 21-item form (P.F. Lovibond, personal communication, June 2000). Regarding the construct validity of the DASS-21 Anxiety and Depression scales, it has been shown that the Depression scale is highly correlated with the BDI ($r = .79$), as is the Anxiety scale with the BAI ($r = .85$), and that these correlations were considerably greater than the correlations with the opposing constructs ($r = .51$ between DASS Depression and BAI; $r = .62$ between DASS Anxiety and BDI; Antony et al., 1998). As for the full-scale, the DASS Anxiety scale was actually more highly correlated with the BDI than with the STAI, suggesting the latter measure taps depressive symptoms.

The present programme of research employed both the DASS-42 and DASS-21 scales. The full-scale version was employed for the selection of participants for the studies comprising Chapters 4, 5, and 6 for it captured a wider range of anxiety and depressive symptoms than did the short-form. The short-form was utilised in the actual experiments for the purpose of verifying participants’ trait anxiety levels at the time of testing, and this version was selected for the purpose of brevity in light of other demands made of participants in this present programme of research (see Sections 4.7.7, 5.5.7, and 6.8.6 for descriptions of experimental procedures).

2.4 The present study

Part of the difficulty in interpreting anxiety-linked impairments in working memory performance is due to the possible influence of comorbid depression. The significant degree of overlap in symptoms, and the potential ensuing overlap in measures
designed to tap each construct, means that discriminating between the impact of anxiety and depression on working memory performance is difficult. A factor further complicating the comorbid depression issue is the state/trait distinction in the existing anxiety-working memory literature, which has made it difficult to identify if anxiety-linked impairments in working memory performance are attributable to state anxiety, trait anxiety, or situational stress. As a first step towards clarifying the state/trait anxiety issue, the anxiety and depression distinction was examined at the trait level. Thus, the factor structure of two well-established and widely utilised measures of anxiety and depression, the STAI and BDI-2, taken together, was compared with the factor structure of the DASS Depression and Anxiety scales (both the 42-item and 21-item versions) which were developed to maximise the distinction between anxiety and depression. It was predicted that, consistent with the existing literature (e.g. Antony et al., 1998; L.A. Clark & Watson, 1991a; Gotlib & Cane, 1989; S.H. Lovibond & P.F. Lovibond, 1995), the DASS scales would provide a clearer demarcation between anxiety and depression symptoms than would the STAI and BDI-2, as indicated by fewer cross-loading items. For each set of factor analyses, a confirmatory factor analysis was conducted with two factors specified, consistent with expected anxiety and depression factors. Correlations between the four measures were also examined to shed further light on the specificity of each measure in tapping the construct it was designed to.

2.5 Method

2.5.1 Participants

Participants in the STAI and BDI-2 analysis numbered 1807 in total, of whom 29.6% (534) were male. All were first-year undergraduate students enrolled in an introductory psychology course, and aged between 16 and 53 years (M = 18.82, SD = 4.28; age details were not provided for two participants). The participants in the DASS analysis numbered 1605 in total, 28.8% (462) of whom were male. All were first-year undergraduate students enrolled in an introductory psychology course, and aged between 16 and 54 years (M = 18.78, SD = 4.12; age details were not provided for two participants). Each set of analyses (i.e. STAI and BDI-2, DASS Anxiety and Depression) comprised data from participants collected over a period of 3 years. Five hundred and eight participants were common to both these participant pools. These were aged between 16 and 47 years (M = 18.83, SD = 4.11; age details were not
provided for two participants), and 29.1% (148) of these participants were male. These participants’ responses on all four measures will be considered for investigating correlations between these measures.

2.5.2 Measures

2.5.2.1 STAI. The STAI-trait was utilised in the present study. It is a 20-item instrument measuring the presence of more enduring symptoms of anxiety (“how you generally feel”). Respondents indicate on a four-point scale ranging from “Almost never” (1) to “Almost always” (4), how applicable each item is in terms of how the respondent generally feels. Total scores may range from 20 to 80, and are obtained by summing across the items, noting reverse-scored items.

2.5.2.2 BDI-2. The BDI-2 is a 21-item instrument measuring the degree of depressive symptoms experienced in the preceding 2 weeks. Respondents indicate the severity of the symptoms using a four-point scale (0 to 3) in a range of content areas including sadness, appetite, sleep, and loss of interest. Total scores may range from 0 to 21. These are obtained by summing across all items.

2.5.2.3 DASS. Two versions of the DASS were employed, the DASS-42, and the DASS-21. For each version, only the Depression and Anxiety scales were considered although the instrument was administered intact (i.e. including the Stress scale). The present study utilised instructions to assay the presence of more enduring symptoms of depression and anxiety (“in a typical week in the past 12 months”). Each subscale comprises 14 items in the 42-item version, and 7 items in the 21-item version. Respondents indicate the frequency of the symptoms experienced on a four-point scale ranging from “Did not apply to me at all” (0) to “Applied to me very much, or most of the time” (3). The total score for each scale can therefore range from 0 to 42 for the 42-item version, and 0 to 21 for the 21-item version. These are obtained by summing across all items on each scale.

2.5.3 Procedure

Participants completed the STAI and BDI-2, the DASS-42 Depression and Anxiety scales, or both in the case of the 508 participants common to both participant pools,
amongst other measures as part of group testing sessions. The DASS-42 scale was administered intact (i.e. including the Stress scale), however only the Depression and Anxiety scales were included for analyses. DASS-21 Anxiety and Depression ratings were obtained from the administration of the 42-item DASS.

2.6 Results
Prior to each analysis reported below, the data set was screened for bivariate outliers (Cook’s D > 1; cf. Tabachnick & Fidell, 1989). No outlier data points were identified. All analyses were conducted using SPSS for Windows 11.0.

2.6.1 STAI and BDI-2 analyses
Scores on the STAI and BDI-2 were highly correlated, $r = .72$, $p < .001$. The Kaiser-Meyer-Olkin statistic of .96 indicated good factorability of items. Responses on the STAI and BDI-2 were analysed using principal axis factoring with oblique rotation (direct oblimin, delta = 0). Two factors were specified for extraction, corresponding with expected anxiety and depression factors. The former was expected to comprise STAI items, while the latter was expected to comprise BDI-2 items. An oblique rotation was selected as the two constructs were expected to be correlated. These two factors (eigenvalues were 11.56 and 2.08) accounted for 33.24% of the total variance. The pattern matrix indicating factor loadings for this two-factor solution is shown in Table 2.1 (loadings .30 and greater are printed in bold). The first factor, identified as an Anxiety factor, contained all of the STAI items, as well as several BDI-2 items (Worthlessness, Self-dislike, Self-criticalness, Past failure, Pessimism, and Sadness). The second factor, identified as a Depression factor, contained 11 of the 21 BDI-2 items. Four BDI-2 items did not exhibit meaningful loadings on either factor (i.e. <.30).

2.6.2 DASS-42 analyses
Scores on the Depression and Anxiety scales were moderately correlated, $r = .62$, $p < .001$. The Kaiser-Meyer-Olkin statistic of .95 indicated good factorability of items. Responses on the DASS-42 Depression and Anxiety scales were analysed using principal axis factoring with oblique rotation (direct oblimin, delta = 0). As with the analyses on the STAI and BDI-2, it was expected that two factors would emerge – an anxiety factor (on which the DASS-42 Anxiety items were expected to load) and a
### Table 2.1. Two-factor solution: STAI and BDI-2 items

<table>
<thead>
<tr>
<th>Item</th>
<th>Anxiety</th>
<th>Depression</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am happy (STAI)</td>
<td>.74</td>
<td>-.05</td>
</tr>
<tr>
<td>I feel secure (STAI)</td>
<td>.73</td>
<td>-.06</td>
</tr>
<tr>
<td>I feel satisfied with myself (STAI)</td>
<td>.73</td>
<td>-.06</td>
</tr>
<tr>
<td>I am content (STAI)</td>
<td>.72</td>
<td>-.06</td>
</tr>
<tr>
<td>I lack self-confidence (STAI)</td>
<td>.68</td>
<td>-.12</td>
</tr>
<tr>
<td>I am a steady person (STAI)</td>
<td>.64</td>
<td>-.02</td>
</tr>
<tr>
<td>I feel pleasant (STAI)</td>
<td>.64</td>
<td>-.04</td>
</tr>
<tr>
<td>I am “calm, cool, and collected” (STAI)</td>
<td>.64</td>
<td>-.10</td>
</tr>
<tr>
<td>I feel inadequate (STAI)</td>
<td>.63</td>
<td>-.05</td>
</tr>
<tr>
<td>I feel like a failure (STAI)</td>
<td>.56</td>
<td>.01</td>
</tr>
<tr>
<td>I wish I could be as happy as others seem to be (STAI)</td>
<td>.54</td>
<td>.12</td>
</tr>
<tr>
<td>I make decisions easily (STAI)</td>
<td>.52</td>
<td>-.06</td>
</tr>
<tr>
<td>I feel nervous and restless (STAI)</td>
<td>.52</td>
<td>.02</td>
</tr>
<tr>
<td>I worry too much over something that really doesn’t matter (STAI)</td>
<td>.51</td>
<td>.08</td>
</tr>
<tr>
<td>I get in a state of tension or turmoil as I think over my recent concerns and interests (STAI)</td>
<td>.48</td>
<td>.15</td>
</tr>
<tr>
<td>I take disappointments so keenly that I can’t put them out of my mind (STAI)</td>
<td>.46</td>
<td>.09</td>
</tr>
<tr>
<td>Worthlessness (BDI-2)</td>
<td>.43</td>
<td>.09</td>
</tr>
<tr>
<td>Self-dislike (BDI-2)</td>
<td>.41</td>
<td>.29</td>
</tr>
<tr>
<td>I feel that difficulties are piling up so that I cannot overcome them (STAI)</td>
<td>.39</td>
<td>.17</td>
</tr>
<tr>
<td>Self-criticalness (BDI-2)</td>
<td>.39</td>
<td>.19</td>
</tr>
<tr>
<td>Some unimportant thought runs through my mind and bothers me (STAI)</td>
<td>.38</td>
<td>.14</td>
</tr>
<tr>
<td>I feel rested (STAI)</td>
<td>.37</td>
<td>.15</td>
</tr>
<tr>
<td>Past failure (BDI-2)</td>
<td>.35</td>
<td>.24</td>
</tr>
<tr>
<td>I have disturbing thoughts (STAI)</td>
<td>.34</td>
<td>.17</td>
</tr>
<tr>
<td>Pessimism (BDI-2)</td>
<td>.34</td>
<td>.25</td>
</tr>
<tr>
<td>Sadness (BDI-2)</td>
<td>.33</td>
<td>.28</td>
</tr>
<tr>
<td>Suicidal thoughts or wishes (BDI-2)</td>
<td>.28</td>
<td>.28</td>
</tr>
<tr>
<td>Tiredness/fatigue (BDI-2)</td>
<td>-.03</td>
<td>.60</td>
</tr>
<tr>
<td>Changes in appetite (BDI-2)</td>
<td>-.04</td>
<td>.55</td>
</tr>
<tr>
<td>Changes in sleeping pattern (BDI-2)</td>
<td>-.07</td>
<td>.51</td>
</tr>
<tr>
<td>Concentration difficulty (BDI-2)</td>
<td>-.09</td>
<td>.51</td>
</tr>
<tr>
<td>Loss of energy (BDI-2)</td>
<td>.07</td>
<td>.50</td>
</tr>
<tr>
<td>Loss of interest (BDI-2)</td>
<td>.13</td>
<td>.44</td>
</tr>
<tr>
<td>Agitation (BDI-2)</td>
<td>.18</td>
<td>.37</td>
</tr>
<tr>
<td>Loss of pleasure (BDI-2)</td>
<td>.27</td>
<td>.36</td>
</tr>
<tr>
<td>Guilty feelings (BDI-2)</td>
<td>.21</td>
<td>.35</td>
</tr>
<tr>
<td>Irritability (BDI-2)</td>
<td>.18</td>
<td>.34</td>
</tr>
<tr>
<td>Crying (BDI-2)</td>
<td>.22</td>
<td>.30</td>
</tr>
<tr>
<td>Indecision (BDI-2)</td>
<td>.26</td>
<td>.30</td>
</tr>
<tr>
<td>Punishment feelings (BDI-2)</td>
<td>.24</td>
<td>.27</td>
</tr>
<tr>
<td>Loss of interest in sex (BDI-2)</td>
<td>.05</td>
<td>.22</td>
</tr>
</tbody>
</table>

Note: Factor loadings .30 and above are printed in bold
depression factor (on which the DASS-42 Depression items were expected to load). An oblique rotation was selected as the two constructs were expected to be correlated. The two factors extracted (eigenvalues were 10.48 and 2.49) accounted for 46.33% of the total variance. The pattern matrix indicating factor loadings for this two-factor solution is shown in Table 2.2 (loadings .30 and greater are printed in bold). The first factor was identified as a Depression factor, and contained all of the DASS-42 Depression items, although one of these item (“I just couldn’t seem to get going”) loaded slightly higher on the second factor (.31) than on this factor (.30). The second factor was identified as an Anxiety factor, and contained all the DASS-42 Anxiety items, as well as the aforementioned DASS Depression item.

2.6.3 DASS-21 analyses
Scores on the DASS-21 Anxiety and Depression scales were moderately correlated, $r = .57$, $p < .001$. The Kaiser-Meyer-Olkin statistic of .92 indicated good factorability of items. As with the analyses conducted on the full scale of the DASS, responses on the scales were analysed using principal axis factoring with oblique rotation (direct oblimin, delta = 0) with two factors specified for extraction, corresponding with expected depression and anxiety factors. These two factors (eigenvalues were 5.40 and 1.42) accounted for 49.46% of the total variance. The pattern matrix indicating factor loadings for this two-factor solution is shown in Table 2.3 (loadings .30 and greater are printed in bold). The first factor was identified as a Depression factor, and contained all the DASS-21 Depression items. The second factor was identified as an Anxiety factor, and contained all the DASS-21 Anxiety items.

2.6.4 Correlations between DASS-42 and DASS-21 scores, STAI scores, and BDI-2 scores
Correlations between scores on the full-scale and short-form versions of the DASS, STAI, and BDI-2 were obtained for the 508 participants who completed all of these measures. Scores on the full-scale and short-forms of the DASS were highly correlated ($r = .95$, $p < .001$ for the Anxiety scale; $r = .98$, $p < .001$ for the Depression scale). The STAI and BDI-2 scores were also highly correlated ($r = .70$). Table 2.4 presents the correlations between the DASS-42 scores, STAI scores, and BDI-2 scores, while Table 2.5 presents the corresponding correlations for the DASS-21 scales.
Table 2.2. **Two factor solution: DASS-42 Anxiety (DASS-A) and Depression (DASS-D)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Depression</th>
<th>Anxiety</th>
</tr>
</thead>
<tbody>
<tr>
<td>I felt I was pretty worthless (DASS-D)</td>
<td>.87</td>
<td>-.08</td>
</tr>
<tr>
<td>I felt that life wasn’t worthwhile (DASS-D)</td>
<td>.85</td>
<td>-.08</td>
</tr>
<tr>
<td>I felt that life was meaningless (DASS-D)</td>
<td>.85</td>
<td>-.16</td>
</tr>
<tr>
<td>I could see nothing in the future to be hopeful about (DASS-D)</td>
<td>.82</td>
<td>-.06</td>
</tr>
<tr>
<td>I felt I wasn’t worth much as a person (DASS-D)</td>
<td>.80</td>
<td>-.04</td>
</tr>
<tr>
<td>I felt I had nothing to look forward to (DASS-D)</td>
<td>.67</td>
<td>.08</td>
</tr>
<tr>
<td>I felt that I had lost interest in just about everything</td>
<td>.66</td>
<td>.09</td>
</tr>
<tr>
<td>I couldn’t seem to get any enjoyment out of the things I did (DASS-D)</td>
<td>.64</td>
<td>.13</td>
</tr>
<tr>
<td>I was unable to become enthusiastic about anything (DASS-D)</td>
<td>.64</td>
<td>.06</td>
</tr>
<tr>
<td>I felt sad and depressed (DASS-D)</td>
<td>.62</td>
<td>.19</td>
</tr>
<tr>
<td>I couldn’t seem to experience any positive feeling at all (DASS-D)</td>
<td>.61</td>
<td>.13</td>
</tr>
<tr>
<td>I felt down-hearted and blue (DASS-D)</td>
<td>.61</td>
<td>.17</td>
</tr>
<tr>
<td>I found it difficult to work up the initiative to do things (DASS-D)</td>
<td>.38</td>
<td>.27</td>
</tr>
<tr>
<td>I experienced trembling (DASS-A)</td>
<td>-.10</td>
<td>.71</td>
</tr>
<tr>
<td>I had a feeling of shakiness (DASS-A)</td>
<td>-.04</td>
<td>.66</td>
</tr>
<tr>
<td>I was aware of the action of my heart in the absence of physical exertion (DASS-A)</td>
<td>-.13</td>
<td>.62</td>
</tr>
<tr>
<td>I felt I was close to panic (DASS-A)</td>
<td>.14</td>
<td>.60</td>
</tr>
<tr>
<td>I found myself in situations that made me so anxious I was most relieved when they ended (DASS-A)</td>
<td>.11</td>
<td>.56</td>
</tr>
<tr>
<td>I had a feeling of faintness (DASS-A)</td>
<td>-.02</td>
<td>.55</td>
</tr>
<tr>
<td>I felt scared without any good reason (DASS-A)</td>
<td>.17</td>
<td>.54</td>
</tr>
<tr>
<td>I was worried about situations in which I might panic and make a fool of myself (DASS-A)</td>
<td>.13</td>
<td>.51</td>
</tr>
<tr>
<td>I experienced breathing difficulty (DASS-A)</td>
<td>.02</td>
<td>.50</td>
</tr>
<tr>
<td>I had difficulty in swallowing (DASS-A)</td>
<td>.01</td>
<td>.48</td>
</tr>
<tr>
<td>I felt terrified (DASS-A)</td>
<td>.15</td>
<td>.46</td>
</tr>
<tr>
<td>I feared that I would be ‘thrown’ by some trivial but unfamiliar task (DASS-A)</td>
<td>.16</td>
<td>.46</td>
</tr>
<tr>
<td>I perspired noticeably in the absence of high temperatures or physical exertion (DASS-A)</td>
<td>-.07</td>
<td>.40</td>
</tr>
<tr>
<td>I was aware of dryness of my mouth (DASS-A)</td>
<td>-.02</td>
<td>.37</td>
</tr>
<tr>
<td>I just couldn’t seem to get going (DASS-D)</td>
<td>.30</td>
<td>.31</td>
</tr>
</tbody>
</table>

Note: Factor loadings .30 and above are printed in bold
Table 2.3. Two factor solution: DASS-21 Anxiety (DASS-A) and Depression (DASS-D) items

<table>
<thead>
<tr>
<th>Item</th>
<th>Depression</th>
<th>Anxiety</th>
</tr>
</thead>
<tbody>
<tr>
<td>I felt I wasn’t worth much as a person (DASS-D)</td>
<td>.76</td>
<td>.03</td>
</tr>
<tr>
<td>I felt that life was meaningless (DASS-D)</td>
<td>.76</td>
<td>-.10</td>
</tr>
<tr>
<td>I felt I had nothing to look forward to (DASS-D)</td>
<td>.70</td>
<td>.02</td>
</tr>
<tr>
<td>I couldn’t seem to experience any positive feeling at all (DASS-D)</td>
<td>.69</td>
<td>.05</td>
</tr>
<tr>
<td>I was unable to become enthusiastic about anything (DASS-D)</td>
<td>.68</td>
<td>.02</td>
</tr>
<tr>
<td>I felt down-hearted and blue (DASS-D)</td>
<td>.64</td>
<td>.12</td>
</tr>
<tr>
<td>I found it difficult to work up the initiative to do things (DASS-D)</td>
<td>.44</td>
<td>.20</td>
</tr>
<tr>
<td>I experienced trembling (DASS-A)</td>
<td>-.06</td>
<td>.68</td>
</tr>
<tr>
<td>I was aware of the action of my heart in the absence of physical exertion (DASS-A)</td>
<td>-.12</td>
<td>.64</td>
</tr>
<tr>
<td>I felt I was close to panic (DASS-A)</td>
<td>.18</td>
<td>.56</td>
</tr>
<tr>
<td>I felt scared without any good reason (DASS-A)</td>
<td>.21</td>
<td>.51</td>
</tr>
<tr>
<td>I experienced breathing difficulty (DASS-A)</td>
<td>.03</td>
<td>.50</td>
</tr>
<tr>
<td>I was worried about situations in which I might panic and make a fool of myself (DASS-A)</td>
<td>.19</td>
<td>.44</td>
</tr>
<tr>
<td>I was aware of dryness of my mouth (DASS-A)</td>
<td>.03</td>
<td>.34</td>
</tr>
</tbody>
</table>

Note: Factor loadings .30 and above are printed in bold

Table 2.4. Correlations between DASS-42 Anxiety and Depression scores, STAI scores, and BDI-2 scores.

<table>
<thead>
<tr>
<th></th>
<th>DASS-42 Anxiety</th>
<th>DASS-42 Depression</th>
</tr>
</thead>
<tbody>
<tr>
<td>DASS-42 Depression</td>
<td>.61</td>
<td></td>
</tr>
<tr>
<td>STAI</td>
<td>.55</td>
<td>.63</td>
</tr>
<tr>
<td>BDI-2</td>
<td>.56</td>
<td>.74</td>
</tr>
</tbody>
</table>

Note: All ps < .001

Due to the similarity in correlations observed between the STAI and BDI-2 scores with the full-scale and short-form versions of the DASS Anxiety and Depression scores, these will be discussed together. Overall, the DASS Depression and Anxiety scales appear to have good discriminant validity, as indicated by higher correlations of DASS Depression scores with BDI-2 scores than with STAI scores. Correlations between the DASS Anxiety scores and the STAI and BDI-2 scores were similar, suggesting that the STAI measures depressive symptoms in addition to anxiety symptoms. Consistent with
research by Antony et al. (1998), DASS Depression scores were more highly correlated with the STAI than with the DASS Anxiety scores.

Table 2.5. Correlations between DASS-21 Anxiety and Depression scores, STAI scores, and BDI-2 scores.

<table>
<thead>
<tr>
<th></th>
<th>DASS-21 Anxiety</th>
<th>DASS-21 Depression</th>
</tr>
</thead>
<tbody>
<tr>
<td>DASS-21 Depression</td>
<td>.57</td>
<td></td>
</tr>
<tr>
<td>STAI</td>
<td>.51</td>
<td>.62</td>
</tr>
<tr>
<td>BDI-2</td>
<td>.52</td>
<td>.72</td>
</tr>
</tbody>
</table>

Note: All ps < .001

2.7 Discussion

The focus of this chapter was on identifying measures of anxiety and depression that maximise the distinction between these two constructs at the trait level. The factor analyses, in addition to the correlations, suggest that the DASS-42 and DASS-21 Depression and Anxiety scales are useful tools for this purpose. First, the results of the factor analysis revealed the DASS items loaded more cleanly on the factors they were hypothesised to in comparison with the STAI and BDI-2 factor structure. Second, the correlational analyses indicate that the DASS Depression and Anxiety scales exhibit better discriminant validity than the STAI and BDI-2. Notably, the STAI appears to poorly discriminate between anxiety and depression. This finding extends existing research suggesting that the STAI measures symptoms that are not unique to anxiety (Bieling et al., 1998; Gotlib & Cane, 1989).

A strength of this study is that it clearly advises caution in the selection of psychometric instruments within the anxiety and working memory literature. The issue of comorbid depression is one that affects much of the research in this field (e.g. Calvo et al., 1994; Derakshan & Eysenck, 1998; Ikeda et al., 1996; Sorg & Whitney, 1992; Tohill & Holyoak, 2000), and by selecting instruments that maximise the distinction between anxiety and depression, impairments in working memory performance may be more clearly attributed to anxiety alone.
Altogether, the findings of this chapter suggest that both the DASS-42 and DASS-21 Depression and Anxiety scales are useful tools in maximising the distinction between anxiety and depression at the trait level. The identification of such instruments is the first step in addressing the issue of potential comorbid depression within the anxiety-working memory relationship. This study has served to address one of the factors complicating an interpretation of the anxiety and working memory literature that were identified in Section 1.6. The following chapter presents another preliminary study, this time addressing the comparability of tasks evaluating the different working memory systems (see Section 1.6.1).
CHAPTER 3: WORKING MEMORY TASKS

3.1 Introduction

Section 1.6.1 identified that differences in tasks utilised to assess the various working memory systems render a clear interpretation of anxiety-linked impairments in working memory performance difficult where two or more working memory systems are evaluated. Presently, studies examining two or more working memory systems typically employ tasks that differ in ways other than the critical process of interest (e.g. sensory and motor differences, Fiez, 2001). The literature reviewed in Section 1.6.1, however, suggested that Markham and Darke’s (1991) utilisation of the digit span and Corsi tasks, together with research into the n-back and running memory tasks (Awh et al., 1996; Morris & Jones, 1990), may provide a way forward to developing parallel forms of span tasks to assess all three working memory systems while minimising task difference across these systems.

It was noted in Section 1.6.1 that the span tasks may be equated on most dimensions (e.g. number of trials at each sequence length, conditions determining termination of the task) with only the nature of the stimuli and the method of response differing between the two tasks. The present study therefore sought to further minimise task differences, specifically by equating the mode of presentation and method of response between tasks designed to tap the VSSP and PL. While the mode of presentation and method of response remains fairly constant in administrations of the Corsi task within the working memory literature (i.e. visual presentation/manual response; de Renzi & Nichelli, 1975; Markham & Darke, 1991), presentation and response formats may be varied for verbal span tasks such as the digit span task (e.g. Beaumont, 1985). For example, auditory stimuli may be employed in conjunction with a vocal response format (auditory/vocal). Alternatively, visual stimuli may be presented and a manual response format employed (visual/manual) which is more similar to that utilised in the Corsi task in comparison to the auditory/vocal format, thus serving to further minimise task differences in assessing the different working memory systems. Visually presented

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5 It is noted that there exists several other working memory tasks that may be suitable for the assessment of various working memory systems. However, the intention of the present programme of research was to adopt working memory tasks that minimised task differences across the working memory systems. Section 1.6.1 identified the span tasks as ideal tools for this purpose.
material (that may be verbalised, for example, letters and digits) is recoded verbally where possible, however this comes at a cost to performance compared with the auditory presentation format which has obligatory access to the PL (Morris, 1986).

A study pertinent to the focus on the presentation and response formats of verbal span tasks is one conducted by Beaumont (1985) who presented visual/manual, visual/vocal, and auditory/vocal formats of a digit span task. Beaumont’s study is significant for it permitted an evaluation of the cost to performance associated with computer administration (visual/manual, employing a touchscreen monitor) compared with the more conventional (auditory/vocal) format. The study also allowed an evaluation of whether a visual rather than an auditory presentation format was also associated with a cost to performance (i.e. comparing the visual/vocal and auditory/vocal formats). The results of Beaumont’s study revealed that (a) digit span scores were lower under the visual/manual format than under the auditory/vocal format; and (b) where response format was equated between different presentation/response formats, the visual presentation of stimuli was itself associated with a cost to performance. The latter finding supports the assertion that the recoding of visual material into a verbal form comes at a cost to performance (Morris, 1986).

While it has been suggested that visual material that may be verbalised is recoded verbally where possible (Morris, 1986), the question arises as to whether a visual mode of presentation may also engage the VSSP (which is responsible for the storage of visual and spatial information). As the present study aimed to employ a visual/manual format for the verbal span task in order to further minimise task differences between the verbal and spatial span tasks, this issue is a pertinent one. To investigate this, the present study compared performance on two versions of a verbal span task (letter span; auditory/vocal format and visual/manual format) under either verbal interference or spatial interference, with the expectation that both formats of the verbal span task would be more susceptible to verbal than to spatial interference. Performance on these two tasks was contrasted with that on a spatial span task (Corsi), with the expectation that performance on this task would be more susceptible to spatial than verbal interference. That is, a double dissociation should emerge between performance of the two verbal tasks on the one hand, and the spatial task on the other, thereby verifying that the visual/manual format of the verbal span task engages the PL. Additionally,
performance on the auditory/vocal and visual/manual formats of the verbal span task was expected to be equally affected by both spatial and verbal interference, thus attesting to Morris’ assertion that visually presented stimuli are recoded verbally.

3.2 The present study
The present study sought to employ a visual/manual format for the verbal span task to enhance task comparability between spatial and verbal span tasks. To verify that the visual/manual format of the verbal span task engaged the PL as it is proposed to, the study employed an interference task design. Participants completed one spatial span task (Corsi task), and two verbal span tasks (auditory/vocal and visual/manual formats of a letter span task), each under verbal and spatial interference (articulatory suppression and tapping, respectively). It was expected that performance on the spatial span task would be more impaired by spatial than by verbal interference. Conversely, performance on the verbal span tasks was expected to be more impaired by verbal than by spatial interference. Thus, an interaction between memory task and interference task was predicted. It was also expected that performance on both verbal span tasks would be equally affected by both verbal and spatial interference – that is, it was predicted that there would be no format x interference task interaction.

3.3 Method

3.3.1 Experimental design
The present study employed a repeated-measures design with two factors: (a) Memory Task (Spatial, Verbal-Visual/Manual, Verbal-Auditory/Vocal); and (b) Interference Task (Spatial, Verbal). The combination of these factors yielded six experimental conditions.

3.3.2 Participants
Participants were 12 first-year undergraduate students enrolled in an introductory psychology course, aged 17 or 18 ($\bar{M} = 17.58$, $SD = 0.51$), and including six males. All were fluent in English, and had normal or corrected-to-normal vision and hearing.
3.3.3 Apparatus

All working memory and interference tasks were programmed using MetaCard 2.2 software and presented on a 38cm NEC MultiSync V500 MicroTouch monitor using MicroTouch Touchscreen Version 3.4 software. A Hyundai IBM-compatible PC with a QWERTY keyboard was utilised.

3.3.4 Stimulus materials/tasks

3.3.4.1 Working memory tasks. Three memory tasks were employed – a Spatial task, and two Verbal tasks. Within the Verbal tasks, one employed a Visual/Manual format and the other, an Auditory/Vocal format. These tasks were span tasks, and employed the same trial structure for each experimental condition. First, there were three practice trials, each requiring recall of a sequence of two items. The first test trial utilised a sequence of three items. The sequence lengths for subsequent trials were governed by an up-down procedure. Correct recall of the sequence, position-respecting, on a trial resulted in the presentation of a sequence one greater in length on the next trial; incorrect recall resulted in the presentation of a sequence one less in length on the subsequent trial. Fourteen test trials were presented in total.

The Spatial task was a variation of the Corsi blocks task (de Renzi & Nichelli, 1975). Nineteen blue 2.7cm squares were presented in a fixed but haphazard arrangement (see Figure 3.1). The squares remained on-screen for the duration of the presentation of the to-be-recalled sequence. The to-be-recalled squares for each sequence were selected randomly without replacement. Each trial commenced with the prompt, “You will be presented with x blocks” (where x denotes the number of to-be-recalled items) which appeared centrally and remained for 2s. This was replaced by a “Start” button, which initiated the presentation phase 1.5s after the button was pressed. Following this, the array of squares appeared. The to-be-recalled sequence was presented consecutively with each square illuminated in red for 1s, and followed immediately by its successor in the sequence. After the presentation of the last item, the array of squares disappeared and 8s of the interference task was presented (see Section 3.3.4.2). A period of 2s lapsed following this, after which the recall phase was signalled by a 520 ms, 500Hz, sine-wave tone, and the reappearance of the 19 squares. Participants
recalled the presented sequence by touching the squares on the monitor. Each square was illuminated in red upon contact and remained lit until the end of that trial. A period of 500ms lapsed between the end of response and the presentation of the next trial. Figure 3.1 presents an example of a trial under each interference task condition.

For each of the Verbal tasks, to-be-recalled items were selected from 19 consonants, which were all the consonants of the English alphabet minus ‘W’ (which is trisyllabic) and ‘Y’ (which can form words such as ‘BY’ and ‘MY’). In the presentation phase, the to-be-recalled sequence was selected randomly without replacement, from the pool of 19 consonants. For the Visual/Manual format, the letter stimuli were 4.7cm high and displayed centrally, and were presented at a rate of 1 per second. In the recall phase, responses were made on a blue letter board displaying the 19 consonants in alphabetic order (see Figure 3.2). The black 1.6cm-high letters were each contained within a 3.4cm square. Participants responded by pressing within the boundaries of the squares, and each square lit up in green when pressed and remained illuminated until the last to-be-recalled letter was pressed. All other aspects of the trial (e.g. presentation durations, interference task, etc.) were identical to that outlined for the Spatial task save for the sentence preceding each trial (“You will be presented with x letters” where x denotes the number of to-be-recalled letters). Figure 3.2 presents an example of a trial under each interference condition.

The Auditory/Vocal format of the verbal task was matched to the Visual/Manual format, except that an auditory mode of presentation and a vocal mode of response were employed. The consonants were recorded by a female speaker using SoundForge 4.5, with a sampling rate of 44,100Hz and a 16-bit mono format. Each sound file was approximately 450ms in length. In the presentation phase of each trial, the to-be-recalled sequence was presented at a rate of one letter per second, while the computer monitor was blank. As with the other tasks, the beginning of the recall phase was signalled by a 520ms, 500Hz, sine-wave tone, and the computer monitor was also blank during this phase. Participants’ responses were recorded on audiotape, and were also scored concurrently by the experimenter, who entered the accuracy of participants’ response using the keyboard in order to determine the sequence length to be presented on the next trial.
Figure 3.1 Order of presentation for one trial of the Spatial task under each interference condition.
Figure 3.2 Order of presentation for one trial of the Visual/Manual Verbal task under each interference condition.
3.3.4.2 **Interference tasks.** Two interference tasks were utilised – Spatial and Verbal. The Spatial task required participants to tap around locations denoted by four blocks. Each trial commenced with a “Ready for tapping” visual prompt presented centrally and remaining on-screen for 1s. This was replaced by four 3.8cm x 3.5cm blocks in a square configuration (see Figure 3.1a), which coincided with the start of a sequence of sixteen 200ms, 1000Hz sine-wave tones presented at a rate of 2 per second. The participant was required to tap the blocks in a clockwise fashion commencing with the top left block, in time with the presented tones. The computer recorded the number of responses made.

For the Verbal interference task, the same 16 tones employed in the tapping task were presented, but accompanied by a blank screen. Each trial commenced with a “Ready for 1,2,3,4” visual prompt presented centrally for 1s. Participants were required to say “1,2,3,4” repeatedly in time with the tones, articulating one digit with each tone. Participants’ verbal responses were recorded on audiotape.

3.3.5 **General procedure**

All participants were tested individually, with the experimenter present throughout the experiment. After being seated in front of the computer, participants were provided with instructions outlining the procedure for the tasks, and instructed to complete any manual tasks using the index finger of their dominant hand. The order of testing the six experimental conditions was balanced across participants. To repeat, the procedure for each trial consisted of (a) a two second visual prompt indicating the length of the upcoming to-be-remembered sequence; (b) presentation of the blocks/letters of the sequence at a 1 per second rate; (c) a one second visual prompt preparing the participant for the interference task; (d) eight seconds of the interference task; and (e) recall of the sequence. Following the completion of trials for the six experimental conditions, participants were thanked and fully debriefed.
3.4 Results

Two sets of analyses were performed. The first served to determine whether any differences in interference task performance varied as a function of memory task. Such differences could complicate the interpretation of memory span scores. The second set of analyses sought to address whether the memory tasks tap the working memory subsystems they are purported to by examining the relative influence of the two interference tasks, and also to determine whether verbal memory task performance invoked the PL irrespective of mode of presentation and response (i.e. Auditory/Vocal versus Visual/Manual). All analyses were conducted using SPSS for Windows 11.0. Prior to analyses, the data set was screened for outliers (> 3 standard deviations). No outliers were identified.

3.4.1 Interference task performance

The mean number of responses (standard deviation, SD, in brackets) under each Memory Task x Interference Task condition is shown in Table 3.1. These were subjected to a 2 (Interference Task: Spatial, Verbal) x 3 (Memory Task: Spatial, Verbal-Visual/Manual, Verbal-Auditory/Vocal) repeated-measures analysis of variance (ANOVA). This revealed a main effect of Interference Task, $F(1,11) = 6.35, p < .05$, with more responses made on the Verbal task ($M = 15.84, SD = .19$) than on the Spatial task ($M = 15.52, SD = .44$). No other effects were significant. Importantly, the Memory Task x Interference Task interaction yielded $F(2,22) = .04, n.s.$, indicating that performance on the Spatial and Verbal Interference Tasks did not show different patterns of performance across the three memory tasks.

Table 3.1 Means (and standard deviations in parentheses) of number of responses made per trial in each Memory Task x Interference Task condition.

<table>
<thead>
<tr>
<th>Interference Task</th>
<th>Memory Task</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spatial</td>
<td>Verbal (Visual/Manual)</td>
<td>Verbal (Auditory/Vocal)</td>
</tr>
<tr>
<td>Spatial</td>
<td>15.49 (.57)</td>
<td>15.58 (.60)</td>
<td>15.49 (1.05)</td>
</tr>
<tr>
<td>Verbal</td>
<td>15.82 (.28)</td>
<td>15.85 (.30)</td>
<td>15.85 (.25)</td>
</tr>
</tbody>
</table>
3.4.2 Memory task performance

The calculation of span scores only considered the last eight of the 14 trials, for these trials were expected to provide asymptotic performance under the up-down method. The sequence lengths presented on these eight trials were used to produce a span score by averaging the sequence lengths across the last eight trials, and subtracting half a point (the up-down method means that performance at asymptote is expected to oscillate between correct and incorrect responses for span and span + 1 length - 0.5 length sequences, respectively; Halford, Maybery, O’Hare, & Grant, 1994).

The mean span scores (with standard error bars) for the six experimental conditions are presented in Figure 3.3. From the figure, it appears that span scores on the Spatial task were lower when performed concurrently with Spatial than with Verbal interference, while the converse was the case for both Verbal tasks. Furthermore, memory span scores on the Auditory/Vocal format of the Verbal task appear to be higher overall than scores on the Visual/Manual format of the Verbal task.

![Figure 3.3](image-url)

**Figure 3.3.** Means (and standard errors) of memory span scores for each Memory Task x Interference Task condition.
To verify these observations, memory span scores were subjected to a 3 (Memory Task: Spatial, Verbal-Visual/Manual, Verbal-Auditory/Vocal) x 2 (Interference Task: Spatial, Verbal) repeated-measures ANOVA. Consistent with the aim of the study, the Memory Task factor was partitioned into two orthogonal comparisons using Helmert contrasts: (a) the Spatial task versus the two Verbal tasks, and (b) the Visual/Manual Verbal task versus the Auditory/Vocal Verbal task. The first of these comparisons (Spatial versus Verbal) yielded a significant effect, $F(1,11) = 7.52, p < .05$, with lower span scores observed for the Spatial task ($M = 3.58; SD = 0.84$) than for the two Verbal tasks ($M = 4.10, SD = .70$). This comparison also interacted with Interference Task, $F(1,11) = 47.27, p < .001$. Consistent with the pattern observed in Figure 3.3, memory span scores on the Spatial Task were significantly lower when the task was performed concurrently with Spatial than with Verbal interference, $t(11) = 5.03, p < .001$. Conversely, memory span scores for the Verbal memory tasks were significantly lower when they were performed concurrently with Verbal than with Spatial interference, $t(11) = 8.29, p < .001$.

The second comparison (contrasting Visual/Manual with Auditory/Vocal formats of the Verbal task) yielded a significant effect, $F(1,11) = 24.77, p < .001$, with lower span scores under the Visual/Manual format ($M = 3.88; SD = 0.78$) than the Auditory/Vocal format ($M = 4.33; SD = 0.64$). Importantly, this second comparison (Verbal-Visual/Manual versus Verbal-Auditory/Vocal) did not interact with Interference Task, $F(1,11) = .00, n.s.$, suggesting that Spatial and Verbal interference affected performance on the Visual/Manual and Auditory/Vocal formats of the Verbal Memory Task in a similar manner. For both formats of the Verbal task, Verbal interference was linked with lower span scores than was Spatial interference, $t_s > 4.56, ps < .001$.

3.5 Discussion

The aim identified at the outset of this chapter was to further minimise differences in tasks utilised to assess the various working memory systems, with a particular focus on the VSSP and the PL. This was achieved by equating the mode of presentation and method of response between tasks designed to tap these two working memory systems, selecting a visual presentation and manual response format (visual/manual). To establish that this format of a verbal span task engaged the PL (cf. Morris, 1986),
performance on the visual/manual format of the task was compared with performance on an auditory/vocal format of the verbal span task. Together with a spatial span task, the two formats of the verbal span task were performed concurrently with spatial and verbal interference. It was demonstrated that the spatial task was more susceptible to spatial than to verbal interference whereas the converse was true for both the verbal tasks. Importantly, it was observed for the two verbal tasks that the visual/manual and auditory/vocal formats were affected by verbal and spatial interference in a similar manner (i.e. no verbal task format x interference task interaction was observed), suggesting that both tasks engage the PL. This is consistent with Morris' assertion that visually presented material is recoded verbally where possible.

Morris (1986) also claimed that the recoding of visual material into verbal form comes at a cost to performance, and this was supported not only by Beaumont's (1985) findings, but also by the observation in the present study of lower span scores under a visual/manual format of the verbal task than under an auditory/vocal format of the same task. It remains to be seen whether a manual response format itself is associated with a cost to performance as this cannot be elucidated from the present experimental design. However, it is likely that the manual response format is a contributing factor, for it necessitates searching for the appropriate response stimuli on the display.

Three potential criticisms could be raised about the present study. First, it may be argued that there was only a small sample size (n = 12). However, it is important to note that this modest sample size was sufficient to demonstrate the key effect – that of the two forms of interference having differential effects on verbal and spatial memory consistent with the proposed reliance on different modality-specific memory systems.

A second potential criticism concerns the absence of a no-interference control condition against which to compare the effects of verbal and spatial interference. It is noted that there are studies that compared performance under verbal or spatial interference with performance in a control condition, for verbal and spatial short-term memory tasks similar to those used in the present study (e.g. Frencham, Fox, & Maybery, 2003; see also Baddeley, 1986, for a review). Critically, the aim of this study was not to evaluate the absolute extent of decrement in performance on a particular task due to a particular form of interference. Rather, the purpose of the study was to demonstrate that the two
verbal tasks invoke a different working memory system to that evoked by the spatial task. This was accomplished by demonstrating differential effects of the two types of interference on the performance of tasks from the two modalities (i.e. without a need for no-interference control conditions).

A third potential criticism that may be raised relates to the imposition of the interference only in the retention, and not the processing, intervals within the trial. It is acknowledged that introducing the interference at the processing and retention intervals may have resulted in greater levels of interference (Meiser & Klauer, 1999). However, the aim of the present study was not to maximise absolute levels of interference, but rather to demonstrate that the two forms of memory (i.e. verbal and spatial) were differentially sensitive to the two types of interference. Moreover, the inclusion of interference throughout the trial may have yielded confounds in the experiment. For instance, by introducing tapping during sequence presentation, visual attention may have been drawn away from encoding the memory sequence, thus a spurious main effect of tapping may have resulted.

In summary, this chapter established the visual/manual format of the letter span task as a suitable parallel to the Corsi task in examining the PL and VSSP (respectively). From these tasks, parallel tasks may be derived to assess the CE by drawing on research into the n-back and running memory tasks (e.g. Awh et al., 1996; Morris & Jones, 1990), and this is addressed more fully in the next chapter (see Section 4.7.6). Together with the previous chapter addressing the issue of comorbid depression, these two chapters represent an initial foray into addressing the four limitations presenting difficulties in the interpretation of the current anxiety-working memory literature that were raised in Section 1.6. To refresh, these four limitations pertain to comorbid depression, working memory tasks, the state/trait anxiety distinction, and the cognitive/somatic anxiety distinction. Building on the findings of this and the previous chapter, the following chapter provides a way to address the state/trait anxiety distinction and is also a preliminary investigation into a role for somatic anxiety in the anxiety-working memory relationship.
4.1 Introduction

The literature review presented in Chapter 1 outlined the relationship between anxiety and working memory, and also identified limitations in the current literature that cloud the interpretation of this relationship (see Section 1.6). These limitations relate to the issue of comorbid depression, a lack of comparability across tasks assessing different components of the working memory system, as well as the state/trait anxiety distinction, and the cognitive/somatic anxiety distinction. As part of a series of initial methodological studies to address these limitations, Chapter 2 addressed the issue of comorbid depression by identifying measures that maximise the distinction between depression and anxiety at the trait level while Chapter 3 identified suitable tasks that permit a comprehensive assessment of all components of the working memory system. The present chapter provides a preliminary exploration into the cognitive/somatic anxiety distinction with reference to the anxiety-working memory link, specifically focusing on whether somatic anxiety plays a role in this relationship. It builds on the previous two chapters by incorporating the mood measures delineated in Chapter 2, and utilising the working memory tasks that formed the focus of investigation in Chapter 3. The design of the present study also provided a means of examining the state/trait anxiety distinction.

4.2 State/trait anxiety distinction

At the outset, it is important to highlight that the exploration of a potential role for somatic anxiety in the anxiety-working memory relationship occurs at the state level. This focus is adopted because state anxiety is implicated in the Processing Efficiency Theory (PET) as being responsible for impaired working memory performance (Eysenck & Calvo, 1992). Eysenck and Calvo further identify state anxiety to be determined interactively by trait anxiety and situational stress, although they acknowledge that state and trait anxiety are difficult to distinguish empirically. The absence of clarity regarding the state/trait distinction is magnified by the piecemeal approach some studies adopt in investigating whether it is state or trait anxiety that impairs working memory. If state anxiety is determined interactively by trait anxiety and
situational stress as outlined by the PET, it is incumbent on studies evaluating this theory to incorporate both these factors when endeavouring to manipulate state anxiety levels. Indeed, many studies in the anxiety-working memory literature do adopt this approach, selecting high and low trait anxious individuals and subjecting them to stressful conditions in order to influence state anxiety levels (e.g. Darke, 1988a,b; Derakshan & Eysenck, 1998; Leon & Revelle, 1985; Markham & Darke, 1991; Sorg & Whitney, 1992). However, in many of these studies, state anxiety levels are not actually measured, thereby making it difficult to establish that state anxiety is indeed determined interactively by trait anxiety and situational stress and, more importantly, that impairments in working memory performance are attributable to elevated levels of state anxiety. The notable exception to this is the study conducted by Murray and Janelle (2003) in which high and low trait anxious participants were subjected to stressful situations, and the corresponding effect on state anxiety levels was measured. Murray and Janelle’s findings revealed a significant trait anxiety x mood induction interaction on state anxiety ratings, which supports Eysenck and Calvo’s assertion that state anxiety is determined interactively by these two factors.

Concordant with Murray and Janelle’s (2003) study, the present study aimed to clarify the state/trait distinction by systematically examining trait anxiety and situational stress. Low and high trait anxiety groups were composed, and within each group, half underwent a stressful mood induction procedure designed to induce an anxious mood, while the other half underwent a non-stressful mood induction procedure designed to induce a neutral mood. Unlike in the Murray and Janelle study, a between-subjects design was chosen for the purpose of examining the state/trait distinction to avoid factors such as practice effects that may limit an interpretation of anxiety-working memory effects (refer to Section 1.6.3). Additionally, the present study also measured state anxiety levels at three phases of the experiment to verify the efficacy of the mood induction technique. Prior to discussing the specific predictions that stem from this design, the focus of this chapter will shift to address a potential role for somatic anxiety in the anxiety-working memory relationship.
4.3 A role for somatic anxiety in the anxiety-working memory relationship?

It is recognised within the literature that anxiety is multifaceted, and cognitive and somatic components of anxiety are commonly delineated (Barlow, 1985; DeGood & Tait, 1987; Schwartz, Davidson, & Goleman, 1978; Steptoe & Kearsley, 1990). The experience of cognitive anxiety is manifest in mental thoughts and processes, encompassing worry – including evaluative concerns – and concentration difficulties (Ree, 2001; Schwartz et al., 1978). The experience of somatic anxiety, on the other hand, relates to autonomic-endocrine arousal symptoms such as elevated heart rate, stomach distress, sweating, and muscle tension (Schwartz et al., 1978), however it is noted that physiological measurements of somatic anxiety symptoms may not exhibit a perfect relationship with the subjective experience of somatic anxiety (Ree, 2001).

There is considerable support for the cognitive/somatic distinction. For example, clinical studies report that patients exhibit differing profiles of cognitive and somatic symptoms (see Steptoe & Kearsley, 1990), and that therapeutic interventions should be tailored to the different profiles of cognitive and somatic symptoms in order to maximise treatment efficacy (Schwartz et al., 1978). The cognitive/somatic distinction is also supported within the field of sport psychology, where it has been demonstrated that cognitive and somatic anxiety make distinct contributions to performance (Burton, 1988; Butt, Weinberg, & Horn, 2003; Parfitt, Hardy, & Pates, 1995). Of central pertinence to the present programme of research is the field of test anxiety research. Within this field, the cognitive/somatic distinction is represented as one between worry and emotionality, and it has been demonstrated that worry, but not emotionality, is linked with impaired test performance (Liebert & Morris, 1967).

Since Liebert and Morris (1967) identified that worry, but not emotionality, is responsible for impaired performance, research into the role that cognitive anxiety plays in working memory performance has flourished (e.g. Darke, 1988a; Leon & Revelle, 1985; C. MacLeod & Donnellan, 1993; Richards et al., 2000; Sorg & Whitney, 1992; Tohill & Holyoak, 2000). This research has demonstrated repeatedly that elevated levels of cognitive anxiety, typically engendered by imposing evaluative stress on participants (see Calvo et al., Experiments 1-3; Darke, 1988a,b; Derakshan & Eysenck, 1998; Ikeda
et al., 1996), were linked with impaired working memory performance (see Table 1.1 for a review).

The role of somatic anxiety in the anxiety-working memory relationship has been less extensively studied in the literature. However, a handful of studies into the impact of different types of mood (e.g. elation, depression, as well as anxiety) on working memory performance potentially hold the key to identifying a link between somatic anxiety and working memory performance. Specifically, these studies utilised mood induction procedures that may be considered to be more somatic than cognitive in nature, and demonstrated an adverse effect on working memory performance (e.g. Hudetz et al., 2000; Meinhardt & Pekrun, 2003; Palfai & Salovey, 1993-4). Techniques utilised in these studies included guided imagery, music plus Velten instruction (individuals were required to repeat a series of statements and put themselves in the mood dictated by the statement; Albersnagel, 1988), imagined emotionally laden life events, and viewing affect-laden pictures and film clips. These techniques may be considered to be more somatic than cognitive because, importantly, they do not place the individual under evaluative stress.

Taking a step back from the PET, which focuses on cognitive anxiety (worry), it is noted that there exist more generic models documenting the relationship between mood and performance. One such model is the Resource Allocation Model (RAM; Ellis & Ashbrook, 1988), which was originally utilised to account for depression-linked impairments in working memory performance. The RAM, as briefly outlined in Section 1.6.2, assumes a fixed-capacity information processing system. Adopting this model as a theoretical framework, Meinhardt and Pekrun (2003) suggest that emotions direct attention to the source of the emotion, thereby drawing resources from the fixed capacity system. Where elevations in mood engender intrusive thoughts, the demand on attentional resources is more pronounced. Additionally, individuals are often motivated to engage in mood repair (cf. Isen, 1984) when the mood is a negative one (Spies et al., 1996), and this activity also drains attentional resources (Krohne et al., 2002). For example, an individual may experience feelings of disgust after viewing a grotesque image and, when aware of this, may endeavour to minimise this negative feeling by visualising a pleasant image instead. Attentional resources, in this example, are diverted to the experience of disgust, and also in generating the image in order to
diminish feelings of disgust. Thus, negative mood states not only consume resources, but the process of mood repair makes additional demands on the finite pool of resources.

That the RAM has been used to account for the effect of mood on performance is significant, for it was identified in Section 1.6.2 that this model bears similarities to Sarason’s (1984) attentional interference theory on which the PET is based. Like the attentional interference theory, the RAM predicts that the effects of elevated levels of mood on performance is more pronounced with increasing task difficulty, as the demands of such tasks are likely to exceed the already reduced pool of resources (which have been consumed in focusing on the mood, and also in engaging in mood repair). Thus, it is likely that less cognitive forms of anxiety may actually impact on working memory performance.

Altogether, the literature reviewed in the current section suggests it is possible that more somatic forms of anxiety may engender impaired performance, and this forms the focus of this chapter.

4.4 The Profile of Mood States (POMS)

The POMS (McNair, Lorr, & Droppleman, 1992) is a 65-adjective rating scale that asks respondents to rate, on a five-point scale ranging from “Not at all” (0) to “Extremely” (4), the extent to which they have been feeling the states described by the adjectives “during the past week including today”. Factor analytic studies indicate six distinct mood dimensions (although see Norcross, Guadagnoli, & Prochaska, 1984); these include Tension-Anxiety, Depression-Dejection, Anger-Hostility, Vigour-Activity, Fatigue-Inertia, and Confusion-Bewilderment. Only two of these scales were utilized in the present study. The first, Tension-Anxiety (Anxiety), was included as the focus of the experiment was to measure changes in anxiety as a result of the mood induction. Items comprising this scale include “tense”, “on edge”, “uneasy”, “anxious”, and “restless”. As elevations in anxious mood have been demonstrated to co-occur with elevations in depressed mood (Albersnagel, 1988), and depressed mood has itself been found to impact on working memory performance (e.g. Channon, 1996; Channon & Baker, 1994), the Depression-Dejection (Depression) scale was also included. Items on this
scale include “unhappy”, “sad”, “hopeless”, and “worthless”. Only validity and reliability data pertaining to these two scales will be discussed.

Both the Anxiety and Depression scales exhibit high internal consistencies (coefficient alphas upwards of .90; McNair et al., 1992). Test-retest reliability estimates range from moderate ($r$s around .50) for a period of six-weeks, to moderately high ($r$s around .70) for a 29-day period. The Anxiety scale also shows good concurrent validity with the Taylor Manifest Anxiety Scale (MAS; Taylor, 1953), and the Depression scale exhibits a moderately high correlation with the BDI (McNair et al., 1992).

The POMS is also available in a short-form which contains 30 of the original 65 items (Shacham, 1983). Relative to the original form, which comprised nine Anxiety items and 15 Depression items, the short form comprises six Anxiety items and eight Depression items. Studies utilizing various populations (e.g. university students, cancer patients, ‘healthy’ individuals) have indicated that the Anxiety short form has higher internal consistency than the original form, and the Depression short form has slightly lower internal consistency than the original form (Curran, Andrykowski, & Sudts, 1995; Malouf, Schutte, & Ramerth, 1985; Shacham, 1983). Furthermore, the correlation between the short form and original form of both these scales is extremely high ($r$s > .95; Shacham, 1983). This shorter version suited the aims of the present experiment, for the multiple administration of mood measures was necessary to examine the efficacy of the mood induction procedure. In the present experiment, mood measures were administered prior to mood induction, immediately following mood induction, and at the end of the experiment. The difference between the first two permitted an analysis of the efficacy of the mood induction conditions, and the difference between the last two allowed an examination of the permanence of the mood induction. The necessity for multiple administrations of the desired Anxiety and Depression scales, as well as the utilization of other mood measures, meant that the short form was useful in limiting fatigue and boredom in participants.

As the POMS was utilized at various points in the experiment to assay the efficacy of the mood induction procedure, it was necessary to alter the time-frame of the POMS from the original “during the past week, including today” period to “right now”. Research indicates that this amendment does not appreciably alter the factor structure of the
POMS (McNair et al., 1992). Furthermore, this amended format is sufficiently sensitive to detect changes in mood resulting from the effects of anxiety-inducing versus neutral-inducing films (McNair et al., 1992). It is noteworthy that correlations between the Anxiety scale and the MAS (Taylor, 1953), which is a trait measure, were lower for the “right now” time-frame than for the “in the past week, including today” time-frame.

Another amendment to the POMS for the purpose of the present experiment was the alteration of the five-point scale to a 10-cm-long visual analogue scale where the extremes were labelled “Not at all” and “Extremely” (consistent with the labels on the five-point scale of the POMS). Visual analogue scales (VAS) are favoured where simplicity, ease of understanding, and quickness of completion are required (Lingjaerde & Føreland, 1998). Extending the POMS from a five-point scale to the VAS format is expected not only to capitalize on these benefits, but also to allow greater sensitivity in measuring changes in mood throughout the experiment due to a greater range of permissible scores. Specifically, in contrast to the five-point scale permitted by the original POMS response format, the VAS version requires respondents to make a mark along the scale to depict the severity of the particular state described by the adjective, with scores ranging from 0 to 10 (fractional scores permitted) obtained by determining the distance from the left side of the scale (“Not at all”) to the mark made by respondents.

4.5 Comorbid depression

Most of the anxiety-working memory studies to date do not address the possibility, in light of the overlap in symptoms between anxiety and depression, that anxiety-linked deficits in working memory performance may reflect depression. One study that did address the issue of comorbid depression employed statistical methods to isolate the contributions of anxiety and depression (C. MacLeod & Donnellan, 1993). The present study adopted a similar approach. Measures of trait and state depression were obtained using the DASS Depression and POMS Depression scales, respectively. Where trait anxiety was implicated in analyses of working memory performance, the effects of trait depression were examined using blocking (G.A. Miller & Chapman, 2001). This involved dividing participants into trait depression groups on the basis of their DASS Depression scores, with this variable then included in the analyses. The low trait depression group comprised those individuals who endorsed DASS
Depression ratings between 0 and 9 (inclusive), which corresponds with symptom severity in the normal range (S.H. Lovibond & P.F. Lovibond, 1995). The high trait depression group comprised those individuals who endorsed DASS Depression ratings of 10 and above, which corresponds with symptom severity in the mild, moderate, severe, and extremely severe ranges (S.H. Lovibond & P.F. Lovibond, 1995). To address the issue of comorbidity at the state level, partial correlations incorporating POMS Depression ratings were utilized in instances where POMS Anxiety ratings were correlated with working memory performance.

4.6 The present study

The literature review presented in Section 4.3 suggests a role for more somatic forms of mood in affecting working memory performance. If this is equally applicable in the case of anxiety – that is, that somatic anxiety is linked with deficits in working memory performance – this would suggest that the relationship between anxiety and working memory is not as narrow as presumed by the PET (i.e. not specific to worry). The first and foremost aim of the present study, therefore, was to investigate if more somatic forms of anxiety impact on working memory performance. Along with this, it was sought to clarify whether any such anxiety-linked impairments were attributable to state or to trait anxiety. To this end, high and low trait anxiety groups underwent either an anxious or a neutral music mood induction procedure, and the effects of the mood manipulation procedures were examined using the POMS Anxiety and Depression scales. If, as predicted by Eysenck and Calvo (1992), that state anxiety is determined interactively by trait anxiety and situational stress, this interaction should be reflected in the POMS Anxiety ratings.

Working memory performance was evaluated in the present study using span tasks. It was identified in Section 1.6.1 that comparable tasks suitable for the assessment of all three working memory systems might be derived from span tasks (e.g. digit span, Corsi blocks task). Assessing the slave systems is relatively straightforward, and Chapter 3 provided a preliminary investigation of the spatial span task and the visual/manual format of the verbal span task for this purpose. Assessing the CE is more difficult since it is purportedly modality-free, thus this study extends these two tasks to yield tasks that capture CE processing by adopting the running memory task format (Pollack et al., 1959). This format presents participants with a long list of items of unpredictable length.
with the instruction to recall only a particular set of items at the end of the sequence.
The continued necessity to update the contents of working memory is proposed to engage CE processes (Morris & Jones, 1990; see Section 1.6.1). Thus, the present study compared two aspects of working memory tasks – task modality (spatial, verbal) and task status (fixed, running). This yielded four unique memory tasks – fixed spatial, fixed verbal, running spatial, and running verbal. The fixed spatial and verbal tasks were variants of the Corsi blocks and verbal span tasks (respectively) reported in Chapter 3. The running spatial and verbal tasks adopted a running memory format but otherwise are comparable to the fixed spatial and verbal tasks.

What types of effects on working memory performance can be expected to be manifest through manipulating the more somatic form of anxiety examined in the present study? It was suggested in Section 4.3 that the experience of a negative mood, and the process of mood repair, divert attentional resources away from the task at hand. Thus, of the four working memory tasks employed in the present study, it was expected that the performance on the two running tasks would be most adversely affected.

To summarise, the present study examined the specificity of the PET in relation to the cognitive component of anxiety being of critical importance. It is noted that the mechanism via which less cognitive forms of anxiety may affect working memory performance are similar to those outlined by the PET regarding the effects of worry on performance. The present study therefore sought to examine the specificity of the PET in this regard.

4.7 Method

4.7.1 Design

The present experiment employed a mixed design with two between-subjects factors of Trait Anxiety Group (Low, High) and Mood Induction (Neutral, Anxious); and two within-subjects factors of Task Modality (Spatial, Verbal) and Task Status (Fixed, Running).
4.7.2 Participants

Participants were 64 first-year undergraduate students enrolled in an introductory psychology course at the University of Western Australia (UWA). They were aged between 17 and 35 years (\( M = 18.84, \ SD = 2.64 \)), and included 19 males. All were fluent in English, and had normal or corrected-to-normal vision and hearing.

Participants were selected on the basis of their scores on the DASS-42 Anxiety scale administered during introductory psychology classes a few weeks prior to the actual experiment. From this, participants who endorsed the most extreme ratings were invited to participate in the experiment. Ethical procedures in place at UWA precluded the identification of the DASS-42 scores of each individual who agreed to participate, therefore making it difficult to report the range of scores comprising these extremities.

The DASS-21 instrument was therefore administered at the time of testing, with the allocation of participants into the Trait Anxiety Groups based on these ratings (these DASS-21 scores were doubled to yield full-scale scores). Participants with scores of 6 or below were allocated to the Low Trait Anxiety Group (scores of 0-7 are in the normal range; S.H. Lovibond & P.F. Lovibond, 1995), while participants with scores of 8 or above were allocated to the High Trait Anxiety Group (encompassing the mild, moderate, severe, and extremely severe anxiety ranges; S.H. Lovibond & P.F. Lovibond, 1995).

4.7.3 Mood induction procedure

Two pieces of classical music were selected for the mood induction procedure. The Anxious Mood Induction condition utilised Stravinsky’s ‘The Rite of Spring (Part 2: The Sacrifice)’ while the Neutral Mood Induction condition used Fauré’s ‘Opus 19’. For each, a 7-minute excerpt was extracted from the piece, along with three 2-minute

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6 A power analysis using (a) 64 participants; (b) a significance criterion of .05; (c) an estimated medium effect size of .25; (c) degrees of freedom of the numerator of 2 or 1 (note: numerator degrees of freedom do not exceed 2 throughout the present programme of research); yields power of .88 and .81 for numerator degrees of freedom of 2 and 1 (respectively). This is similar to the conventional level of power of .80 recommended by Cohen (1988). A related issue concerns the lack of adjustment of significance levels. The alpha level was kept at .05 even though multiple tests were conducted in this, and subsequent studies. This was done because adopting a more conservative level (e.g. one that was adjusted for the number of tests made) would have eroded power substantially. This would have been especially problematic given that the absence of significant effects was a critical outcome in some studies. However, it is recognised that retaining an alpha level of .05 may have resulted in Type 1 errors in some instances. Replication of some of the key significant outcomes in follow-up research would clearly be desirable.
segments derived from the 7-minute excerpt for the purpose of ‘topping-up’ mood throughout the experiment. These segments were edited using SoundForge 4.5, sampled at a rate of 44,100Hz using a 16 Bit Stereo format. Both pieces of music have been previous utilised in research (Albersnagel, 1988), and found to be effective in engendering anxious (in the case of Stravinsky’s piece) and neutral (in the case of Fauré’s piece) moods.

4.7.4 Mood measures
Trait mood levels were measured using the DASS Anxiety and Depression scales. State mood levels were measured using the POMS Anxiety and Depression scales.

4.7.5 Apparatus
The apparatus was identical to that used in the study described in Chapter 3 (refer to Section 3.3.3).

4.7.6 Working memory tasks
The four working memory tasks – Fixed Spatial, Running Spatial, Fixed Verbal, and Running Verbal – were adaptations of the spatial memory task and visual/manual verbal memory task utilised in Chapter 3. Unlike the up-down procedure employed in the previous chapter, however, four trials were presented at each sequence length, commencing with a sequence length of three and extending up to a sequence length of ten. The successful recall of the sequence, position-respecting, on at least one of the four trials, led to an increment in sequence length. Tasks were terminated if participants failed to respond correctly on every one of the four trials.

The running tasks additionally adapt the Pollack et al. (1959) methodology outlined in Section 1.6.1, with the intention of presenting participants with a sequence of items for which they are not aware of the total number of items to occur, only that they are to recall a certain number of items at the end of the sequence. The preceding items that are not required to be recalled collectively form the prepend. Prepends and to-be-recalled items were constructed as follows: Within one set of four trials at a given sequence length, the number of items forming the prepend was such that for three of the four trials, one was 8, one was 9, and one was 10. The fourth trial comprised a
prepend of either 8, 9, or 10 items, and this was determined randomly. The order of presentation of the number of prepend items across the four trials at the one sequence length was randomised. The prepend items, along with the to-be-recalled items, were randomly selected without replacement from the 19 squares/letters described in Chapter 3.

4.7.6.1 Fixed Spatial task. Each block of four trials at a given sequence length was preceded by the sentence “You will be presented with x blocks” (where x denotes the sequence length) that appeared centrally and remained onscreen for 2s. This was replaced by a button labelled “Start”, which initiated the trial 1s after the button was pressed. Following this, the array of 19 blue outline squares (see spatial memory task from Section 3.3.4.1) appeared, and the to-be-recalled sequence was presented consecutively, with each square illuminated in red for 1s, and followed immediately by its successor in the sequence. The to-be-recalled sequence was selected randomly, without replacement, from the 19 squares in the array. A period of 500ms lapsed between the offset of the last block and the start of the recall phase, which was indicated by a 916ms, 22,050Hz tone, along with the illumination in red of the borders of all the squares for a period of 20ms (the display of squares did not disappear between the presentation and recall phases). Participants recalled the sequence by touching the squares. Each square was illuminated in red following contact until the end of the recall sequence. A period of 500ms lapsed between the recall of the last square and the presentation of the next trial. The task commenced at Sequence Length 3 and was preceded by three practice trials of Sequence Length 2.

4.7.6.2 Fixed Verbal task. Each block of four trials at a given sequence length was preceded by the sentence “You will be presented with x letters” (where x denotes the sequence length) that appeared centrally and remained onscreen for 2s. This was replaced by a button labelled “Start”, which initiated the trial 1s after the button was pressed. Following this, the to-be-recalled letters were displayed centrally (see the visual/manual verbal memory task from Section 3.3.4.1), presented at a rate of one per second, with each replaced by its successor. The items were selected, without replacement, from the 19 letters utilised in this task. A period of 500ms lapsed between the offset of the last to-be-recalled letter and the onset of the recall phase, which was
indicated by a 916ms, 22,050Hz tone using a 16 Bit Stereo format, and the presentation of the letter board (see Section 3.3.4.1). Participants recalled the sequence by touching within the square that housed each letter. Each square was illuminated in green following contact until the end of the recall sequence. A period of 500ms lapsed between the recall of the last letter and the presentation of the next trial. The task commenced at Sequence Length 3 and was preceded by three practice trials of Sequence Length 2.

4.7.6.3 Running Spatial task. The Running Spatial task was identical in format and procedure to the Fixed Spatial task, save for the sentence at the start of each block of four trials at a given sequence length (“You are to remember the last x blocks” where x denotes the sequence length), and also that the to-be-recalled sequence was preceded by the prepend (with no demarcation between the prepend and the to-be-recalled squares). The task commenced at Sequence Length 2 and was preceded by three practice trials at this sequence length (with prepends of 8, 9, and 10 items, respectively).

4.7.6.4 Running Verbal task. The Running Verbal task was identical in format and procedure to the Fixed Verbal task, save for the sentence at the start of each block of four trials at a given sequence length (“You are to remember the last x letters” where x denotes the sequence length), and also that the to-be-recalled sequence was preceded by the prepend (with no demarcation between the prepend and the to-be-recalled letters). As with the Running Spatial task, this task commenced at Sequence Length 2 and was preceded by three practice trials at this sequence length (with prepends of 8, 9, and 10 items, respectively).

4.7.6.5 Calculating performance indices. For all four tasks, two indices of performance were adopted. The first index was memory span, and this was obtained using a fractional scoring method (Hulme, Maughan, & G. Brown, 1991). For the fixed tasks, the sequence of items reported for each trial was scored as correct or incorrect, position-respecting, with the span score then calculated as a quarter point for each correct trial, plus two (to accommodate the fact that testing started at Sequence Length 3). Memory span scores were calculated in the same manner for the running tasks,
except that the quarter point for each correct trial was added to one (with testing commencing at Sequence Length 2). For example, on a fixed task, imagine a participant answered all 4 trials correctly on Sequence Length 3, answered 3 trials correctly on Sequence Length 4, answered 2 trials correctly on Sequence Length 5, and obtained only one correct response for Sequence Length 6, with no correct response at Sequence Length 7. The participant’s score is calculated as such: $1 + 0.75 + 0.5 + 0.25 + 0 = 2.5$, plus 2 to accommodate the fact that testing started at Sequence Length 3). This yields a span score of 4.5.

The second index of performance was reaction times (in milliseconds). Reaction times were parsed into preparatory intervals (from onset of prompt to respond to first response) and inter-item intervals (from offset of first response to onset of next response and so on). It has been argued that both of these intervals reflect the time taken to mentally scan through the items held in memory in order to identify the correct item to be recalled next. While the operation of this process is predominantly performed prior to recall (i.e. in the preparatory interval), the process of scanning reoccurs (in the inter-item intervals) and has the effect of refreshing representations of items (Cowan, 1992; Cowan et al., 1994).

Reaction times were considered only for those trials for which the recalled sequence was correct (position-respecting). For each sequence length, the median of the valid intervals was calculated. These were then averaged across all valid trials for that given sequence length. For example, a participant recorded the following reaction times for trials at Sequence Length 4:

| Trial 1:       | 1200  800 1000 900 | Correct response |
| Trial 2:       | 1100  750  800 850 | Correct response |
| Trial 3:       | 1245  650  580 700 | Incorrect response |
| Trial 4:       | 1000  600  800 700 | Correct response |

Trial 3 is omitted from analysis (incorrect response). The preparatory interval is the first value in each of the trials, marking the duration from the onset of prompt to respond to first response. The preparatory interval for this participant for Sequence Length 4 on this task is obtained by averaging 1200, 1100, and 1000 to yield 1100ms.
To calculate the inter-item interval for this participant for Sequence Length 4 of this task, we need to first obtain the median score for each trial. The inter-item intervals for each trial are those values subsequent to the first value in each trial (i.e. they comprise values from the offset of first response to onset of next response and so on). Thus, 900 is the median inter-item interval for Trial 1, 800 for Trial 2, and 700 for Trial 4 (Trial 3 is omitted as the participant did not score a correct response on this trial). The inter-item interval for this sequence length is then obtained by averaging these values (900, 800, 700) to yield 800ms.

4.7.7 General procedure

All participants were tested individually. After reading an information sheet and filling in a consent form relating to participation in the experiment, participants completed the DASS-21 (trait version). Participants then completed the practice trials of one of the tasks (order of presentation of tasks was counterbalanced across all participants), followed by the POMS Anxiety and Depression measures. They were then presented with the mood induction procedure, following which they completed both POMS scales again. This was followed by test trials of the first memory task. Participants then completed the three remaining memory tasks, with each task incorporating a 2-minute music mood induction (the top-up) inserted following the instructions and practice trials, and prior to the actual task. At the end of all four working memory tasks, participants completed the POMS Anxiety and Depression scales. Participants were then thanked and fully debriefed.

The assignment of participants into the various mood induction condition was such that within each Trait Anxiety Group, half were allocated to the Neutral Mood Induction condition and half to the Anxious Mood Induction condition (i.e. n = 16 per condition).

4.8 Results

4.8.1 Overview of Analyses

Two sets of analyses were performed. The first set served to assay participants’ enduring (trait) mood levels, as well as the efficacy of the mood induction procedure. The second set of analyses evaluated the effect of anxiety on the working memory
tasks, and this was examined using memory span scores and preparatory and inter-item intervals. Within this, the effects of state and trait anxiety were examined as outlined in Section 4.2, and the issue of comorbid depression was addressed as outlined in Section 4.5.

4.8.2 Participant mood levels and efficacy of mood induction procedure

4.8.2.1 Participant characteristics at testing time. It was desired that the more enduring mood characteristics of participants did not differ according to allocation into the different mood induction conditions. DASS-21 Anxiety and Depression ratings were therefore each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Mood Induction: Neutral, Anxious) ANOVA. Prior to analyses, DASS-21 scores were doubled to form full-scale scores. Each analysis revealed significant effects of Trait Anxiety Group, with the High Trait Anxiety Group endorsing higher ratings than the Low Trait Anxiety Group (see Table 4.1). No other effects were significant. Notably, an absence of effects involving Mood Induction indicates that the allocation of participants into the mood induction conditions did not systematically differ according to trait mood.

Table 4.1. F values and means (and standard deviations in parentheses) for the main effect of Trait Anxiety Group on trait mood measures.

<table>
<thead>
<tr>
<th>Measure</th>
<th>F-value</th>
<th>Trait Anxiety Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>DASS-21 Anxiety</td>
<td>$F(1,60) = 187.32^a$</td>
<td>3.25 (2.02)</td>
</tr>
<tr>
<td>DASS-21 Depression</td>
<td>$F(1,60) = 22.70^a$</td>
<td>6.69 (6.00)</td>
</tr>
</tbody>
</table>

*a denotes $p < .001$

It was also desired that the allocation of participants into the different mood induction conditions did not differ according to state mood at the beginning of testing. To evaluate this, the POMS Anxiety and Depression ratings in the Pre Mood Induction Phase were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Mood Induction: Neutral, Anxious) ANOVA. The analyses revealed that the only significant effects to emerge involved Trait Anxiety Group, with higher ratings endorsed by the
High Trait Anxiety Group compared to the Low Trait Anxiety Group (see Table 4.2). Importantly, there were no effects involving Mood Induction, indicating that the allocation of participants into the mood induction conditions did not vary systematically as a function of state mood.

4.8.2.2 Efficacy of mood induction procedures. To assay the impact of the mood induction procedure, POMS Anxiety and Depression ratings were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Mood Induction: Neutral, Anxious) x 3 (Phase: Pre Mood Induction, Post Mood Induction, Post Experiment) mixed-design ANOVA where Phase was a within-subjects variable. As there were more than two levels of the within-subjects variable, in instances where Mauchly’s test of the sphericity assumption was violated, Huynh-Feldt Epsilon-corrected values were reported. Similarly, where independent samples t tests were utilized to decompose significant interaction effects, in instances where violations of Levene’s test for equality of variances occurred, corrected values with equal variances not assumed were reported. These corrections were applied in all subsequent analyses where they were pertinent.

<table>
<thead>
<tr>
<th>Measure</th>
<th>F-value</th>
<th>Trait Anxiety Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>POMS Anxiety</td>
<td>F(1,60) = 20.05^a</td>
<td>7.24 (6.93)</td>
</tr>
<tr>
<td>POMS Depression</td>
<td>F(1,60) = 11.15^b</td>
<td>5.94 (7.73)</td>
</tr>
</tbody>
</table>

^a denotes p < .001; ^b denotes p < .01

POMS Anxiety ratings. The analysis revealed a main effect of Mood Induction, F(1,60) = 9.07, p < .001, indicating that the Anxious Mood Induction was associated with higher levels of POMS Anxiety ratings compared with the Neutral Mood Induction (M = 17.94, SD = 11.34, and M = 9.81, SD = 11.84, respectively). A main effect of Trait Anxiety Group was also evident, F(1,60) = 10.57, p < .01, with higher POMS Anxiety...
ratings endorsed by the High Trait Anxiety Group, $M = 18.27$, $SD = 13.15$, than by the Low Trait Anxiety Group, $M = 9.48$, $SD = 9.49$.

There was also a significant Phase x Mood Induction interaction effect, $F(2,120) = 10.89$, $p < .001$, indicating that the effect of the Anxious and Neutral Mood Inductions was not equivalent across all phases of the experiment (see Figure 4.1). This revealed that while POMS Anxiety ratings did not differ between the two mood induction conditions at the Pre Mood Induction Phase, $t(62) = .53$, n.s., higher ratings were endorsed by participants in the Anxious Mood Induction condition at the Post Mood Induction Phase, $t(57.19) = 4.28$, $p < .001$, with this difference maintained at the Post Experiment Phase, $t(62) = 2.48$, $p < .01$. No other effects were significant.

Figure 4.1. Means (and standard errors) of POMS Anxiety Ratings for each Mood Induction condition at each phase of the experiment.
POMS Depression ratings. The analysis revealed a main effect of Trait Anxiety Group, $F(1,60) = 13.75, p < .001$, with higher ratings endorsed by the High Trait Anxiety Group ($M = 15.88, SD = 13.18$) than by the Low Trait Anxiety Group ($M = 5.96, SD = 7.09$). No other effects were significant. Importantly, the Phase x Mood Induction interaction was not significant, indicating that the mood induction manipulation did not systematically affect POMS Depression ratings.

4.8.3 Working memory performance

4.8.3.1 Memory span scores. Memory span scores were calculated as outlined in Section 4.7.6.5. In order to evaluate the effect of anxiety on memory, span scores were subjected to a $2 \times 2 \times 2 \times 2$ mixed-design ANOVA, where the latter two were within-subjects variables. One outlier was removed from the Running Verbal Task memory span scores as it exceeded three standard deviations of the mean. There was a main effect of Memory Task, $F(1,59) = 7.22, p < .01$, with higher span scores on the Spatial task, $M = 4.43, SD = .52$, than on the Verbal task, $M = 4.24, SD = .56$. There was also a significant Task Status main effect, $F(1,59) = 808.45, p < .001$. This indicated higher memory span scores for the Fixed tasks, $M = 5.20, SD = .55$, than for the Running tasks, $M = 3.47, SD = .48$.

There was also a Task Modality x Task Status interaction, $F(1,59) = 15.05, p < .001$ (see Figure 4.2). Here, memory span scores were equivalent between Fixed Spatial and Verbal Tasks, $t(62) = .40, n.s.$, while scores on the Running Spatial task were higher than scores on the Running Verbal task, $t(62) = 5.00, p < .001$.

The only other significant effect was a Task Status x Trait Anxiety Group x Mood Induction interaction, $F(1,59) = 4.35, p < .05$. The Trait Anxiety Group x Mood Induction interaction was not significant, indicating that the mood induction manipulation did not systematically affect POMS Depression ratings.
interaction was examined at each level of Task Status, and this indicated that this interaction was significant for the Fixed tasks, $F(1,59) = 5.12, p < .05$, but not for the Running tasks, $F(1,59) = .22$, n.s. (see Figure 4.3). For the Fixed tasks, memory span scores did not differ between mood induction conditions for both Trait Anxiety Groups, $t$s < 1.93. Rather, the effect reflected the crossover in the span scores between the Trait Anxiety Groups. As the Trait Anxiety Group factor was implicated, in order to examine if this effect reflected the operation of anxiety, or whether it could be attributed to depression, the impact of depression was examined by ‘blocking’ subjects on their trait depression score and including this as a factor in the analysis (refer to Section 4.5). This revealed an absence of a significant Trait Anxiety Group x Mood Induction x Trait Depression x Task Status interaction, $F(1,55) = .47$, n.s., and furthermore that the Trait Anxiety Group x Mood Induction x Task Status interaction remained significant, $F(1,55) = 6.27, p < .05$. Thus, the effects were attributable to anxiety rather than to depression.

![Figure 4.2](image-url)

**Figure 4.2.** Means (and standard errors) of memory span scores for each Task Modality x Task Status condition.
Figure 4.3. Means (and standard errors) of memory span scores for each Trait Anxiety Group x Mood Induction condition for each Task Status condition.
4.8.3.2 Reaction time analyses. The reaction time analyses considered both the preparatory and inter-item intervals. These were calculated as outlined in Section 4.7.6.5. Reaction times were considered only for those trials for which the recalled sequence was correct (position-respecting). Only those sequence lengths on which almost all participants had obtained at least one correct trial were considered. For the Fixed tasks, these were sequence lengths of 3, 4, and 5, while for the Running tasks, these were sequence lengths of 2 and 3 (note that for the latter, one participant did not obtain any correct responses and so provided no useable data). Outliers beyond three standard deviations of the mean of preparatory and inter-item intervals (across all participants for that particular sequence length) were then eliminated. This resulted in the omission of no more than two data points per sequence length, and did not constitute meaningful analysis for each given sequence length.

Three sets of analyses were performed. The first was a parallel analysis to the memory span analyses, and sought to compare performance across Task Modality and Task Status, but for the one sequence length, 3 (this sequence length was selected as almost all participants obtained at least one correct response for it). The second set compared performance on Fixed tasks only, but permitted an investigation of the impact of increasing sequence length. The third set of analyses also permitted an investigation of the impact of increasing sequence length, however this was in relation to the Running tasks only. For each of these sets of analyses, both preparatory and inter-item intervals were considered.

Parallel reaction time analyses. Preparatory and inter-item intervals for Sequence Length 3 were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Mood Induction: Neutral, Anxious) x 2 (Task Modality: Spatial, Verbal) x 2 (Task Status: Fixed, Running) mixed-design ANOVA. The latter two were within subjects variables. There were two outliers in the preparatory interval analysis (one each from the Fixed Verbal and Running Spatial tasks) and another two in the inter-item interval analysis (one each from the Fixed and Running Verbal tasks). Both sets of analyses revealed main effects of Task Modality and Task Status. For the Task Modality effect, longer intervals were observed for Verbal than for Spatial tasks (see Table 4.3). For the
Task Status effects, longer preparatory intervals were observed for Running than for Fixed tasks (see Table 4.4), however the converse was true for inter-item intervals.

Both analyses also revealed Task Modality x Task Status interaction effects, with $F(1,57) = 9.95$, $p < .01$, for the preparatory interval analyses, and $F(1,57) = 7.70$, $p < .01$, for the inter-item interval analyses. Preparatory intervals were longer for the Running tasks than for the Fixed tasks, $t_s > 4.60$, with the difference being more pronounced for Verbal than for Spatial tasks (see Figure 4.4). In contrast, inter-item intervals were longer for the Fixed than for the Running tasks, $t_s > 2.53$, with this difference being more pronounced for Verbal than for Spatial tasks. No effects involving Trait Anxiety Group or Mood Induction were significant.

Table 4.3. F values and means (and standard deviations in parentheses) of reaction time intervals for the main effect of Task Modality for the parallel reaction time analyses.

<table>
<thead>
<tr>
<th>Interval</th>
<th>F-value (df)</th>
<th>Spatial Mean (SD)</th>
<th>Verbal Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparatory</td>
<td>$F(1,57) = 93.42^a$</td>
<td>824.10 (237.11)</td>
<td>1561.97 (594.88)</td>
</tr>
<tr>
<td>Inter-item</td>
<td>$F(1,57) = 39.13^a$</td>
<td>659.05 (157.81)</td>
<td>791.32 (203.43)</td>
</tr>
</tbody>
</table>

$^a$denotes $p < .001$

Table 4.4. F values and means (and standard deviations in parentheses) of reaction time intervals for the main effect of Task Status for the parallel reaction time analyses.

<table>
<thead>
<tr>
<th>Interval</th>
<th>F-value (df)</th>
<th>Fixed Mean (SD)</th>
<th>Running Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparatory</td>
<td>$F(1,57) = 35.88^a$</td>
<td>988.17 (270.85)</td>
<td>1396.15 (551.72)</td>
</tr>
<tr>
<td>Inter-item</td>
<td>$F(1,57) = 24.58^a$</td>
<td>784.24 (202.79)</td>
<td>665.03 (175.81)</td>
</tr>
</tbody>
</table>

$^a$denotes $p < .001$
Figure 4.4. Means (and standard errors) of reaction time intervals for each Task Modality x Task Status condition for the parallel reaction time analyses.
**Fixed reaction time analyses.** Preparatory and inter-item interval reaction times were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Mood Induction: Neutral, Anxious) x 2 (Task Modality: Spatial, Verbal) x 3 (Sequence Length: 3, 4, 5) mixed-design ANOVA, with the latter two being within-subjects variables. As there were more than two levels of the within-subjects variable, in instances where Mauchly’s test of sphericity assumption was violated, Huynh-Feldt Epsilon-corrected values are reported. There were seven outliers in the preparatory interval analysis (one from Sequence Length 4 and two from Sequence Length 5 of the Spatial task; and one from Sequence Length 3, two from Sequence Length 4, and one from Sequence Length 5 for the Verbal task). There were three outliers in the inter-item interval analysis (one from Sequence Length 4 and two from Sequence Length 5 of the Verbal task). For both sets of analyses, there was a significant main effect of Task Modality, with longer intervals on Verbal than on Spatial tasks (see Table 4.5).

The preparatory interval analysis also yielded a significant main effect of Sequence length, \( F(2,106) = 6.82, p < .01 \). This reflected differences between Sequence Lengths 3 and 4, and 4 and 5, \( t_s > 2.06 \) (\( M = 972.40, SD = 268.03, \) for Sequence Length 3; \( M = 911.04, SD = 247.94, \) for Sequence Length 4; \( M = 1028.34, SD = 293.73, \) for Sequence Length 5). No other effects were significant for the preparatory interval analysis, nor were there any other significant effects for the inter-item interval analysis. No effects involving Trait Anxiety Group or Mood Induction were significant.

Table 4.5. F values and means (and standard deviations in parentheses) of reaction time intervals for the main effect of Task Modality for the fixed reaction time analyses.

<table>
<thead>
<tr>
<th>Interval</th>
<th>F-value</th>
<th>Task Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spatial</td>
</tr>
<tr>
<td>Preparatory</td>
<td>( F(1,53) = 154.04^a )</td>
<td>730.36 (243.79)</td>
</tr>
<tr>
<td>Inter-item</td>
<td>( F(1,57) = 50.98^a )</td>
<td>672.54 (183.33)</td>
</tr>
</tbody>
</table>

\(^a\)denotes \( p < .001 \)
Running reaction time analyses. Preparatory and inter-item interval reaction
times were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Mood Induction:
Neutral, Anxious) x 2 (Task Modality: Spatial, Verbal) x 2 (Sequence Length: 2, 3)
mixed-design ANOVA. The within-subjects variables were Task Modality and
Sequence Length. Three outliers were removed from the preparatory interval analysis
(one from Sequence Length 2 and one from Sequence Length 3 of the Spatial task, and
one from Sequence Length 2 of the Verbal task). Three outliers were also removed
from the inter-item interval analysis (one from Sequence Length 2 of the Spatial task,
and one each from Sequence Lengths 2 and 3 of the Verbal task).

For the preparatory interval analysis, there was a significant main effect of Task
Modality, $F(1,56) = 71.74, p < .001$. Longer intervals were observed for the Verbal task,
$M = 1494.26, SD = 583.23$, than for the Spatial task, $M = 872.16, SD = 239.19$. There
was also a main effect of Sequence Length, $F(1,56) = 47.57, p < .001$. Longer intervals
were observed at Sequence Length 3, $M = 1424.66, SD = 561.30$, than at Sequence
Length 2, $M = 941.76, SD = 254.59$. The Task Modality x Sequence Length interaction
yielded $F(1,56) = 31.58, p < .001$ (see Figure 4.5). An increase in Sequence Length
served to elevate preparatory intervals, $t_s > 2.26$, and this was more pronounced on the
Verbal task than on the Spatial task.

For the inter-item interval analysis, the main effect of Task Modality yielded $F(1,56) =
3.89, p = .053$. This indicated a trend for longer intervals on the Verbal task, $M =
707.26, SD = 200.62$, than on the Spatial task, $M = 651.75, SD = 172.45$. Neither of the
analyses yielded significant effects involving Trait Anxiety Group or Mood Induction.

To summarise, the reaction time analyses did not reveal any effects involving Trait
Anxiety Group or Mood Induction. The memory span analyses revealed a significant
Trait Anxiety Group x Mood Induction interaction, although this unexpectedly involved
differences for the fixed rather than running tasks.
4.8.3.3 State anxiety and working memory performance. An unexpected finding from the present study was that the POMS Anxiety analyses did not yield a significant Trait Anxiety x Mood Induction interaction.\(^8\) The absence of this interaction is surprising as state anxiety is deemed to be determined interactively by these two factors (Eysenck & Calvo, 1992). However, it is possible that state anxiety may be determined by other factors (e.g. the POMS Anxiety analyses indicated that both trait anxiety and mood induction contributed independently to ratings). A more direct means of comparing the relationship between state anxiety and working memory performance is therefore to examine correlations between these variables. State anxiety scores were obtained by averaging POMS Anxiety ratings between the Post Mood Induction and Post Experiment phases. Additionally, to address the possibility that state anxiety

\(^8\) A potential explanation for this absence of a Trait Anxiety x Mood Induction interaction on the POMS Anxiety analyses may be that trait anxiety levels were too low for this interaction to manifest. To evaluate this, the data were reanalysed with only the upper and lower quartile of the trait anxiety scores. This yielded \(F(2,58) = .81\), n.s., indicating that the absence of a Trait Anxiety x Mood Induction interaction was not due to insufficiently high trait anxiety levels.
depression scores may mediate the anxiety-working memory relationship, correlations between state depression ratings and indices of working memory performance were also examined. As for the POMS Anxiety ratings, state depression scores were obtained by averaging POMS Depression ratings between the Post Mood Induction and Post Experiment phases. Where indices of working memory performance were correlated with both anxiety and depression ratings, partial correlations were then conducted to isolate the effects of anxiety.

The full set of correlational analyses is presented in Appendix A. Overall, there was a general absence of significant correlations between POMS Anxiety ratings and indices of working memory performance. The notable exception was the inter-item interval analyses for Sequence Length 3 of the Fixed Verbal task, although this index was also correlated with state depression ratings. Partial correlational analyses indicate that when state depression ratings were controlled for, the correlation between state anxiety ratings and this index of working memory performance was rendered non-significant ($r = -.00$). Thus, it appears that state depression served to mediate the observed anxiety-working memory relationship. It is also noted that the inter-item interval for Sequence Length 4 on the same task was significantly correlated with state depression ratings but not state anxiety ratings.

4.9 Discussion

The primary aim of the present study was to investigate the possibility of a link between somatic anxiety and working memory performance and, in doing so, to test the specificity of the PET (i.e. whether worry is necessary for anxiety to affect working memory performance). Within this, it was considered that elevated levels of somatic anxiety may impair performance by draining attentional resources in a manner similar to Sarason’s (1984) attentional interference theory, on which the PET is based. A subsidiary aim was to investigate the state/trait anxiety distinction that serves to cloud the existing literature (see Section 1.6.3). Prior to the evaluation of these aims, results pertaining to participant trait mood and the efficacy of the mood induction procedure will be discussed.
4.9.1 Trait mood and efficacy of mood induction procedure

High trait anxious individuals not only endorsed significantly higher trait anxiety ratings compared to low trait anxious groups, but they also endorsed significantly higher levels of trait depression.

The results of the mood induction procedure indicated that the anxious mood induction condition increased state anxiety ratings, whereas the neutral mood induction condition did not, with the effects of the mood induction procedures sustained until the end of the experiment. Also evident in the POMS Anxiety analyses was an effect of trait anxiety group, with higher POMS Anxiety ratings endorsed by the high trait anxious group than by the low trait anxious group. This suggests that both trait anxiety and situational stress contribute to state anxiety. Interestingly, there was an absence of a trait anxiety group x mood induction interaction on the anxiety ratings, an outcome contrary to what would be expected if state anxiety was determined interactively by these two factors (cf. Eysenck & Calvo, 1992). Rather, trait anxiety and situational stress (i.e. the anxious mood induction condition) appear to make independent contributions to state anxiety.

Another noteworthy observation from the analyses of the efficacy of the mood induction procedure is that the POMS Depression ratings did not vary according to mood induction condition. This suggests specificity of the mood induction procedure in affecting anxiety but not depression. The absence of effects of the mood induction on POMS Depression ratings contrasts with Albersnagel’s (1988) study employing the same musical pieces, which found the anxious mood induction to also elevate depression levels. One possible explanation for the discrepancy is the nature of the measurements employed – while Albersnagel also utilized a visual analogue scale similar to that employed in the present study, each mood state was assessed using one item only. For example, the measurement of anxiety consisted of a 10cm long line with one endpoint labelled “At this moment, I feel completely relaxed” and the other labelled “At this moment, I feel very tensed” (sic, Albersnagel, 1988, p. 81). The use of several items to capture finer distinctions in the present study, in contrast to the single-item used by Albersnagel, is likely to account for the discrepant findings.
4.9.2 Somatic anxiety and working memory performance - a tenable link?

The present study examined the specificity of the PET regarding cognitive anxiety as being of critical importance in light of research into the impact of less cognitive forms of mood on working memory performance (cf. Krohne et al., 2002; Meinhardt & Pekrun, 2003). More somatic forms of anxiety were hypothesized to affect working memory performance via the consumption of attentional resources, which would be most likely to be reflected in impaired performance on the two running memory tasks. Unexpectedly, this was not supported in the analyses for the memory span scores and for the reaction times. There was a notable absence of anxiety-linked effects on reaction times. For the memory span score analyses, there was a trait anxiety x mood induction interaction, however this involved differences for the fixed tasks rather than the running tasks and even then the two-way interaction was not consistent with what would be expected (see Figure 4.3).

Regarding the state/trait anxiety distinction, the results of the present study indicate that the single effect of anxiety on working memory indices was attributable to the interaction between trait anxiety and mood induction. While this would theoretically be proposed to reflect state anxiety (Eysenck & Calvo, 1992), it is noted that the analysis of POMS Anxiety ratings did not yield a significant trait anxiety x mood induction interaction. Furthermore, the analyses reported in Section 4.8.3.3 revealed no significant correlations between POMS Anxiety ratings and indices of working memory performance that were independent of POMS Depression ratings, although POMS Depression ratings themselves appeared to be linked with some indices of performance. Again, as the focus of the study was on somatic and not cognitive anxiety, a conclusive discussion regarding this topic cannot be entered into and will, instead, be postponed to the next chapter wherein the focus on more cognitive forms of anxiety is expected to demonstrate more robust effects and, in turn, shed light on the state/trait anxiety distinction.

Another plausible explanation for the absence of anxiety-linked impairments in working memory performance may be that the working memory tasks selected are insufficiently taxing on working memory resources. However, the more probable explanation at this point in time, given a body of evidence (see Table 1.1 for a review) demonstrating an anxiety-linked effect on working memory, is that the lack of utilization of a cognitive
mood induction is the reason for the absence of anxiety-linked impairments in working memory performance.

4.9.3 Chapter summary
The present study aimed to investigate a tenable link between somatic anxiety and working memory performance by evaluating the specificity of the PET. The possibility that somatic anxiety can affect working memory performance by consuming attentional resources for the purpose of mood repair (cf. Krohne et al., 2002; Spies et al., 1996), along the lines of how worry affects performance according to the PET, was not supported. Rather, it appears that more cognitive forms of anxiety may be necessary for anxiety-linked impairments to manifest, and this forms the focus of the next study. However, in light of an effect of the somatic mood induction on memory span scores in the present study, this manipulation of mood was retained in the next study. The next study was also poised to further elucidate the state/trait anxiety distinction.
5.1 Introduction
The previous chapter suggested an effect of somatic anxiety on working memory performance, although it was contrary in form to that which was predicted. Specifically, anxiety did not impair working memory performance on tasks proposed to engage the CE (i.e. the running memory tasks). The absence of effects in support of the PET is most likely to reflect that the effects of anxiety on working memory performance are specific to cognitive anxiety. Thus, the incorporation of a cognitive mood induction procedure to elicit cognitive anxiety should reveal anxiety-linked impairments in working memory performance consistent with the predictions of the PET. As the somatic mood induction procedure was linked with impaired working memory performance in the previous chapter (although the effect was in an unexpected direction), the somatic mood induction was retained. Thus, the distinction between cognitive and somatic anxiety – first discussed in Section 1.6.4 – forms the focus of the present study. This study also served to shed further light on the state/trait anxiety distinction via the retention of the procedure wherein high and low trait anxious individuals are subjected to anxious and neutral mood induction procedures. The issue of comorbid depression was also further explored in the present study by adopting the statistical analyses utilised in the previous study (see Section 4.5).

5.2 Cognitive versus somatic anxiety
From the viewpoint of the distinction between cognitive and somatic anxiety, it follows that the present study should include a mood induction procedure that would induce heightened levels of cognitive anxiety. To this end, ego threat instructions were utilised, as this is a tool proposed to engender worry that is used in many anxiety-working memory studies (e.g. Calvo et al., 1994; Darke, 1988a, b; Derakshan & Eysenck, 1998). This involves informing participants that their task performance is indicative of their level of intelligence, furthermore that their performance will be compared with that of other participants. It has been demonstrated that this type of condition (i.e. evaluation) elicits greater effort from participants on a cognitive task (A.M. Williams et al., 2003). As the previous chapter demonstrated an anxiety-linked performance deficit (admittedly
unexpected in form) employing music as a mood induction technique, it is of interest to retain this technique, thereby permitting an investigation of how cognitive anxiety and somatic anxiety impact on working memory performance. Thus, high and low anxious participants underwent somatic and cognitive mood induction procedures. There were two levels to each mood induction procedure – for the cognitive mood induction procedure, these were no ego threat and ego threat instructions, and for the somatic mood induction procedure, these were neutral and anxious music (the somatic mood induction is henceforth referred to as the music mood induction). This permits an observation of whether the different mood induction procedures have independent or interactive effects on working memory performance.

It is interesting to note that the type of anxiety elicited by a given mood induction procedure is not necessarily unique to the mood expected to be elicited by a particular procedure. Ree (2001), for instance, examined the impact of cognitive and somatic stressors (proximity to examinations and inhalation of carbon dioxide, respectively) on cognitive and somatic anxiety. The cognitive stressor produced equivalent elevations in cognitive and somatic anxiety, whereas the somatic stressor elevated somatic but not cognitive anxiety. In light of the demonstration (albeit limited) in the previous chapter of an anxiety-linked deficit in working memory performance due to the music mood induction – which may arguably be classified as a somatic rather than a cognitive stressor – it is possible that the cognitive mood induction may have a two-fold effect on working memory performance.

5.3 Additional mood measures

The inclusion of a cognitive mood induction procedure warranted a revision of the anxiety measures employed. The items comprising the POMS Anxiety scale utilised in the previous chapter are primarily somatic/affective in nature and may therefore not capture the full range of anxiety symptoms. Three additional measures were included in the present study to address this issue - the State and Trait Inventory of Cognitive and Somatic Anxiety (STICSA; Ree, 2001), the Penn State Worry Questionnaire (PSWQ; Meyer, M.L. Miller, Metzger, & Borkovec, 1990), and the Cognitive Interference Questionnaire (CIQ; I.G. Sarason & Stoops, 1978).
5.3.1 State and Trait Inventory of Cognitive and Somatic Anxiety (STICSA)

It was desired in the present study to include an instrument that captured the cognitive and somatic aspects of anxiety to measure participants’ anxiety levels in response to the different mood induction procedures. Presently, there exists an instrument that makes the cognitive/somatic anxiety distinction, the Cognitive and Somatic Anxiety Questionnaire (CSAQ; Schwartz et al., 1978). However, the items on this scale are not measures of state anxiety, thereby limiting its suitability for the aims of evaluating the efficacy of mood induction procedures in the present study. More recently, the STICSA (Ree, 2001) has been developed to capture both state and trait dimensions of cognitive and somatic anxiety. The STICSA consists of a somatic subscale (11 items in total) with items including “I feel dizzy”, “My face feels hot”, and “I have butterflies in my stomach”, while items comprising the cognitive subscale (10 items in total) include “I think that others won’t approve of me”, and “I think the worst will happen”.

The time-frame of the trait form refers to how the respondent feels “most of the time”, and respondents indicate the extent to which they endorse each item on a four-point scale ranging from “Almost never” (1) to “Almost always” (4). The time-frame of the state form refers to "right now at this moment", and respondents indicate their endorsement of each item on a four-point scale ranging from “Not at all” (1) to “Very much” (4). For both state and trait scales, scores may range from 11 to 44 for the somatic scale, and 10 to 40 for the cognitive scale. The state and trait cognitive and somatic scales of the STICSA all exhibit good reliability and validity (Ree, 2001). Internal consistency estimates are high (coefficient alphas upwards of .74), and the trait scales show high test-retest reliabilities ($r_s > .65$). The scales have sound convergent and discriminant validities, with state and trait cognitive scales exhibiting significantly greater correlations with the STAI than with the BDI-II. However, it should be noted that the same was not true for the state and trait somatic scales (i.e. correlations with the STAI were not significantly greater than the correlations with the BDI-II), although Ree views this to reflect the greater emphasis that the STAI places on the cognitive than the somatic dimension of anxiety.

The state version of the STICSA is ideally suited for the purpose of the present experiment, which endeavoured to manipulate cognitive and somatic anxiety levels via the different mood induction procedures. However, the trait version of the STICSA may
also be suitable for the present experiment, complementing the existing trait anxiety measures (DASS and PSWQ). Consequently, this version will also be included.

**5.3.2 Penn State Worry Questionnaire (PSWQ)**

The PSWQ (Meyer et al., 1990) is a 16-item content-free measure of worry that assesses the duration and uncontrollability of worry. It comprises statements such as “If I don’t have enough time to do everything I don’t worry about it”, “When I am under pressure I worry a lot”, and “I’ve been a worrier all my life”. Five of the 16 items are positively worded (e.g. “I find it easy to dismiss worrisome thoughts”). Respondents are required to indicate, on a five-point scale ranging from “Not at all typical” (1) to “Very typical” (5), how typical each statement is of them. Total scores may range from 16 to 80. Unlike the STICSA-Trait scale, which provides a more general measure of cognitive anxiety, the PSWQ focuses specifically on worry, which has been argued to be a critical component in the effects of anxiety on working memory (although it is noted that the PET views state, rather than trait, worry as integral in working memory performance; Eysenck & Calvo, 1992).

Factor analytic studies of the PSWQ have unearthed one general factor (T.A. Brown, 2003; T.A. Brown, Antony, & Barlow, 1992; Molina & Borkovec, 1994; although see Fresco Haimberg, Mennin, & Turk, 2002). The PSWQ exhibits very high internal consistencies (coefficient alphas upwards of .91; Meyer et al., 1990), has test-retest reliabilities ranging from .74 to .93 (periods ranging from 2 to 10 weeks; Meyer et al., 1990; Molina & Borkovec, 1994; Stöber, 1998), and is moderately correlated with the STAI-trait.

The PSWQ is also moderately correlated (rs upwards of .59) with other measures of worry such as the Worry Domains Questionnaire and the Student Worry Scale (Davey, 1993; Stöber, 1998), with single-item questionnaires about the percentage of days spent worrying, and also with the frequency of worrying about topics of current concern (Meyer et al., 1990; Molina & Borkovec, 1994). The PSWQ also exhibits higher correlations with the cognitive than with somatic scales of the CSAQ, with this finding consistent with conceptualisations of worry as a form of cognitive anxiety (Meyer et al., 1990).
## 5.3.3 Cognitive Interference Questionnaire (CIQ)

The CIQ (I.G. Sarason & B.R. Sarason, 1987) is a 22-item measure administered upon completion of the task(s) of interest that assesses the number of non task-focused thoughts experienced during task performance. These thoughts may be parsed into three types – task-relevant thoughts, task-irrelevant thoughts, and the degree of mind-wandering. Task-relevant thoughts concern an individual’s appraisal of his/her own task performance, and comprise ten items including “I thought about how poorly I was doing”, “I thought about the purpose of the experiment” and “I thought about how others have done on this task”. Task-irrelevant thoughts comprise 11 items including “I thought about members of my family” and “I thought about friends”. For both the task-relevant and task-irrelevant thoughts, respondents indicate the frequency with which they experienced the thought on a five-point scale ranging from “Never” (1) to “Very Often” (5). Scores may vary from 10 to 15 for task-relevant thoughts, and from 11 to 55 for task-irrelevant thoughts. A single mind-wandering item requires respondents to indicate the degree to which they felt their mind wandered while completing the task on a seven-point scale ranging from “Not at all” (1) to “Very much” (7).

Factor analysis of the CIQ confirms the distinction between task-relevant and task-irrelevant thoughts (I.G. Sarason, B.R. Sarason, Keefe, Hayes, & Shearin, 1986). Additionally, it was found that the mind-wandering item loaded on the same factor as the task-irrelevant thoughts. The distinction that the CIQ makes between task-relevant and task irrelevant thoughts is an important one, with research demonstrating that it is the former that accounts for detrimental performance on cognitive tasks (I.G. Sarason & B.R. Sarason, 1987). Thus, the present study focused only on the task-relevant thoughts measured by the CIQ (items 1 to 10).

With the inclusion of the cognitive mood induction condition, it was necessary to reconsider the intervals at which the state mood measures were administered. It was desired that the present format would be as close as possible to that employed in the previous study. The sequence of events in this format involved participants completing

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9 It is noted that the labels of the subscales within the CIQ can be confusing - all thoughts measured by the CIQ are non task-focused thoughts, in that they are not necessary for successful task completion. Task-relevant thoughts in the context of the CIQ are thoughts that are non task-focused, but related to one’s own performance on the task.
the trait mood measures followed by a practice session of the task and the state mood measures (Pre Mood Induction Phase), undergoing the music mood induction and completing a second set of the mood measures (Post Mood Induction Phase), completing the memory tasks and then a final set of the mood measures (Post Experiment Phase). For the present study, however, administering the ego threatening instructions along with the music meant that these mood induction techniques are immediately flanked by the administration of the mood measures (in the Pre and Post Mood Induction phases), and it is possible that the aims of the cognitive mood induction condition may be rendered transparent. To overcome this potential limitation, administration of the mood measures in the Post Mood Induction phase was therefore omitted. While this may not capture the full effect of the mood induction procedures throughout the duration of the experiment, it is necessary in light of the introduction of the cognitive mood induction condition.

5.4 The present study

The present study constituted a direct evaluation of the PET. It adopted the experimental design utilised in the previous chapter, with the addition of a cognitive mood induction manipulation and, along with this, three measures designed to capture the cognitive symptoms of anxiety. Together, this led to the identification of three aims:

1. To demonstrate that elevated levels of state anxiety are linked with impoverished working memory performance.
2. To demonstrate that the cognitive mood induction condition, in interaction with trait anxiety, serves to elevate levels of cognitive anxiety.
3. For 1, to demonstrate that any such effects implicate cognitive rather than somatic anxiety.
4. For 1, to further investigate whether anxiety-linked impairments are due to trait or state anxiety.

The present programme of research has yet to replicate the detrimental effects of anxiety on working memory performance evident in the existing literature (e.g. Darke, 1988a,b; Derakshan & Eysenck, 1998; C. MacLeod & Donnellan, 1993; Sorg & Whitney, 1992; Tohill & Holyoak, 2000), thus this was the first and foremost aim of the current study.
The second aim of this study was to demonstrate that the cognitive mood induction condition served to elevate levels of cognitive anxiety. It was expected that ego threatening instructions would increase cognitive anxiety relative to no ego threatening instructions, as reflected in elevated STICSA State Cognitive Anxiety ratings and a greater number of CIQ task-relevant thoughts. Trait anxiety was also expected to be implicated as state anxiety is proposed to be determined interactively by trait anxiety and stress (Eysenck & Calvo, 1992). In light of Ree’s (2001) findings, STICSA State Somatic Anxiety and POMS Anxiety ratings may be affected. The anxious music was expected to elevate somatic anxiety in a manner similar to that demonstrated in the previous chapter, as reflected in STICSA State Somatic Anxiety and POMS Anxiety ratings, relative to the neutral music. The music mood induction is not expected to impact on CIQ task-relevant thoughts.

As it was hypothesised that the limited evidence of anxiety-linked impairments in performance in the previous study resulted from the somatic nature of the mood induction procedure employed, the third aim was to examine whether any impairments in performance in the present study were attributable to cognitive rather than somatic anxiety. It was expected that the cognitive mood induction variable would be implicated in instances where anxiety-linked impairments in performance were observed, particularly on indices of processing efficiency (reaction times). In light of the specific effect on working memory performance attributable to the music mood induction in the previous study, it was expected that the trait anxiety x music mood induction x task status interaction on accuracy would also be observed in the present study.

Finally, the fourth aim of this study was to further explore the state/trait anxiety distinction. The previous study pointed to an effect on working memory performance as resulting from the interaction between trait anxiety and mood induction, although it is interesting to note that the state anxiety ratings were not concordantly affected, nor were the state anxiety ratings correlated with memory span scores on the fixed tasks (which had shown the three-way interaction in the ANOVA). State anxiety ratings also did not correlate with many other indices of working memory performance (see Section 4.8.3.3). The effects of state and trait depression will be examined by employing those statistical methods utilised in the previous study. In evaluating the PET in the present
study, it is noted that state cognitive anxiety is proposed to be the source of impaired performance.

The inclusion of the cognitive mood induction procedure designed specifically to engender worry meant that the following predictions of the PET could be evaluated. Each prediction will be stated first and the associated relationship will be elaborated later.

- That motivational factors enhancing effort typically benefit the performance of low-anxious individuals to a greater extent than is the case for high anxious individuals (Prediction 1.4)

- The performance on a central task will be adversely affected by an additional load to a greater extent in anxious than in non anxious groups (Prediction 1.5)

- Anxiety reduces transient storage capacity (Prediction 2.2)

- Anxiety has powerful adverse effects on tasks with high storage and processing demands (Prediction 2.3)

- Anxiety does not generally impair performance on tasks not involving the CE and/or PL components of the working memory system (Prediction 2.4)

Regarding Prediction 1.4, motivational factors that enhance effort are expected to benefit the performance of low anxious individuals to a greater extent than they benefit the performance of high anxious individuals. This is because high anxious individuals already have a restricted working memory capacity due to non task-focused thoughts consuming resources, and these individuals will already be expending additional effort in order to attain a level of performance effectiveness equivalent to that of low anxious individuals. Eysenck and Calvo (1992) note that while ego threat instructions may be utilised as a motivational factor, it is important to note that they additionally increase
worry. Thus, while motivation is supposed to enhance performance by the increased application of effort, worry is proposed to decrease performance by occupying capacity within the working memory system.

Prediction 1.5 states that performance on a central task will be adversely affected by an additional load to a greater extent in high anxious than in low anxious individuals. The available pool of resources is proposed to be already reduced for high anxious individuals due to worry, thus these individuals are more susceptible compared with low anxious individuals to increases in load. Regarding the ‘additional load’, it is not explicitly stated if this pertains to a memory or to a processing load. Consequently, this prediction may be assayed by examining the impact of (a) an increase in the number of to-be-recalled items; and (b) the transition from fixed to running tasks across the same number of to-be-recalled items, for the latter – but not the former – is proposed to additionally invoke processing demands. It is expected that elevated levels of anxiety will result in disproportionately poorer performance on sequences with a greater number of to-be-recalled items, and also on the running compared to the fixed tasks.

Prediction 2.2 states that anxiety reduces transient storage capacity, and Eysenck and Calvo (1992) explicitly state that anxiety should impair performance on the digit span task. Anxiety, in this instance, refers to state anxiety, moreover it is specifically cognitive anxiety, as worry is presumed to consume capacity in the PL due to its verbal nature.

Prediction 2.3 states that anxiety has powerful adverse effects on tasks with high storage and processing demands. Compared to low anxious individuals, high anxious individuals have a reduced pool of resources to devote to task performance due to worry. Thus, if a task makes low demands on resources, the available pool of resources is able to successfully cope. If, however, a task makes high demands on resources that outstrip the available pool, then performance is expected to be impaired. Thus, performance on the running tasks is expected to be more adversely affected by elevated levels of anxiety than would be performance on the fixed tasks.

Prediction 2.4 states that anxiety does not generally impair performance on tasks that do not involve the CE and PL. This is because it is only these latter systems that are
presumed to be affected by worry. Thus, anxiety would not be expected to impair performance on the fixed spatial task, which purportedly engages only the VSSP.

For the above predictions, the PET draws the distinction between effectiveness and efficiency, suggesting that high anxious individuals may expend additional effort to counter the deleterious effects of anxiety, and that this may be reflected in lower processing efficiency (Eysenck & Calvo, 1992). In the present study, memory span scores are regarded as measures of effectiveness, while processing times are considered to be indices of processing efficiency.

Altogether, the present study endeavours to expand the scope of the previous experiment via the inclusion of a cognitive mood induction condition, and measures that capture a greater range of anxiety symptoms. This expansion permitted a more comprehensive evaluation of the theories explicating the anxiety and working memory relationship, especially the PET.

5.5 Method

5.5.1 Design

The present study employed a mixed design with the three between-subjects factors of Trait Anxiety Group (Low, High), Music Mood Induction (Neutral, Anxious), Cognitive Mood Induction (No Ego Threat, Ego Threat); and the two within-subjects factors of Task Modality (Spatial, Verbal), and Task Status (Fixed, Running).

5.5.2 Participants

Participants were 64 first-year undergraduate students enrolled in an introductory psychology course selected in the same manner as reported in the previous chapter. Participants were aged between 17 and 43 years ($M = 18.75, SD = 3.64$) and included 15 males. All were fluent in English, and had normal or corrected-to-normal vision and hearing.
5.5.3 Mood induction procedures

Music mood induction. The Neutral and Anxious Music Mood Induction conditions were identical to those described in the previous chapter.

Cognitive mood induction. In the No Ego Threat Cognitive Mood Induction condition, participants were informed that the tasks were measures of working memory, that some trials would be more difficult than others, and that they should try their best to complete all trials. In the Ego Threat Cognitive Mood Induction condition, participants were informed that the tasks were a measure of intelligence, and that their performance would be compared to that of other participants.

5.5.4 Mood measures
Trait mood levels were measured using the DASS Depression and Anxiety scales, the STICSA-Trait Cognitive and Somatic scales, and the PSWQ. State mood levels were measured using the POMS Anxiety and Depression ratings, the STICSA-State Cognitive and Somatic scales, and the CIQ (task-relevant thoughts).

5.5.5 Apparatus
This was identical to that utilised in the previous study.

5.5.6 Working memory tasks
The four working memory tasks employed in this study were identical to those outlined in the previous chapter.

5.5.7 General procedure
All participants were tested individually. After reading an information sheet and completing a consent form pertaining to participation in the experiment, participants completed the DASS-21 (trait), PSWQ, and the STICSA Trait scales. This was followed by the presentation of written instructions outlining the first memory task and the practice session for the task. Participants then completed the POMS Anxiety and Depression scales, along with the STICSA State Somatic and Cognitive scales (Pre Mood Induction Phase). The cognitive mood induction and the seven-minute music
mood induction were then administered, followed by the completion of the first memory task. The three remaining working memory tasks followed, each preceded by a two-minute music mood induction top-up and the reiteration of the cognitive mood induction instructions. Upon completion of all four working memory tasks, participants concluded with the POMS, the STICSA State, and the CIQ (Post Experiment Phase). The order of presentation of the working memory tasks was counterbalanced across participants. Participants were then thanked for their participation and fully debriefed.

Assignment of participants into the various mood induction conditions was as follows: Within each Trait Anxiety Group, half were allocated to the Neutral Mood Induction and half to the Anxious Mood Induction. Within each of these, half were allocated to the No Ego Threat Cognitive Mood Induction and half to the Ego Threat Cognitive Mood Induction (i.e. n = 8 for each of the between-subjects cells in the design).

5.6 Results

5.6.1 Overview of analyses

Two sets of analyses were performed, with the first evaluating participants’ trait mood levels and also the impact of the mood induction procedures. The second set of analyses evaluated the impact of mood on working memory task performance. This was examined using both the memory span scores and reaction times, with the latter parsed into preparatory and inter-item intervals. Within this, the state/trait anxiety distinction and the issue of comorbid depression were also explored. Where correlations are reported, the data were first screened for univariate outliers, with data points exceeding three standard deviations of the mean eliminated, and then screened for bivariate outliers, with any data points exceeding a Cook’s D of 1 eliminated from analyses (cf. Tabachnick & Fiddell, 1989).

5.6.2 Participant mood levels and efficacy of mood induction procedures

5.6.2.1 Participant characteristics at testing time. It was desired that the more enduring mood characteristics of participants did not differ according to their allocation to the different mood induction conditions. It was expected that the composition of participants into Low and High Trait Anxiety Groups would result in differences in the level of anxiety as measured by the DASS Anxiety, STICSA Trait
Somatic Anxiety, and STICSA Trait Cognitive Anxiety ratings. Furthermore, in light of the relationship between depression and anxiety, and worry and anxiety, it was possible that the two Trait Anxiety Groups may also differ on DASS Depression and PSWQ ratings. To evaluate these expectations, the trait measures were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) ANOVA. Prior to analyses, DASS scores were converted to full-scale equivalent scores in the manner outlined in the previous chapter. STICSA Trait Cognitive and Somatic Anxiety ratings were obtained by summing across the respective items, and PSWQ scores were obtained by summing across the items on the scale, noting reverse-scored items.

For each of these analyses, the single significant effect was the main effect of Trait Anxiety Group, with participants in the High Trait Anxiety Group endorsing higher ratings than their Low Trait Anxiety counterparts (see Table 5.1). Thus, Trait Anxiety Groups differed on all of the trait mood measures. Importantly, there was no systematic difference in trait mood ratings between participants allocated into the different mood induction conditions.

Table 5.1. F values, means (and standard deviations in parentheses) for the main effect of Trait Anxiety Group on trait mood measures.

<table>
<thead>
<tr>
<th>Measure</th>
<th>F value</th>
<th>Trait Anxiety Group Low</th>
<th>Trait Anxiety Group High</th>
</tr>
</thead>
<tbody>
<tr>
<td>DASS Anxiety</td>
<td>$F(1,56) = 198.59^a$</td>
<td>2.94 (2.44)</td>
<td>16.69 (4.84)</td>
</tr>
<tr>
<td>DASS Depression</td>
<td>$F(1,56) = 32.69^a$</td>
<td>4.69 (3.79)</td>
<td>15.50 (9.63)</td>
</tr>
<tr>
<td>PSWQ</td>
<td>$F(1,56) = 35.70^a$</td>
<td>37.38 (10.43)</td>
<td>55.38 (13.48)</td>
</tr>
<tr>
<td>STICSA Trait Somatic Anxiety</td>
<td>$F(1,56) = 65.94^a$</td>
<td>14.19 (2.32)</td>
<td>21.25 (4.13)</td>
</tr>
<tr>
<td>STICSA Trait Cognitive Anxiety</td>
<td>$F(1,56) = 55.78^a$</td>
<td>15.78 (2.99)</td>
<td>23.78 (5.22)</td>
</tr>
</tbody>
</table>

$^a$denotes $p < .001$

It was further desired that the participants in the different mood induction conditions did not differ according to state mood levels at the time they were allocated to these conditions. To evaluate this, the state measures in the Pre Mood Induction Phase
(POMS Anxiety, POMS Depression, STICSA State Somatic Anxiety, STICSA State Cognitive Anxiety) were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) ANOVA. The only significant effects were main effects of Trait Anxiety Group (see Table 5.2), with higher ratings endorsed by the High Trait Anxiety Group compared to the Low Trait Anxiety Group.

Table 5.2. F values and means (and standard deviations in parentheses) for the main effect of Trait Anxiety Group on state mood measures in the Pre Mood Induction Phase.

<table>
<thead>
<tr>
<th>Measure</th>
<th>F-value</th>
<th>Trait Anxiety Group</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>POMS Anxiety</td>
<td>$F(1,56) = 11.07^b$</td>
<td>8.27 (8.33)</td>
<td>17.50 (12.61)</td>
<td></td>
</tr>
<tr>
<td>POMS Depression</td>
<td>$F(1,56) = 11.04^b$</td>
<td>5.56 (8.13)</td>
<td>13.74 (11.45)</td>
<td></td>
</tr>
<tr>
<td>STICSA State Somatic Anxiety</td>
<td>$F(1,56) = 24.67^a$</td>
<td>12.91 (2.01)</td>
<td>17.44 (4.54)</td>
<td></td>
</tr>
<tr>
<td>STICSA State Cognitive Anxiety</td>
<td>$F(1,56) = 27.20^a$</td>
<td>12.41 (2.50)</td>
<td>18.34 (5.84)</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ denotes $p < .001$; $^b$ denotes $p < .01$

Overall, these analyses indicate that the High and Low Trait Anxiety Groups differed not only on several measures of trait and state anxiety, but also on worry, and trait and state depression ratings. Importantly, participants' mood ratings did not systematically differ according to their allocation to the different mood induction conditions.

5.6.2.2 Efficacy of mood induction procedures. To evaluate the efficacy of the mood induction procedures, the POMS Anxiety and Depression ratings, STICSA State Cognitive and Somatic ratings, and the CIQ rating were examined. As the first four ratings were measured both at the Pre Mood Induction and Post Mood Induction Phases, each of these ratings was subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) x 2 (Phase: Pre Mood Induction, Post Experiment) mixed-design ANOVA where the latter factor was a within-subjects variable and the rest, between-subjects variables. In contrast to the POMS and STICSA-State Anxiety measures, the
CIQ task-relevant thoughts was administered only in the Post Experiment Phase. Consequently, this rating was subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) ANOVA. For all sets of analyses, where independent samples t tests were utilized to decompose significant interaction effects, in instances where violations of Levene’s test for equality of variances occurred, corrected values with equal variances not assumed were reported. This correction was applied in all subsequent analyses where it was pertinent.

For all of these ratings, there was a significant main effect of Trait Anxiety Group (see Table 5.3) such that the High Trait Anxiety Group endorsed higher ratings than the Low Trait Anxiety Group. Additional significant results pertaining to each of the measures will now be discussed.

Table 5.3. F values and means (and standard deviations in parentheses) for the main effect of Trait Anxiety Groups on state mood measures.

<table>
<thead>
<tr>
<th>Measure</th>
<th>F-value</th>
<th>Trait Anxiety Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>POMS Anxiety</td>
<td>F(1,56) = 15.03(^a)</td>
<td>8.44 (7.97)</td>
</tr>
<tr>
<td>POMS Depression</td>
<td>F(1,56) = 14.15(^b)</td>
<td>5.77 (7.59)</td>
</tr>
<tr>
<td>STICSA State Somatic Anxiety</td>
<td>F(1,56) = 27.53(^a)</td>
<td>13.75 (2.60)</td>
</tr>
<tr>
<td>STICSA State Cognitive Anxiety</td>
<td>F(1,56) = 41.40(^a)</td>
<td>12.73 (2.46)</td>
</tr>
<tr>
<td>CIQ task relevant</td>
<td>F(1,56) = 16.34(^a)</td>
<td>25.56 (4.68)</td>
</tr>
</tbody>
</table>

\(^a\) denotes p < .001; \(^b\) denotes p < .01

**POMS Anxiety ratings.** Interestingly, in contrast to the previous chapter, no Phase x Music Mood Induction effects were observed for the POMS Anxiety ratings.

**POMS Depression ratings.** There was a significant main effect of Phase, \(F(1,56) = 4.25, p < .05\), with higher POMS Depression ratings endorsed in the Post Experiment Phase (\(M = 11.70, SD = 13.84\)) than in the Pre Mood Induction Phase (\(M = 9.65, SD = 10.68\)). There was also a significant interaction effect involving Trait Anxiety...
Group and Cognitive Mood Induction, $F(1,56) = 4.28$, $p < .05$ (see Figure 5.1). Here, POMS Depression ratings for Low and High Trait Anxiety Groups did not differ under the No Ego Threat Cognitive Mood Induction condition, $t(30) = 1.79$, n.s. However, the experience of the Ego Threat Cognitive Mood Induction condition elicited significantly higher POMS Depression ratings for the High Trait Anxiety Group than for the Low Trait Anxiety Group, $t(24.38) = 3.23$, $p < .01$.

Figure 5.1. Means (and standard errors) of POMS Depression ratings for each Trait Anxiety Group x Cognitive Mood Induction condition.

**STICSA State Somatic Anxiety ratings.** There was a significant main effect of Phase, $F(1,56) = 11.86$, $p < .01$. Higher STICSA Somatic Anxiety ratings were endorsed in the Post Experiment Phase ($M = 17.19$, $SD = 5.44$), than in the Pre Mood Induction Phase ($M = 15.17$, $SD = 4.16$). No other effects were significant.

**STICSA State Cognitive Anxiety ratings.** The effect of Phase yielded $F(1,56) = 3.99$, $p = .051$, indicating a trend for the endorsement of higher STICSA Cognitive Anxiety ratings at the Post Experiment Phase ($M = 16.40$, $SD = 5.40$) than at the Pre Mood Induction Phase ($M = 15.38$, $SD = 5.37$). The effect of Cognitive Mood Induction
yielded $F(1,56) = 3.80, p = .056$, indicating a trend for higher ratings in the Ego Threat condition ($M = 16.84, SD = 6.07$) than in the No Ego Threat condition ($M = 14.93, SD = 3.46$). No other effects approached significance.

**CIQ Task-relevant ratings.** There was a significant main effect of Cognitive Mood Induction, $F(1,56) = 5.48, p < .05$, such that higher ratings were endorsed in the Ego Threat Cognitive Mood Induction condition, $M = 29.78, SD = 6.33$, than in the No Ego Threat Cognitive Mood Induction condition, $M = 26.69, SD = 5.28$. No other effects were significant.

Two patterns are evident from these analyses. First, it appears that participants’ more enduring (i.e. trait) mood was strongly related to state mood. Second, it appears that the mood induction conditions are characterized by a mixed degree of efficacy. Regarding the Music Mood Induction, this did not appear to appreciably alter mood levels, as measured by the POMS Anxiety and Depression ratings, as well as the STICSA-State Somatic Anxiety ratings. However, all participants indicated they were feeling more anxious in the Post Experiment Phase than in the Pre Mood Induction Phase. The Cognitive Mood Induction condition appears to have invoked changes in participants’ mood levels, with participants in the Ego Threat condition endorsing significantly higher CIQ task-relevant thoughts than their No Ego Threat condition counterparts. There was also a trend for the former to endorse higher STICSA-State Cognitive Anxiety ratings, however this was not modified by Phase. An unexpected finding was that POMS Depression ratings were affected by the interactive effects of Trait Anxiety Group and Cognitive Mood Induction condition, which is surprising in light of an absence of such an effect on the POMS Anxiety ratings.

The mixed results of the mood induction procedures pose difficulties for an analysis of the effects of anxiety on working memory performance. On the one hand, it may seem futile to investigate the relationship between anxiety and working memory by comparing groups for whom mood levels did not appreciably vary as a function of the mood induction conditions. A more logical approach would therefore be to divide participants into those whose anxiety ratings increased, and decreased, as a result of the anxious and neutral mood induction procedures (respectively), and use this division as a basis for evaluating the hypotheses of the current study.
On the other hand, it would be remiss to conclude that neither of the mood induction procedures appreciably altered anxiety ratings as the mood measures were not administered immediately post mood induction. In the previous chapter (see Figure 4.1), anxiety ratings were elevated for participants in the anxious mood induction condition and lowered for those in the neutral mood induction condition when these measures were obtained immediately following the initial mood induction procedure, with this difference tapering off in the Post Experiment Phase. It is likely that a similar pattern was evident under the present mood induction conditions, however the necessity to alter the administration of the measures (i.e. eliminating the administration of mood measures in the Post Mood Induction Phase) to preserve the integrity of the cognitive mood induction procedure is likely to have obfuscated any such effects. Furthermore, that participants receiving Ego Threat instructions endorsed a significantly greater number of CIQ task-relevant thoughts relative to their No Ego Threat counterparts suggests that the Cognitive Mood Induction procedure was effective.

Consequently, both methods of allocation (i.e. based on initial allocation into mood induction conditions, and based on changes in anxiety ratings) will be employed. Results pertaining to the original allocation of participants into groups are presented in the next section, while results pertaining to the allocation of participants into groups based on changes in anxiety ratings are discussed later as part of the subsidiary analyses.

5.6.3 Working memory tasks

5.6.3.1 Memory span scores. Memory span scores for the four tasks were calculated in the same manner as in the previous chapter. Two outliers were removed from analyses – one was from the Running Spatial Task, and the other from the Running Verbal Task. In order to examine the effect of anxiety on memory span, the memory span scores were subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) x 2 (Task Modality: Spatial, Verbal) x 2 (Task Status: Fixed, Running) mixed-design ANOVA. The within-subjects variables were Task Modality and Task Status.
The ANOVA revealed a main effect of Task Status, $F(1,54) = 1178.07$, $p < .001$, with higher memory span scores evident on the Fixed tasks, $M = 5.07$, $SD = .59$, than on the Running tasks, $M = 3.17$, $SD = .51$. Also evident was a main effect of Cognitive Mood Induction, $F(1,54) = 11.17$, $p < .01$, with higher memory span scores under Ego Threat instruction, $M = 4.31$, $SD = .49$, than under No Ego Threat instruction, $M = 3.93$, $SD = .44$. There was also a Task Status x Cognitive Mood Induction interaction, $F(1,54) = 10.32$, $p < .01$ (see Figure 5.2). No significant difference in memory span scores between the two Cognitive Mood Induction conditions on Running tasks was evident, $t(60) = 1.62$, n.s. For Fixed tasks, however, the Ego Threat condition elicited significantly higher memory span scores than did the No Ego Threat condition, $t(60) = 4.26$, $p < .001$.

![Figure 5.2. Means (and standard errors) of memory span scores for each Cognitive Mood Induction x Task Status condition.](image-url)
A significant Task Modality x Task Status interaction was also evident, $F(1,54) = 8.05, p < .01$ (see Figure 5.3). Further analysis of this interaction revealed that memory span scores for the Fixed Spatial and Fixed Verbal tasks did not differ, $t(61) = .58$, n.s. However, lower memory span scores were observed on the Running Verbal than on the Running Spatial task, $t(61) = 3.17, p < .01$. No other effects were significant.

![Figure 5.3](image)

Figure 5.3. Means (and standard errors) of memory span scores for each Task Modality x Task Status condition.

**5.6.3.2 Reaction time analyses.** As in the previous chapter, only those sequence lengths for which almost all participants had successfully attempted at least one trial were considered. For the Fixed tasks, these were sequence lengths of 3 and 4; sequence lengths 2 and 3 were chosen for Running tasks. The calculation of the reaction times (i.e. parsing into preparatory and inter-item interval reaction times, the use of medians, and the criteria determining the removal of outliers) was identical to that outlined in the previous chapter. No more than three data points per sequence length were omitted as outliers.
Three sets of reaction time analyses were conducted consistent with those reported in Chapter 4. The first compared performance on the one sequence length (Sequence Length 3) across all four working memory tasks, and permitted a comparison of the impact of anxiety in conjunction with the Task Status and Task Modality variables on reaction times (parallel reaction time analyses). The second set of analyses compared performance on two sequence lengths (Sequence Lengths 3 and 4) on Fixed tasks only (fixed reaction time analyses), while the third set compared performance on two sequence lengths (Sequence Lengths 2 and 3) on Running tasks only (running reaction time analyses). These latter two sets of analyses permitted a comparison of the impact that increasing sequence length (which may be argued to reflect increasing load) has on the performance of tasks that make heavy demands on the CE (i.e. the Running tasks), and tasks that make lesser demands on the CE (i.e. the Fixed tasks). For each of these analyses, both the preparatory and inter-item intervals were considered.

Parallel reaction time analyses. Preparatory and inter-item interval reaction times for Sequence Length 3 were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) x 2 (Task Modality: Spatial, Verbal) x 2 (Task Status: Fixed, Running) mixed-design ANOVA. The latter two variables were within-subjects variables.

Both sets of analyses revealed main effects of Task Modality such that longer reaction times were observed for Verbal than for Spatial tasks (see Table 5.4). Additional significant effects on the preparatory interval analyses are discussed below. No other effects were significant for the inter-item interval analyses.

For the preparatory interval reaction time analysis, there was also a significant main effect of Task Status, $F(1,49) = 44.87$, $p < .001$, with longer intervals evident on Running tasks ($M = 1416.46$, $SD = 64.07$) than on Fixed tasks ($M = 848.18$, $SD = 245.46$). Also evident was a significant Task Modality x Task Status interaction, $F(1,49) = 18.40$, $p < .001$ (see Figure 5.4). The nature of this interaction was as for the first study, that is, while longer reaction times were observed for the Verbal than for the Spatial tasks, this difference was more pronounced for the Running, $t(56) = 7.06$, $p < .001$, than for the Fixed tasks, $t(56) = 9.45$, $p < .001$. 
Table 5.4. F-values and means (and standard deviations in parentheses) for the main effect of Task Modality for each reaction time interval for the parallel reaction time analyses.

<table>
<thead>
<tr>
<th>Interval</th>
<th>F-value</th>
<th>Task Modality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spatial</td>
</tr>
<tr>
<td>Preparatory</td>
<td>$F(1,49) = 73.86^a$</td>
<td>735.55 (236.74)</td>
</tr>
<tr>
<td>Inter-item</td>
<td>$F(1,49) = 26.07^a$</td>
<td>602.95 (141.17)</td>
</tr>
</tbody>
</table>

$^a$ denotes $p < .001$

Figure 5.4. Means (and standard errors) of preparatory interval reaction times for each Task Modality x Task Status condition for the parallel reaction time analyses.
Also evident in the preparatory interval reaction time analyses was a Task Status x Cognitive Mood Induction interaction, $F(1,49) = 5.43, p < .05$. From Figure 5.5, it is evident that for participants in the No Ego Threat condition, longer reaction times were evident on the Running than on the Fixed tasks, $t(27) = 4.51, p < .001$. The same pattern was also apparent for those in the Ego Threat condition, $t(28) = 5.46, p < .001$, however it appears that this difference is more pronounced than that observed for their No Ego Threat counterparts. Reaction times for the Fixed and Running tasks considered separately did not differ as a function of Cognitive Mood induction condition ($t$s < 1.93, n.s.).

![Figure 5.5](image_url)

**Figure 5.5.** Means (and standard errors) of preparatory interval reaction times for each Cognitive Mood Induction x Task Status condition for the parallel reaction time analyses.

*Fixed reaction time analyses.* Preparatory and inter-item interval reaction times were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) x 2 (Task
Modality: Spatial, Verbal) x 2 (Sequence Length: 3, 4) mixed-design ANOVA. The latter two variables were within-subjects variables. For both sets of analyses, longer reaction times were evident for Verbal than for Spatial tasks (refer to Table 5.5). Additional significant effects involving preparatory intervals are discussed below. No other effects were significant for the inter-item interval reaction time analyses.

Table 5.5. F values, means (and standard deviations in parentheses) for the main effect of Task Modality for each reaction time interval for the fixed reaction time analyses.

<table>
<thead>
<tr>
<th>Interval</th>
<th>F-value</th>
<th>Task Modality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spatial</td>
</tr>
<tr>
<td>Preparatory</td>
<td>$F(1,54) = 92.10^a$</td>
<td>646.82 (255.27)</td>
</tr>
<tr>
<td>Inter-item</td>
<td>$F(1,55) = 29.86^a$</td>
<td>619.67 (160.23)</td>
</tr>
</tbody>
</table>

$^a$ denotes ps <.001

For the preparatory interval reaction times, there was also a main effect of Music Mood Induction, $F(1,54) = 4.88$, $p < .05$, reflecting longer reaction times under the Neutral, $M = 902.89$, $SD = 222.14$, than Anxious Music Mood Induction condition, $M = 788.55$, $SD = 203.30$. The Trait Anxiety Group x Music Mood Induction x Cognitive Mood Induction x Sequence Length interaction yielded $F(1,54) = 3.99$, $p = .051$. In decomposing this interaction using simple interactions, the only significant interaction was isolated to the lower Sequence Length (i.e. 3), and to the Neutral Music Mood Induction condition only. Here, the preparatory interval reaction times of participants in the Low Trait Anxiety Group were not differentially affected by the Cognitive Mood Induction procedure, $t(14) = 1.49$, n.s. In contrast, reaction times for High Trait Anxiety participants were significantly longer under No Ego Threat Cognitive Mood Induction than under Ego Threat Mood Induction, $t(14) = 2.87$, $p < .05$. This component of the four-way relationship is presented in Figure 5.6.
Figure 5.6. Means (and standard errors) of preparatory interval reaction times for each Trait Anxiety Group x Cognitive Mood Induction condition, under Sequence Length 3 and Neutral Music Mood Induction, for the fixed reaction time analyses.

There was also a significant Trait Anxiety Group x Music Mood induction x Sequence Length x Task Modality interaction effect, $F(1,54) = 4.57, p < .05$. This interaction was decomposed into four two-way ANOVAs that examined each Trait Anxiety Group x Music Mood Induction interaction under each condition of the Sequence Length x Task Modality factors. The Trait Anxiety Group x Music Mood Induction interaction was significant only for the Fixed Spatial task of Sequence Length 4, $F(1,58) = 5.73, p < .05$.

Low Trait Anxiety participants’ preparatory intervals were not unduly affected by the Music Mood Induction, $t(30) = .79$, n.s. However, High Trait Anxiety participants were significantly faster under Anxious than under Neutral Music Mood Induction, $t(28) = 2.70, p < .05$. Figure 5.7 illustrates this relationship.
Figure 5.7. Means (and standard errors) of preparatory interval reaction times for each Trait Anxiety Group x Music Mood Induction condition for the Fixed Spatial task of Sequence Length 4, for the fixed reaction time analyses.

For both the Trait Anxiety Group x Music Mood Induction x Cognitive Mood Induction x Sequence Length and Trait Anxiety Group x Music Mood Induction x Sequence Length x Task Modality interaction effects, it was sought to examine the effects of depression by including Trait Depression as a factor in analyses (cf. Miller & Chapman, 2001). Unfortunately, this resulted in missing cells and the presence of only one data point in one cell (respectively). Thus, blocking could not be adopted to examine the effects of depression in this instance, and analysis of covariance (ANCOVA) incorporating DASS Depression ratings as a covariate was utilized instead. This revealed that the DASS Depression ratings did not account for any variance in performance, $F(1,53) = .80$, n.s., moreover that the interactions summarized above were not altered by the inclusion of the DASS Depression ratings as a covariate.
Thus far, the effects reported in the analyses of reaction times for the Fixed tasks do not support the predictions of the PET – the significant effects involving mood discussed above actually implicated the Music Mood Induction rather than the Cognitive Mood Induction, and latencies were sometimes shorter for conditions expected to induce higher levels of anxiety.

Running reaction time analyses. Preparatory and inter-item interval reaction times were each subjected to a 2 (Task Modality: Spatial, Verbal) x 2 (Trait Anxiety Group: Low, High) x 2 (Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) x 2 (Sequence Length: 2, 3) mixed-design ANOVA, where the latter two were within-subjects variables.

For both the preparatory and inter-item interval reaction times, there were significant main effects of Task Modality and Sequence Length (refer to Tables 5.6 and 5.7). For the Task Modality effects, longer reaction times were evident on Verbal tasks relative to Spatial tasks. For the Sequence Length effects, longer reaction times were observed on the higher sequence length for the preparatory interval reaction times, but unexpectedly, the converse was true for the inter-item interval reaction times.

Table 5.6. F values, means (and standard deviations in parentheses) for the main effect of Task Modality for each reaction time interval for the running reaction time analyses.

<table>
<thead>
<tr>
<th>Interval</th>
<th>F-value</th>
<th>Task Modality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spatial</td>
</tr>
<tr>
<td>Preparatory</td>
<td>F(1,48) = 55.79a</td>
<td>822.25 (263.51)</td>
</tr>
<tr>
<td>Inter-item</td>
<td>F(1,49) = 16.94a</td>
<td>637.67 (169.48)</td>
</tr>
</tbody>
</table>

*a denotes ps < .001
Table 5.7. F values, means (and standard deviations in parentheses) for the main effect of Sequence Length for each reaction time interval for the running reaction time analyses.

<table>
<thead>
<tr>
<th>Interval</th>
<th>F-value</th>
<th>Sequence Length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Preparatory</td>
<td>$F(1,48) = 22.55^a$</td>
<td>983.37 (318.06)</td>
</tr>
<tr>
<td>Inter-item</td>
<td>$F(1,49) = 15.00^a$</td>
<td>738.52 (200.58)</td>
</tr>
</tbody>
</table>

*a denotes $p < .001$

The preparatory interval analysis also revealed a significant Task Modality x Sequence Length interaction, $F(1,48) = 23.28, p < .001$, as well as a significant Sequence Length x Cognitive Mood Induction interaction, $F(1,48) = 6.36, p < .05$. However, both of these interaction effects were modified by a higher-order interaction involving Task Modality, Sequence Length, and Cognitive Mood Induction, $F(1,48) = 4.68, p < .05$. When this three-way interaction was decomposed by testing the Sequence Length x Cognitive Mood Induction interactions separately for the Spatial and Verbal tasks, this two-way interaction was significant only for the latter, $F(1,48) = 5.85, p < .05$ (refer to Figure 5.8). For the Verbal task, participants in the Ego Threat condition exhibited shorter preparatory intervals than those in the No Ego Threat condition, $t(54) = 2.33, p < .05$, at Sequence Length 2. No significant difference was observed between Cognitive Mood Induction conditions at Sequence Length 3, $t(54) = 1.60$, n.s. Furthermore, for both Cognitive Mood Induction groups, an increase in Sequence Length led to significant increases in reaction times, $t_s > 2.67, ps < .05$, with this effect being more pronounced for participants in the Ego Threat condition.

In addition to the Task Modality and Sequence Length main effects observed in the inter-item interval analysis reported already, there was a significant main effect of Cognitive Mood Induction, $F(1,49) = 5.24, p < .05$. Shorter reaction times were observed under the Ego Threat condition ($M = 647.00, SD = 146.16$) than under the No Ego Threat condition ($M = 754.46, SD = 179.68$).
Figure 5.8. Means (and standard errors) of preparatory interval reaction times for each Cognitive Mood Induction x Sequence Length x Task Modality condition for the running reaction time analyses.
Also evident in the running reaction time analysis of the inter-item intervals was a significant Cognitive Mood Induction x Task Modality interaction effect, $F(1,49) = 5.07, p < .05$ (see Figure 5.9). Reaction times were equivalent between Cognitive Mood Induction groups on the Spatial tasks, $t(55) = .58$, n.s., however longer inter-item intervals were observed for those under No Ego Threat instruction than for those under Ego Threat Instruction on the Verbal tasks, $t(55) = 3.09, p < .01$.

Figure 5.9. Means (and standard errors) of inter-item interval reaction times for each Cognitive Mood Induction x Task Modality condition for the running reaction time analyses.

Additionally, the Cognitive Mood Induction x Sequence Length interaction yielded $F(1,49) = 3.72, p = .059$ (refer to Figure 5.10). This indicated a trend for equivalent inter-item intervals for Sequence Lengths 2 and 3 for the Ego Threat group, $t(28) = 1.71$, n.s., with a tendency for longer reaction times on Sequence Length 2 than Sequence Length 3 for the No Ego Threat group, $t(27) = 3.84, p < .01$. 
To summarise thus far, the reaction time analyses did not yield consistent Trait Anxiety Group x Mood Induction (either Music or Cognitive) interaction effects. A clear pattern that emerged was that the Cognitive Mood Induction was implicated in a variety of effects. Overall, this revealed that the experience of Ego Threat instruction was not always linked with impaired performance (see Figures 5.5, 5.6, 5.8, 5.9, 5.10), however it did adversely affect performance in some instances when comparing longer with shorter sequence lengths (see Figure 5.8), or in comparing differences between fixed and running versions of the same task (see Figure 5.5).

5.6.3.3 State anxiety and working memory performance. As with the analyses reported in Chapter 4, correlations between state anxiety ratings and indices of working memory performance were conducted as a more direct means of comparing the relationship between state anxiety and working memory performance (these correlations are reported in full in Appendix B, Table B.1). State anxiety ratings
comprised those ratings administered in the Post Experiment Phase. POMS Depression ratings were also included in order to examine the issue of comorbid depression in the event state anxiety ratings were linked with working memory performance, and also because the analysis of POMS Depression ratings indicated that they were influenced by the interactive effects of Trait Anxiety and Cognitive Mood Induction (Figure 5.1). Overall, there was no consistent support that state anxiety impaired working memory performance. The only evidence of a state anxiety-working memory performance link involved STICSA State Cognitive Anxiety ratings. Cognitive anxiety ratings were positively correlated with preparatory intervals on Sequence Length 4 of the Fixed Spatial task, suggesting that increasing levels of cognitive anxiety were linked with longer preparatory intervals. However, the cognitive anxiety ratings were also positively correlated with memory span scores on the same task, indicating that increasing levels of cognitive anxiety enhanced performance as measured by this index (although it is noted that Eysenck and Calvo, 1992, explicitly state that anxiety may not impair performance accuracy). No effects involving state cognitive anxiety were observed for the running tasks (which would be expected to be most affected according to the PET as these tasks are proposed to tap the CE).

As the PET also makes the explicit prediction that the effects of anxiety are more pronounced with increasing loads imposed by a task (Eysenck & Calvo, 1992), correlation analyses examining the relationship between state anxiety ratings and indices reflecting changes in working memory performance under increasing load were also performed. These indices were derived from comparisons between fixed and running task versions for each modality, and also from increasing sequence lengths on the same task. POMS Depression ratings were also examined to address the issue of comorbid depression. The correlations are reported in full in Appendix B (Table B.2). Overall, there was an absence of effects involving state anxiety ratings. The only exception was that CIQ task-relevant ratings were positively correlated with the difference preparatory intervals reflecting increasing sequence length on the Running Spatial task, indicating that a greater number of endorsed task-relevant thoughts was linked with greater impairment with increasing load. Unexpectedly, the number of task-relevant thoughts endorsed was not linked with performance on the Running Verbal task. This task would be expected to be affected to the greatest extent for it is
proposed to engage both the CE and the PL, which the PET identifies as the working memory systems affected most by anxiety (Eysenck & Calvo, 1992).

Additionally, although a Trait Anxiety x Cognitive Mood Induction interaction effect was revealed in the analysis of POMS Depression ratings, the correlational analyses indicated that these ratings were not linked with indices of working memory performance.

Altogether, the analysis of state anxiety ratings with indices of working memory performance revealed some effects of state anxiety, however these were not observed on tasks that were expected to be most sensitive to the effects of anxiety (i.e. the Running Verbal task).

5.6.4 Subsidiary analyses

This section is motivated by the absence of effects on state anxiety ratings of the mood induction procedures as assessed by changes from the Pre Mood Induction to the Post Experiment Phases. The subsidiary analyses involve the composition of participants into groups based on their response to the mood induction procedures – specifically, whether their scores increased or decreased on a particular mood measure across the two phases of the experiment. These analyses consider changes on all three anxiety measures (POMS Anxiety, STICSA State Somatic, STICSA State Cognitive) for which a change in ratings was not evident on the original analyses. The reclassification of participants according to whether their ratings increased or decreased over the course of the experiment constituted a Mood Change variable (Mood Change: Increased, Decreased) which was designed to replace the Cognitive and Music Mood Induction variables in the original analyses. The data were then reanalysed in a manner similar to the original analyses. It should be noted that for all of these analyses, the only other between-groups factor included was Trait Anxiety Group.

The overall finding from the subsidiary analyses (refer to Appendix C for a detailed summary of analyses) was that the effects summarized in the original analyses were not substantially altered, and that the PET was not convincingly supported. Specifically, there was no clear demonstration that elevated levels of anxiety resulted in lengthened reaction times (i.e. reflecting lower processing efficiency).
5.7 Discussion

The present study extended the study reported in the previous chapter via the inclusion of a cognitive mood induction procedure and measures of cognitive anxiety. The results of this more substantial investigation have bearing on the predictions of the PET regarding the relationship between anxiety and working memory. However, prior to a discussion of the key results, the findings pertaining to participants’ mood levels (both trait mood and state mood in response to the mood induction procedures) will be addressed.

5.7.1 Trait mood and efficacy of mood induction procedures

As in the previous study, high trait anxious individuals endorsed significantly higher levels of trait anxiety (both cognitive and somatic), depression, and a greater tendency to worry compared to their low trait anxious counterparts. Trait anxiety was also strongly related to the level of state anxiety experienced by the individual independent of the impact of the mood induction procedures.

It was predicted that ego threatening instructions would increase cognitive anxiety to a greater extent than would no ego threatening instructions. This was supported, with a greater number of CIQ task relevant thoughts elicited when participants were informed that their performance was being evaluated. There was also a trend towards elevated STICSA State Cognitive Anxiety ratings resulting from the ego threatening instructions. Contrary to the findings of Ree (2001), however, there was no evidence suggesting that the cognitive mood induction procedure resulted in elevations on somatic anxiety ratings. Another unexpected finding was that the POMS Depression ratings were affected by the interaction of trait anxiety and the cognitive mood induction (although POMS Depression ratings were not linked with indices of working memory performance, as indicated by the correlational analyses).

Another prediction regarding the mood induction procedures was that the anxious music would elevate somatic anxiety ratings consistent with that observed in the previous chapter. Unexpectedly, this was not supported in analyses of either the POMS Anxiety ratings, or the STICSA Somatic Anxiety ratings. This is unlikely to reflect a lack of responsiveness of the scales – the POMS was sensitive to changes in
mood in the previous chapter (refer to Figure 4.1) and the STICSA captured increased somatic anxiety ratings between the pre mood induction and post experiment phases. Rather, it is more plausible that the pattern of change in anxiety ratings was similar to that in Figure 4.1 of the previous study; however the exclusion of the administration of mood measures in the post mood induction phase meant that more transient elevations in mood immediately post induction could not be observed.

Altogether, the findings suggest that while the cognitive mood induction appeared to affect cognitive anxiety ratings, a similar demonstration was not provided for the somatic mood induction and somatic anxiety ratings. This latter observation is a likely reflection of the fact that the mood measures were not administered in the post mood induction phase. Given the uncertain efficacy of the mood induction procedures, the relationship between anxiety and working memory was evaluated using both the initial allocation of participants into the mood induction conditions (original analyses), and also using the division of participants according to whether their anxiety ratings increased or decreased on the anxiety ratings as a result of the mood induction procedures (subsidiary analyses). As the results of the subsidiary analyses did not enhance interpretations of the PET over that afforded by the original analyses, an evaluation of the PET will be predicated on the original analyses.

5.7.2 Anxiety and working memory: Evaluating the PET
The present experimental design permitted an evaluation of several predictions of the PET, as well as some of its assumptions. At the outset, it is recognized that the PET makes a distinction between performance effectiveness and processing efficiency (which is regarded to be equal to effectiveness divided by effort). Furthermore, anxiety-linked deficits are expected to be more pronounced on measures of efficiency than of effectiveness. One index of efficiency utilized by the present study and most of the existing anxiety-working memory literature (e.g. Calvo et al., 1994; Derakshan & Eysenck; 1998; C. MacLeod & Donnellan, 1993; Markham & Darke, 1991) is response latency. Using this index, there was only limited support for anxiety-linked impairments in performance (refer to analyses of inter-item interval reaction times for the running tasks). On a measure of effectiveness (memory span scores), ego threat instructions actually enhanced performance relative to no ego threat instructions.
The PET stipulates that worry, the cognitive component of state anxiety, is responsible for anxiety-linked impairments in performance, and also that state anxiety is determined by the interaction between trait anxiety and stress. Thus, it would be expected that anxiety-linked deficits in performance would involve a trait anxiety x cognitive mood induction interaction. Unexpectedly, this was not supported in the present research, where impairments in performance were largely attributable to the effects of the cognitive mood induction condition itself (refer to Figures 5.5 and 5.8). That impairments in performance were linked with the cognitive mood induction itself is important, for it was demonstrated that the ego threatening manipulation resulted in a greater number of worries. There was one effect involving a trait anxiety x cognitive mood induction interaction for the preparatory interval analyses for the fixed tasks, however this additionally involved the music mood induction condition. Furthermore, the pattern of results ran contrary to that predicted by the PET, with the ego threat instruction actually serving to lower reaction times for high trait anxious individuals relative to no ego threat instruction.

Worry is proposed to consume capacity in the CE and, to a lesser extent, the PL due to the verbal nature of worry. This means that tasks that do not tap these systems are not proposed to be affected (Predictions 2.2, 2.4). Fixed spatial task performance was generally not affected by either trait anxiety, mood induction, or state anxiety (it is noted that the correlational analyses yielded a significant relationship between STICSA State Cognitive Anxiety ratings and memory span scores on the fixed spatial task, although the pattern reflected performance being enhanced – rather than impaired – by increasing levels of anxiety; see Section 5.6.3.3). Eysenck and Calvo (1992) also state that performance on a digit span task (similar to the fixed verbal task employed in this study) should be impaired by elevated levels of state anxiety. This was not supported in the present study, as indicated by an absence of effects involving mood variables.

As worry predominantly affects the CE and, to a lesser extent, the PL, it is expected that the negative impact of anxiety would be most pronounced on tasks that make heavy demands on these systems (Prediction 2.3). This is because, relative to low anxious individuals, high anxious individuals have reduced capacity as worry drains the available pool of resources. If the demands of a task do not exceed the already restricted pool, then performance is not expected to be impaired. However, for tasks
that do make heavy demands on these resources, high anxious individuals are expected to be more adversely affected. In the present study, therefore, the task on which anxiety-linked impairments in performance are most likely to be manifest is the running verbal task. Additionally, due to the reduced availability of resources, high anxious individuals should have greater difficulties coping with an additional load (Prediction 1.5). In the present study, this would be reflected either in comparisons between fixed and running tasks at the same sequence length (the latter proposed to additionally invoke a processing load; see parallel reaction time analyses), or in comparisons between different sequence lengths of the same task with an increase in sequence length corresponding with an increase in load (see fixed, and also running, reaction time analyses).

Predictions 1.5 and 2.3 were partially supported by the results of this study. The parallel reaction time analyses indicated that the difference in preparatory intervals between fixed and running tasks was more pronounced for those under ego threat instructions (see Figure 5.5). The running reaction time analyses indicated that the difference in preparatory intervals with increasing sequence length was more pronounced for those under ego threat instructions, moreover this was significant for the running verbal but not the running spatial task (see Figure 5.8). It is noted, however, that the effects involving the same mood variable in the inter-item interval analyses suggested that ego threat instruction actually enhanced performance relative to no ego threat instruction (see Figures 5.9 and 5.10, note also the main effect of cognitive mood induction indicating shorter reaction times for those under ego threat instruction). Thus, the complete pattern of effects involving the cognitive mood manipulation could reflect a tradeoff in reaction times, with ego threat instructions encouraging longer preparatory intervals but shorter inter-item intervals. Importantly, the findings cited in support of Predictions 1.5 and 2.3 involve the cognitive mood induction procedure. The finding that the experience of cognitive stress alone is responsible for impaired performance contrasts with Eysenck and Calvo’s (1992) theory, which would expect trait anxiety x stress interactions to be implicated.

Although high anxious individuals have fewer available resources to devote to a task due to the presence of worry, they are purported to be able to compensate for this limitation by applying additional effort or recruiting additional strategies. One manner in
which effort may be enhanced is via motivational factors. These are proposed to benefit low anxious individuals to a greater extent than high anxious individuals (Prediction 1.4), as the latter are already increasing their level of effort in order to compensate for the negative effects of worry. It is noted that ego threat instruction serves to enhance motivation (although it is also acknowledged that it can also engender worry), and thus effects involving trait anxiety and cognitive mood induction are expected to be manifest. This was generally not supported by the findings (except for the preparatory interval analysis for the fixed reaction times, although the interaction observed involved the music mood induction factor also). Ego threat instruction did, however, enhance performance on memory span scores for the fixed tasks (see Figure 5.2), and had some beneficial effects on inter-item intervals for the running reaction time analyses (see Figures 5.9 and 5.10). This overall effect is not consistent with the predictions of the PET.

To summarise thus far, the findings of this study provided only limited support for the PET. It was observed, on several instances, that an additional load led to greater impairments in performance, however this was attributed to stress (i.e. the mood induction) rather than to the effects of state anxiety (i.e. trait anxiety x mood induction), which is what would be predicted by the PET. Indeed, state anxiety scores did not exhibit a strong relationship with working memory performance, as demonstrated by the correlational analyses. It was also observed in the previous chapter that the music mood induction condition had an impact on memory span scores, however this was not replicated in the present study; furthermore there was an effect involving this variable on reaction times in the fixed reaction time analyses that was not present in the previous study.

The relatively weak effects found in this study – particularly on the running verbal task, on which effects would be expected to be most pronounced – is striking in comparison to studies employing other tasks that also make demands on processing and storage. These tasks include reading span (Darke, 1988a; Sorg & Whitney, 1992), grammatical reasoning with memory load (Derakshan & Eysenck, 1994; C. MacLeod & Donnellan, 1993), analogical reasoning (Leon & Revelle, 1984; Tohill & Holyoak, 2000), and syllogistic reasoning (Darke, 1988b; Markham & Darke, 1991). These discrepant results beg the question of what demands are made by these other tasks that engender
anxiety-related impairments in performance and that are not captured by the running span tasks.

One explanation for the discrepancy is simply that the running verbal task does not make sufficient demands on storage and processing. If this explanation was probable, then ceiling effects would be evident on the task. However, more than a quarter of participants did not obtain at least one correct trial at a sequence length of 3, and more than half of participants did not obtain at least one correct trial at a sequence length of 4, suggesting that this is an unlikely explanation.

An alternative explanation of the absence of strong effects on the running verbal task is the nature of task demands. The types of tasks on which robust anxiety-linked impairments have been demonstrated are varied in form, and each is likely to engage different CE processes. It has recently been suggested that the process of updating may not actually be impaired by elevated levels of anxiety (Dutke & Stöber, 2001).

Adopting a task-based approach, Dutke and Stöber draw a distinction between sequential and coordinative demands which are inherent in the processing steps comprising complex working memory tasks. Tasks high in coordinative complexity make intensive processing and storage demands, and information in each processing step must be integrated with that from other processing steps in order to complete the task. The processing steps in tasks high in sequential complexity, however, are relatively independent and do not require integration between processing steps. Instead, they require the contents of working memory to be frequently updated.

In their study, Dutke and Stöber (2001) presented participants with a counting task wherein they were required to search through 40 lists, with each comprising 10 two-digit numbers, for one of three target numbers. Across the 40 lists, participants were required to count the occurrence of each target number and, where the target occurred for the third time, restart the counting process for that particular target number while retaining the counter for the other two target numbers. This task is high in coordinative complexity because of the necessity to manage three counters (one for each target number) across all 40 trials. Sequential demands were manipulated in this study by

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10 Dutke and Stöber’s (2001) finding was published after the completion of the studies reported in Chapters 4 and 5.
varying the frequency with which the target numbers appeared, with the high sequential demand condition involving a greater frequency of appearance of the target numbers, thereby prompting more frequent revisions of the contents of working memory. High test-anxious participants exhibited faster response times and greater accuracy under high sequential demand than did low test-anxious individuals. Dutke and Stöber proposed that elevated levels of anxiety do not serve to impair performance on tasks high in sequential complexity, for the requirements of the task alleviate the working memory system of one of its functions – that of updating and monitoring the contents of working memory. By task requirements providing external prompts to promote frequent updates of working memory, resources that would normally be allocated to these monitoring and updating functions are freed up and made available for task performance. As high anxious individuals already have reduced working memory capacity due to non task-focused thoughts (i.e. worry), the greater availability of resources means that task performance is less impaired.

Although Dutke and Stöber's (2001) study adopts a task-based approach to examining the anxiety-working memory relationship, their delineation of task demands in complex tasks is not incompatible with the working memory model. Rather, this study raises questions regarding the notion of the CE as a unitary system that can devote resources to different demands required by a task (Baddeley, 1986). According to the unitary viewpoint, if one function of the CE is impaired by anxiety, then all corresponding complex functions would be expected to be impaired, with the implication that performance on other types of CE tasks would also be impaired. Dutke and Stöber's findings clearly suggest that this is not the case, thereby questioning the unity of the CE. The unitary view of this working memory system has also been challenged in recent years within the working memory literature (Baddeley, 1996a; Bull & Scerif, 2001; Collette & Van der Linden, 2002; Lehto, 1996; Miyake et al., 2000), with current conceptualisations of this system arguing for its fractionation. Proponents of this view identify a set of fractionable processes including inhibition, updating, shifting, and the activation of long term memory. Miyake et al. additionally suggest that inhibition may underpin working memory performance, and this process has recently been implicated in the anxiety-working memory relationship (Hopko, Ashcraft, Gute, Ruggerio, & Lewis, 1998). These issues form the focus of the next chapter. To foreshadow, the next chapter presents a study examining whether the CE is a unitary system, or whether it
comprises fractionable CE processes, and investigates one particular CE process – inhibition – that may account for anxiety-linked impairments in performance.

5.7.3 Chapter summary

The findings of the present study provide useful contributions to our understanding of the relationship between anxiety and working memory, particularly in relation to the PET. The results of this study provide only limited support for this model, with anxiety-linked impairments observed only under situations of increasing task demands, but with this attributed to cognitive stress, rather than state cognitive anxiety (see Figures 5.2, 5.5 and 5.8). The experience of cognitive stress also served to enhance performance in some instances (see Figures 5.9 and 5.10). That the effects of (cognitive) stress alone can affect working memory performance without performance being linked with state anxiety levels (see Section 5.6.3.3) is perplexing and contradictory to the predictions of the PET which suggests that it is state anxiety that is responsible for impaired working memory performance, furthermore that state anxiety is determined interactively by trait anxiety and stress.

The absence of robust effects supporting the PET is in contrast to the existing body of literature (see Table 1.1). This discrepancy was attributed to the CE tasks utilized in the present study, specifically that they may engage a CE process that is not impaired by anxiety. This led to a consideration of (a) whether the CE is a unitary system or if its processes may be fractionated; (b) if the CE is not a unitary system, whether anxiety affects these fractionable CE processes equivalently; and (c) whether a CE process such as inhibition may underpin working memory performance. These issues form the focus of the next study.
CHAPTER 6: FRACTIONATING THE CENTRAL EXECUTIVE – A ROLE FOR INHIBITION IN THE ANXIETY-WORKING MEMORY RELATIONSHIP?

6.1 Introduction

The findings of the last chapter raised the possibility that the PET, in its current conceptualisation, may be insufficiently detailed in its delineation of the anxiety-working memory relationship. Greater specification of those CE processes affected by anxiety may be necessary in light of research into the fractionation of CE processes (Miyake et al., 2000) and the finding that some CE processes are not impaired by elevated levels of anxiety (Dutke & Stöber, 2001). Dutke and Stöber’s suggestion that the process of updating is not impaired by elevated levels of anxiety is consistent with the absence of anxiety-linked effects observed on the running memory tasks utilised in the previous chapter, which stands in contrast to robust anxiety-linked working memory performance impairments demonstrated within the literature (see Table 1.1 for a review). In view of the potential need for greater specification of the CE component of working memory within the PET, the present chapter focuses on identifying if there are fractionable processes and, if so, which CE processes are likely to be impaired by elevated levels of anxiety.

Recent research has increasingly focused on the multicomponential nature of the CE. The CE performs a variety of functions including planning, attentional control, updating, inhibition, coordination of the slave systems, switching between tasks or sets, and also the ability to temporarily activate long-term memory (Baddeley, 1996a; Baddeley & Logie, 1999; Lehto, 1996; Morris & Jones, 1990; Pennington, Bennetto, McAleer, & Roberts, 1996; Shallice & Burgess, 1998; Vandierendonck, 2000; Welsh & Pennington, 1988). In its original conceptualisation, the CE was viewed as a unitary system with a general pool of resources that could be allocated to perform whichever of these functions is required by the task at hand (Baddeley, 1986). Recently, however, it has been suggested that its processes may be fractionated (e.g. Baddeley, 1996a; Collette & Van der Linden, 2002; Miyake et al., 2000).\(^{11}\)

\(^{11}\) The discussion of the fractionation of the CE draws heavily on research into executive functions. It is noted that within the existing literature, there is a lack of clarity regarding terminology such that the terms ‘central executive’ and ‘executive functions’ are often used interchangeably (cf. Bull & Scerif, 2001; Collette & Van der Linden, 2002). These terms refer to
6.2 Fractionation of the CE

Support for fractionation of the CE comes from two primary sources. One concerns evidence of clinical dissociations between tasks purported to tap CE functioning and, related to this, the observation that different ‘executive profiles’ can be found in different developmental disorders. Another source is that low correlations exist between tasks deemed to tax CE resources, which is suggestive of distinct CE functions. The underlying premise of these lines of argument is that performance on various CE tasks should be highly correlated if the CE is indeed unitary in nature. Likewise, impaired performance observed on one task would be expected to be accompanied by impaired performance on another.

Dissociations in performance on various CE tasks provide a strong case against the unitary nature of the CE (e.g. Godefroy, Cabaret, Petit-Chenal, Pruvo, & Rosseaux, 1999; Van der Linden, Coyette, & Seron, 1992). For instance, some individuals perform poorly on the Wisconsin Card Sorting Task (WCST, a measure of flexibility and set-switching) but not the Tower of Hanoi task (TOH, a measure of planning), while others exhibit the opposite pattern (see Miyake et al., 2000, for a review). Similarly, children with autism, Tourette syndrome, and attention-deficit hyperactivity disorder (ADHD) have been found to exhibit different profiles of executive dysfunction (Ozonoff & Jensen, 1999; Ozonoff & Strayer, 1997). Testing these individuals on the WCST, TOH, and the Stroop task (a measure of inhibition), Ozonoff and Jensen found that children with autism were characterised by impaired flexibility and planning abilities, while children with Tourette syndrome and ADHD had impaired inhibitory processes (to reiterate, tasks such as the WCST, TOH, and Stroop are considered tasks of CE processing because they require the manipulation, rather than the mere retention, of information). If the CE was unitary in nature, then all CE functions should theoretically be affected equivalently, however the revelation of different profiles of executive dysfunction in Ozonoff and Jensen’s study suggests that the CE is not unitary in nature.

constructs that are closely related (Vandierendonck, 2000; also compare Baddeley, 1996a, who discusses central executive functions, and Miyake et al., 2000, who discuss executive functions). The aim of the present review is not to provide a definitive argument regarding which terminology is more appropriate; consequently, consistent with other researchers (Bull & Scerif, Collette & Van der Linden) these phrases will be used interchangeably.
Low correlations observed on various CE tasks also strengthen the argument for the fractionation of the CE. Lehto (1996), for instance, compared performance on executive function tasks such as the WCST, TOH, and the Goal Search Task, and found low correlations between indices of performance taken from these tasks. Factor analytic studies of performance on various CE tasks also support the notion of a fractionated CE – for example, Welsh, Pennington, and Groisser (1991) found performance on different CE tasks (e.g. WCST) loaded on separate factors. In a similar vein, Miyake et al. (2000), utilising ‘purer’ tasks designed to capture three executive functions (updating, shifting, inhibition), employed factor analytic techniques to demonstrate that these tasks loaded on separate factors corresponding with the functions they were deemed to measure.\(^\text{12}\)

The research reviewed thus far argues for the fractionation of the CE. However, the question arises as to which CE processes may be fractionable, and it is acknowledged that different researchers have identified different CE processes (refer to Table 6.1). The general consensus amongst the literature investigating fractionable CE processes is that the distinct processes include inhibition (although Baddeley, 1996a, argues for selective attention, which Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994, and Passolunghi, Cornoldi, & de Liberto, 1999, identify as an intimately linked, but not equivalent, process), updating, shifting (between tasks or mental sets), and possibly dual tasking. It is noted by Miyake et al. (2000) that this list is by no means exhaustive and provides only an initial foray into exploring fractionable CE processes. Performance on complex tasks is proposed to be determined by a mixture of these processes. For example, performance on the WCST requires flexibility, the ability to shift between sets, and also inhibition, while performance on the TOH task taps planning and also inhibition.

\(^{12}\) It is acknowledged that dissociations in performance may reflect task differences on non-executive processes in addition to putative separable executive processing (e.g. differing demands on language or perceptual processes).
Table 6.1. Summary of some fractionable executive processes identified in the working memory literature

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<td>Updating</td>
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<td>Shifting</td>
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<tr>
<td>Dual tasking</td>
<td>X</td>
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<td>Activating long term memory</td>
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<td>Coordinating slave systems</td>
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6.3 Fractionation of the CE – implications for anxiety and working memory

One implication of the fractionation of the CE for the anxiety-working memory link is that anxiety may not affect all CE functions equally. This is the viewpoint advocated when considering Dutke and Stöber’s (2001) study together with the discrepancy between the findings of the previous chapter and existing studies of the anxiety-working memory relationship. To refresh, the results of the previous chapter failed to demonstrate robust anxiety-linked impairments in working memory performance, which contrasts with the existing anxiety-working memory literature (see Table 1.1). Indeed, Dutke and Stöber’s findings suggest that the process of updating – which is the CE process engaged by the running memory tasks utilised in the previous chapter (see Morris & Jones, 1990) – is not impaired by elevated levels of anxiety. The question therefore arises as to which of the CE processes are impaired by elevated levels of anxiety. Of the remaining fractionable CE processes identified in Table 6.1, anxiety has been demonstrated to impair inhibition (Fox, 1994, Experiment 2; Hopko et al., 1998). It has additionally been suggested that anxiety-linked decrements in working memory performance are due to deficits in inhibitory processes (Hopko et al., 1998), however the veracity of this claim

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13 Miyake et al.’s (2000) study focused on demonstrating that inhibition, updating, and shifting were independent CE processes. However, while attempting to identify which of these processes determined dual task performance (the authors hypothesised shifting), it was revealed that none of the three processes appeared to be particularly influential. Consequently, dual tasking is included as a distinct CE process in this summary table.
hinges on the establishment of a tenable link between inhibition and working memory performance, and also between inhibition and anxiety. The explication of these relationships forms the focus of this chapter.

Despite the fractionation of CE processes, researchers acknowledge that it is difficult to rule out the possibility that the different processes may be underpinned by a common resource (Baddeley, 1996a; Bull & Scerif, 2001; Duncan, Johnson, Swales, & Freer, 1997; Lehto, 1996; Miyake et al., 2000). Miyake et al. found that while the three executive functions of inhibition, shifting and updating were separable, they shared some degree of commonality, and hypothesised that this unifying strand may be inhibition. For instance, shifting requires the inhibition of a current set/task in order to focus on an alternate set/task. Tasks that engage updating processes may involve inhibitory processes in that each additional element added to a series requires the inhibition of an item from the front of the currently maintained memory set (refer to Section 1.6.1 for further description of such tasks). Indeed, research into inhibitory processes suggests that they are integral in successful working memory performance (e.g. Hasher & Zacks, 1988; Passolunghi et al, 1999; Passolunghi & Siegel, 2001; Rosen & Engle, 1998; Whitney, Arnett, Driver, & Budd, 2001).

Miyake et al.’s (2000) identification of inhibition as underpinning other CE processes poses interesting questions for the anxiety-working memory relationship. If it is the case that inhibition is a common denominator in performance on complex working memory tasks that recruit various CE processes, and that anxiety affects inhibition, then we would expect anxiety-linked deficits in performance to be manifest on most – if not all – complex working memory tasks. Evidently, this contrasts with the results of the study reported in the previous chapter, and also with the findings of Dutke and Stöber (2001), thereby leading to one of two possibilities, either (a) anxiety does not affect inhibition and, consequently, does not affect updating, which partly draws on inhibitory processes; or (b) inhibition is not linked with the process of updating, thereby permitting a link between anxiety and impaired inhibitory processes, but not one between anxiety and updating. The present study therefore sought to distinguish between these alternatives. To foreshadow, the present study examines the effect of anxiety on the performance of a variety of working memory tasks, including one of the running span
tasks from the previous study, along with other working memory tasks that purportedly tap inhibitory processes.

The findings of the present study have clear implications for the PET and the anxiety-working memory relationship more generally. Presently, the PET identifies the CE as the working memory system most susceptible to elevated levels of anxiety (Eysenck & Calvo, 1992), and regards the CE to be a unified system. However, studies supporting the predictions of the PET employ a variety of working memory tasks that engage a variety of CE processes and it has been demonstrated that CE processes may be fractionated (Baddeley, 1996a; Miyake et al., 2000), furthermore that not all CE processes are impaired by anxiety (Dutke & Stöber, 2001). This study aims to provide clarification as to whether the current conceptualisation of the CE as a unified system is pertinent (as will be suggested if inhibition is shown to underpin performance on all of the working memory tasks employed in the present study), or whether a revision of the PET detailing greater specification of the CE component of working memory is warranted. For now, however, the following sections are devoted to establishing a link between inhibition and working memory, and between inhibition and anxiety.

6.4 Inhibition and working memory performance

Inhibition has been argued to play an integral role in working memory performance. This is because working memory is a fixed-capacity system, and the more that this system is unfettered by non-task-focused (i.e. task-irrelevant) thoughts, the more capacity there is available to devote to task-focused information (Linville, 1996; Richardson, 1996). In this regard, the role of inhibition is to (a) restrict access to working memory to only those representations that are pertinent to the task at hand; (b) suppress no-longer-relevant representations in working memory; and (c) override the manifestation of prepotent responses to permit the evaluation of alternative responses (Chiappe, Hasher, & Siegel, 2000; Hasher, Quig, & May, 1997; Hasher & Zacks, 1988; Zacks & Hasher, 1994).

Differences in the efficiency of inhibitory processes have been proposed to account for individual and developmental differences in working memory performance (Hasher & Zacks, 1988). Developmental research, for instance, suggests that older adults have poorer working memory spans compared with younger adults on a variety of tasks.
(Charness, 1987; Gick, Craik, & Morris, 1988; Lustig, May, & Hasher, 2001; May, Hasher, & Kane, 1999; West, 1999). Along with this, older adults also have less effective inhibitory processes, as demonstrated using various methodologies such as negative priming (e.g. Hasher, Stoltzfus, Zacks, & Rypma, 1991; Kane et al., 1994), garden-path sentences (e.g. Hamm & Hasher, 1992; Hartman & Hasher, 1991; Hasher et al., 1997), directed ignoring (Connelly, Hasher, & Zacks, 1991), and paired-associate learning (e.g. Lustig, Hasher, & Tonev, 2001). This suggests that for older adults, impaired working memory performance may reflect impaired inhibitory processes.

Research on individual differences also demonstrates that individuals with low working memory spans are characterised by less efficient inhibition mechanisms relative to their high span counterparts (Long & Prat, 2002; Rosen & Engle, 1998). Furthermore, studies of good and poor problem solvers (typically children with versus without reading and learning difficulties) suggest that the latter are hampered by an inability to inhibit irrelevant information (Barrouillet, Fayol, & Lathulière, 1997; Chiappe et al., 2000; Passolunghi et al., 1999; Passolunghi & Siegel, 2001). Importantly, the last two studies reveal that these differences reflect the inhibitory capacity of working memory, rather than problems in storage capacity, processing information, or differentiating between task-relevant and task-irrelevant information.

6.5 Anxiety and inhibition

Thus far, it has been demonstrated that inhibition is intimately linked with working memory. In arguing for an anxiety-working memory deficit that is mediated by inhibition, however, it is also necessary to demonstrate a link between anxiety and inhibition. Linville (1996) suggests that inhibitory processes may be impaired for stressed individuals, and this has been established using various methodologies such as Stroop, negative priming, and directed ignoring tasks.

6.5.1 Stroop tasks

Perhaps the most widely used measure of inhibition is the Stroop task (Stroop, 1935). In it, participants are presented with words printed in a colour, and required to name the colour aloud. The Stroop effect refers to the phenomenon whereby longer colour-naming latencies are evident when the words are printed in a colour that contrasts with
the word itself (e.g. the word ‘red’ printed in yellow, the word ‘blue’ printed in green) than when the to-be-colour-named stimuli are meaningless (e.g. control patches). The difference in colour-naming latencies between the control and conflicting word colour conditions is taken as a measure of the amount of interference experienced (C.M. MacLeod, 1991; Sugg & McDonald, 1994). The Stroop effect arises because reading is an automatic process, and where a word is printed in a dissimilar colour, the prepotent response of reading the word must be inhibited so as to name the colour (Long & Prat, 2002; Ray, 1979). The Stroop task is perhaps one of the earliest measures used to study anxiety-linked deficits in inhibition, and research has shown that elevated levels of stress impair performance on this task (Pallak, Pittman, Heller, & Munson, 1975).

The Stroop task was subsequently modified in the field of anxiety research, and evolved to the emotional Stroop task in an attempt to identify what types of stimuli particularly impair performance (J.M.G. Williams, Mathews, & C. MacLeod, 1996). Here, emotional words (e.g. ‘threat’, ‘danger’, ‘failure’) and neutral words are utilised in place of contrasting colour words and meaningless stimuli. Lengthened colour-naming latencies on emotional words, relative to neutral words, suggest impaired inhibitory processes for such words (J.M.G. Williams et al., 1996). The vast body of research utilising the emotional Stroop (e.g. Chen, Lewin, & Craske, 1996; Dalgleish, 1995; Hopko, McNeil, Gleason, & Rabalais, 2002; C. MacLeod & E.M. Rutherford, 1992; Mogg, Kentish, & Bradley, 1993; Mogg & Marden, 1990; Mogg, Mathews, Bird, & MacGregor-Morris, 1990; A. Richards & Millwood, 1989; A. Richards, L.C. Richards, & McGeeney, 2000) has yielded several findings. In the selective review that follows, only the findings relating to sub-clinically anxious individuals will be examined as this population forms the focus of the present research. For a comprehensive summary of the effects of clinical and subclinical anxiety on performance of the emotional Stroop task, refer to J.M.G. Williams et al. (1996).

Perhaps the most notable impression from the research on the emotional Stroop task in sub-clinically anxious individuals is that the outcomes appear inconsistent at first glance. Some studies report lengthened colour-naming latencies for threat words in high anxious individuals (e.g. Chen et al., 1996, Dalgleish, 1995; Mogg & Marden, 1990; Mogg et al., 1990; Richards & Millwood, 1989), while others note an absence of such effects (e.g. C. MacLeod & E.M. Rutherford, 1992; Martin, R.M. Williams, & D.M.
Clark, 1991). This contrasts with research employing clinically anxious individuals, on which effects of anxiety are almost always apparent (e.g. clinically anxious individuals typically exhibit lengthened colour-naming latencies for threat words; see J.M.G. Williams et al., 1996, for a review). To reconcile the discrepant findings between sub-clinically and clinically anxious individuals, J.M.G. Williams et al. suggested that sub-clinically anxious individuals differ from clinically anxious individuals in their ability to override a tendency to be distracted by threatening material. This argument is supported by research on colour-naming latencies for subliminal and supraliminal stimuli, suggesting a tendency for high anxiety individuals to respond to increasing stress by showing elevated latencies on subliminally-presented threat-related words, but reduced latencies when these words are presented supraliminally (C. MacLeod & E.M. Rutherford, 1992). That is, it appears that subclinically anxious individuals are able to override an automatic orienting response towards threatening information.

As in the anxiety-working memory relationship, questions remain as to whether it is state or trait anxiety that impairs Stroop performance. In a study by Mogg et al. (1990), high and low trait anxious individuals were required to colour-name neutral, general threat, and achievement threat words after experiencing a stressor. Trait anxiety slowed colour naming on threat words relative to non-threat words with no differentiation on naming latencies between the types of threat word. In contrast, the experience of a stressor resulted in lengthened naming latencies on achievement threat words specifically. Thus, trait anxiety and stress contributed independently to impaired performance on threat words. Together with the results of C. MacLeod and E.M. Rutherford (1992) discussed above, it appears that differing degrees of trait anxiety and stress can alter the pattern of Stroop responses. The Mogg et al. study also suggests that the nature of the stimuli employed is a critical determinant in whether an anxiety-related Stroop effect is manifest, with the effects of stress evident on achievement threat words, but with the effects of trait anxiety evident on general threat words. It is noted, however, that Mogg and Marden (1990) found no difference in colour-naming latencies between different types of threat words.

Altogether, the Stroop literature suggests a relationship – albeit a complex one – does exist between anxiety and inhibition. However, it is necessary to be aware of the
numerous variables (e.g. supraliminal vs. subliminal presentation, trait vs. state anxiety, nature of stimuli employed) that mediate this relationship.

### 6.5.2 Negative priming

One limitation of the Stroop effect is that it has been found to comprise two components – initial processing, marking attentional capture (similar to selective attention) and later-stage processing which captures inhibitory processing (Dalgleish, 1995; De Ruiter & Brosschot, 1994; Kindt & Brosschot, 1998b). This limitation led researchers to utilise negative priming as a ‘purer’ measure of inhibitory processes. Negative priming occurs when the response to a particular target on a given trial is slowed if processing of the same target was suppressed on the preceding trial (Fox, 1994; Kindt & Brosschot, 1998a; Tipper, 1985). It is not so much a task, but rather a methodology, and may be adapted to various existing tasks such as the Stroop task. In such an instance, a trial may involve colour-naming the word ‘blue’ in green ink. On the next trial, the word ‘red’ is printed in blue ink. On the first trial, the response ‘blue’ must be inhibited, but that very response is required on the second trial. Response latency on the second trial is a measure of inhibition because inhibiting the response ‘blue’ on the first trial persists on the next, thereby impairing naming the blue ink.

Research on the anxiety-inhibition link utilising negative priming is not as extensive as that employing the basic Stroop task. Of the few available studies, these verify an anxiety-inhibition link, however it appears that the state versus trait anxiety issue is relevant here too. For example, Fox (1994, Experiment 2) found high trait anxious individuals to have impaired inhibitory processes (as evidenced by a lack of negative priming), while Linville (1996) reported two studies using a modified Stroop paradigm in which increasing levels of stress resulted in a decreased ability to inhibit irrelevant information. It is noteworthy that the high anxious individuals in Fox’s study were impaired on non-threat stimuli, which suggests a general deficit in inhibitory processes rather than one that is specific to threatening information.

### 6.5.3 Directed ignoring task

More recently, researchers (Hopko et al., 1998; Sachse, 2000) have adopted the directed ignoring task to study inhibitory functions in anxious individuals. In the
modified format of the task, participants read aloud a paragraph while ignoring
distractors (printed in a font contrasting with the font of the passage) interspersed within
the paragraph. Longer reading times are viewed as reflecting poorer inhibitory
processes. In the different conditions of the standard task, the distractors are typically
grouped into control distractors (e.g. a string of Xs), words related to the passage, and
words unrelated to the passage (Connelly et al., 1991; Kipp, Pope, & Digby, 1998). The
directed ignoring paradigm has been used to investigate developmental differences in
inhibition, revealing less efficient inhibitory processes in older adults relative to younger
ones (e.g. Connelly et al., 1991) and also in children relative to adults (Kipp et al.,
1998).

Hopko et al. (1998) presented low, medium, and high trait mathematics-anxious
individuals with paragraphs that varied in content (mathematics versus non-
mathematics). They paired these paragraphs with three distractor types (control,
unrelated, and related). Control distractors were strings of Xs, unrelated distractors
were words that were neither relevant to paragraph content nor to mathematics, and
related distractors were mathematics words. Stress manipulations were not employed.
The results revealed no interaction of anxiety group and paragraph type on reading
times. However, there was an interaction of anxiety group and distractor type, such that
with increasing levels of anxiety, the discrepancy between reading times on the control
and word (unrelated and related) distractor types became more pronounced. No
differences were apparent between the unrelated and related distractor types, which
suggests a general rather than a specific deficit in inhibitory processes for anxious
individuals.

and low trait anxious individuals (i.e. not focusing on mathematics anxious individuals),
additionally noting that a confound in stimulus selection existed in Hopko et al.’s study.
Specifically, the related distractor types utilised in the study were mathematics words.
When these were utilised with non-mathematics paragraph types, these words were not
relevant to paragraph content but they were threat-related. However, when these were
paired with paragraphs with mathematics content, these related distractors were not
only relevant to paragraph content, but were also threat-related. Sachse noted the
necessity for a distractor type that was related to the paragraph but was not threatening
in content. Thus, Sachse presented high and low trait anxious individuals with paragraphs comprising four distractor types – control (letter strings), unrelated (related to neither paragraph nor to threat), related (related to paragraph but not threat), and threat (not related to paragraph). Unlike in Hopko et al.’s (1998) study, paragraph type was not manipulated, and Sachse also presented the directed ignoring task under stressful conditions. This study revealed longer reading times for high than for low trait anxious individuals, however this was apparent only for distractors that were related to paragraph content, and not for threat distractors nor for unrelated distractors.

Together, Hopko et al.’s (1998) and Sachse’s (2000) studies suggest that there is a deficit in inhibitory processes that is general rather than specific, which is consistent with Fox’s (1994) and Linville’s (1996) findings. That there is an absence of an effect of threatening stimuli is surprising in light of the studies employing the emotional Stroop which demonstrate impaired inhibitory processing for such stimuli (e.g. C. MacLeod & E.M. Rutherford, 1992; Mogg et al., 1991). However, these studies also differ in the nature of the anxiety (i.e. state vs. trait) examined. Both Hopko et al.’s and Sachse’s studies investigated trait anxiety (although all participants in the latter study underwent evaluative stress), while the studies by C. MacLeod and E.M. Rutherford and Mogg et al. investigated how stressful and non-stressful conditions may mitigate or potentiate trait anxiety effects. One aim of the present study is therefore to address the state-trait dichotomy within the inhibition literature.

6.6 Anxiety, inhibition and working memory – a tenable link?

The research reviewed thus far suggests that the anxiety-inhibition-working memory link is a tenable one. This has been the view advocated by Hopko et al. (1998), who argue for an integration of Hasher and Zack’s (1988) and Eysenck and Calvo’s (1992) theories, with performance being determined by the ability to keep non task-focused thoughts out of working memory. This integrated theoretical position provides a plausible account of the anxiety-working memory literature cited thus far. Indeed, this argument is not inconsistent with the findings from Chapter 5, where although ego threat instruction engendered significantly longer reaction times with increasing memory load, this change in reaction times did not correlate with the number of non task-focused thoughts experienced (see Section 5.6.3). Thus, the impact of ego threat on working memory may not be through increasing non task-focused thoughts, but rather
by reducing the capacity to inhibit these thoughts. Furthermore, some of the tasks on which anxiety-linked decrements in performance have been observed (see Table 1.1) are also tasks argued to tap inhibitory processes.

One such task, the reading span task (Daneman & Carpenter, 1980), has been utilised extensively in the study of inhibition and working memory in the elderly and the learning-disabled. In each trial of this task, participants are required to read aloud a set of sentences (typically beginning at two sentences and incrementing to six) and also remember the terminal word of each sentence. Participants then recall all of the terminal words presented in the set and answer a question based on one of the sentences (to verify that the sentence was processed). The task is terminated following failure to recall the terminal words (position-respecting) on each of the three trials at a given set size. Reading span scores are determined either by the largest set size at which two trials were successfully completed (Daneman & Carpenter, 1980; Sorg & Whitney, 1992), or by a weighted scoring system wherein later trials are given greater weighting in light of the greater difficulty expected from a larger set size (Darke, 1988a).

It has been argued that the format of the reading span task, wherein set sizes increment, encourages the build-up of proactive interference (Lustig et al., 2001; May et al., 1999). Specifically, words from preceding trials must be inhibited to focus only on the trial at hand, and while this is relatively easy on the initial trials (which are typically the smaller set sizes), the later trials become more difficult as correct responses must be differentiated from a greater pool of words from preceding trials. To investigate this, Lustig et al. and May et al. varied the format of the reading span task to manipulate the amount of interference present. Older and younger adults completed the standard format of the task, as well as a descending format whereby the largest set size was presented first, with the number of sentences presented decreasing over successive sets. The rationale underpinning this approach is that with the standard format, as larger set sizes (on which higher span scores are determined) are presented in the later trials, individuals with poorer inhibitory processes will inevitably exhibit lower span scores by virtue of failing these larger set sizes. By presenting the larger set sizes earlier, when there are fewer alternative words competing for response selection, individuals with poorer inhibitory processes should exhibit higher span scores on this descending format than on the standard ascending format. Indeed, Lustig et al. and
May et al. found that older adults performed better on the descending than on the ascending format of this task, whereas there was no difference for younger adults on the two formats. Altogether, these two experiments demonstrate that inhibition contributes heavily to successful reading span task performance.

Anxiety-linked deficits in working memory performance have also been observed on a range of problem-solving tasks, including deductive reasoning (Darke, 1988b) and analogical reasoning (Tohill & Holyoak, 2000). It is likely that inhibitory processes are crucial to successful performance on both of these tasks. Selecting the correct response for the problem presented involves examining the information for relevance to the problem presented, examining the potential solutions, and then inhibiting the incorrect responses (Passolunghi et al., 1999; Passolunghi & Siegel, 2001). The work of Passolunghi and colleagues has demonstrated that impoverished problem-solving ability is linked with deficits in inhibitory processes.

Another working memory task on which anxiety-linked deficits in performance has been demonstrated is the grammatical reasoning task (Derakshan & Eysenck, 1998; C. MacLeod & Donnellan, 1993). Here, participants are required to verify a statement describing the relationship between two letters X and Y (e.g. X is before Y, Y is not preceded by X) while simultaneously maintaining a memory load. The memory load may be high (a string of random digits) or low (a string of zeros). Unlike the reading span task, the role of inhibitory processes in this task is less well understood. Of the hypothesised CE processes investigated by researchers (Baddeley, 1996a; Bull & Scerif, 2001; Collette & Van der Linden, 2002; Miyake et al., 2000), it appears that the grammatical reasoning task taps the ability to shift between tasks. However, Miyake et al. argue that the ability to shift between tasks is likely to involve inhibiting an old set in order to switch to a different set. Consistent with this argument, they reported a moderate correlation between shifting and inhibition. Thus, it is not implausible that the grammatical reasoning task taps inhibition to some degree. An alternate account of the CE processes involved in the grammatical reasoning task is that it involves dual-tasking. While Miyake et al. (2000) suggest that the process of dual tasking is independent of inhibition, it must be noted that dual-tasking is conceptually similar to shifting, and the exact nature of differences between the two processes is unclear.
To conclude, inhibition appears to be linked with working memory performance. Research has identified inhibition to be integral to performance on the reading span task (Lustig et al., 2001; May et al., 1999), and it is also likely to play a role in other working memory tasks on which anxiety-linked impairments in performance have been demonstrated. Thus, the anxiety-inhibition-working memory performance link is a tenable one.

6.7 The present study

The present study was initially motivated by an absence of anxiety-linked impairments in performance in the previous two chapters. This, along with the literature reviewed in this chapter (which incorporated discussions of the fractionation of the CE and the role of inhibition in the anxiety-working memory relationship) questioned whether the current conceptualisation of the CE as a unitary system within the PET is adequate, or whether greater specification of distinct processes within the PET is necessary. Altogether, the evolution of the programme of research led to the identification of four specific aims:

1. To demonstrate that elevated levels of anxiety are linked with reduced working memory performance.
2. To demonstrate that elevated levels of anxiety are linked with deficits in inhibitory processes.
3. For 1 and 2, to further investigate whether any anxiety-linked effects are due to trait anxiety, state anxiety, or stress.
4. To determine, for any anxiety-linked impairments in working memory performance observed, if inhibition mediates these relationships.

Regarding the first aim, it has thus far been difficult to demonstrate that heightened levels of anxiety impair working memory performance, and it appears that the source of this is the utilisation of the running memory tasks. Research into the fractionation of CE processes has identified updating as a distinct CE process (e.g. Bull & Scerif, 2001; Collette & Van der Linden, 2002; Miyake et al., 2000), and it has been identified that the process of updating is not actually impaired by anxiety (Dutke & Stöber, 2001). Thus, it
is plausible that the absence of robust effects in the previous chapter is due to the running memory tasks employed. To verify that it is this limitation (and not other factors such as participant characteristics, mood induction manipulations, etc.) that accounts for the absence of robust effects, performance on one of the running span tasks will be compared to performance on other tasks that have demonstrated robust effects. Two such tasks are the reading span task (Darke, 1988a; Sorg & Whitney, 1992), and the grammatical reasoning task (Derakshan & Eysenck, 1998; C. MacLeod & Donnellan, 1993). If it is task limitations that have obscured the anxiety-working memory link thus far, then it is expected that heightened levels of anxiety will affect performance on the reading span and grammatical reasoning tasks, but not necessarily performance on the running span task. The running verbal task was selected for comparison with the reading span and grammatical reasoning tasks for it is the task that would most be expected under the PET to reveal anxiety-linked impairments in performance (as it taps the CE and PL).

The results pertaining to the reading span, grammatical reasoning, and running verbal span tasks also have implications for the conceptualisation of the CE for the PET and, more generally, the tripartite working memory model. Specifically, if the absence of robust effects in the previous study was due to the utilisation of updating tasks, and if anxiety-linked effects are demonstrated on the grammatical reasoning and reading span tasks in the present study, these findings would support fractionable CE processes.

In order to investigate the second aim, whether elevated levels of anxiety are linked with deficient inhibitory processes, the performance of high and low anxious individuals on the directed ignoring task (Hopko et al., 1998; Sachse, 2000) will be compared. While there is a larger body of research on the anxiety-inhibition link utilising the emotional Stroop, there are many factors (e.g. clinical versus subclinical anxiety, trait versus state anxiety, and subliminal versus supraliminal presentation of stimuli) that affect the manifestation of this effect. Consequently, the directed ignoring task was selected for the present study as existing studies using this task have demonstrated a consistent inhibitory deficit in relation to anxiety. This study also sought to extend the existing research regarding the types of stimuli that elicit deficient inhibitory processes. Extending Sachse’s methodology, four types of distractors were utilised – control
(strings of Xs), unrelated (words unrelated to paragraph content), related (words related to paragraph content), and threat (unrelated to paragraph content).

Three comparisons were of particular interest in the directed ignoring task: (a) control distractors (strings of Xs) versus word distractors (related, unrelated, and threat); (b) related distractors versus unrelated and threat distractors; and (c) unrelated distractors versus threat distractors. In the event that elevated levels of anxiety resulted in impaired inhibitory processing, the above three comparisons permitted an examination of whether the inhibition was specific to threat (unrelated versus threat distractors), the semantic relevance of the word (related versus unrelated and threat distractors), or whether the inhibitory deficit was a general one (control versus word distractors). In the event that impaired inhibitory processing was demonstrated for threat words, this category would be parsed into somatic (physical) and cognitive threat words to address the emotional Stroop research which has demonstrated that outcomes can depend on the relevance of the stimuli to the nature of the stressor experienced by individuals (Mogg et al., 1996). The use of two categories of threat words also capitalised on the utilisation of both somatic and cognitive mood induction procedures as an ideal means of investigating such a bias.

The third aim of this study was to examine whether trait anxiety, state anxiety, or stress is responsible for anxiety-linked impairments in working memory and also inhibitory performance (since the experience of stress has been found to affect performance without state anxiety being implicated as demonstrated in Section 5.6.3.3, the stress variable will be considered in addition to the state/trait anxiety distinction). To this end, the methodology utilised in the preceding chapter whereby high and low trait anxious individuals underwent cognitive and somatic mood induction procedures was retained. The difficulty with the findings of the last study, however, was that measuring state anxiety only prior to the mood induction and at the end of the experimental session may have obscured any effects of the mood induction procedures. Consequently, it was necessary to reinstate the methodology utilised in Chapter 4 wherein state anxiety was evaluated prior to mood induction, immediately following mood induction, and post experiment. In order to avoid the post mood induction administration of the state measures rendering the cognitive mood induction procedure transparent, participants
completed the practice session of the first task (the first task participants completed was counterbalanced across the participants) prior to filling in the mood measures.

Finally, the fourth aim sought to establish if inhibition mediates the relationship between anxiety and impaired working memory performance and, if so, the extent to which inhibition mediates this relationship. Where anxiety was implicated in performance on any of the three working memory tasks, the effect of inhibition was controlled for using ‘blocking’ (G.A. Miller & Chapman, 2001) wherein inhibition scores formed a variable of interest in the analyses. Related to the investigation into the extent to which inhibition mediates working memory performance is the issue of whether there exists fractionable CE processes in the working memory system. Presently, Dutke and Stöber’s (2001) finding that anxiety does not affect the process of updating is consistent with Miyake et al.’s (2000) argument that CE processes are fractionable. However, Miyake et al. also suggest that inhibition may underpin the fractionable CE processes which is suggestive of a unified process (i.e. this suggests more of a unified pool of resources, as per the original conceptualisation of the CE as a unitary system; Baddeley, 1986).

The contrasting findings of Dutke and Stöber’s (2001) and Miyake et al.’s (2000) studies, and the theoretical implications of these findings, may be resolved in the present experimental design. Specifically, Dutke and Stöber’s findings will be supported where there is an absence of anxiety-linked impairments on the running verbal task. Miyake et al.’s suggestion that inhibition may underpin CE processes will be supported where (a) anxiety-linked impairments are evident on all working memory tasks, including the running verbal task; and (b) inhibition makes a significant contribution to performance on all three working memory tasks. Additionally, if inhibition does underpin all CE processes, significant correlations between indices of performance on all three working memory tasks, and of these indices with directed ignoring performance, would also be expected.

The aims of the present study have evolved from a consideration of the literature, which indicated a need to investigate inhibitory processes and the role they may play in the link between anxiety and working memory performance. In spite of this shift in the focus of this programme of research, however, it is important to note that the focus on inhibitory processes does not preclude the original aim of the thesis – that of examining
the PET. The predictions of the PET may still be evaluated; the focus on inhibition and fractionable CE processes is merely a more thorough examination of the CE component of the working memory model utilised by the PET. By examining inhibition and fractionable CE processes, greater specification of the CE component of working memory as outlined by the PET may be attainable. Indeed, the design of the present study (which shifted from utilising fixed and running verbal and spatial span tasks to utilising several complex working memory tasks) permitted the evaluation of the following predictions of the PET:

- Anxiety typically impairs secondary task performance (Prediction 1.2)

- The performance of low anxious individuals is enhanced by motivational factors (which increase effort) to a greater extent than is the performance of high anxious individuals (Prediction 1.4)

- The performance of a central task will be adversely affected by an additional load to a greater extent in high anxious than in low anxious groups (Prediction 1.5)

- Anxiety-related effects on performance are contingent on the demands the task makes on resources, and this may be assessed by examining the susceptibility of central task performance to interference from a concurrent load (Prediction 2.1)

- Anxiety has powerful adverse effects on tasks with high storage and processing demands (Prediction 2.3)

Three of the above predictions were also evaluated in the previous study (Predictions 1.4, 1.5, and 2.3), however evaluations of Predictions 1.2 and 2.1 are new to the present study. Prediction 1.2 may be evaluated by examining performance on reading span, which may be conceptualised as comprising two tasks. The grammatical reasoning task also comprises two tasks, however this task does not lend itself easily to an identification of which subtask is secondary. The grammatical reasoning task is
more suited to evaluating Prediction 2.1, which states that the effects of anxiety on a
task (i.e. reasoning subtask) may be assayed by examining the susceptibility of the task
to a concurrent load (i.e. memory subtask; retention of digit strings). Here, it is
expected that the effects of anxiety will be more apparent where the concurrent load
places greater demands on available resources (i.e. under a high memory load).

Regarding the predictions evaluated in the previous study (Predictions 1.4, 1.5, and
2.3), Prediction 1.5 may be examined in the present study by (a) examining the effect of
an additional load in the transition from a lower to a higher sequence length in the
running verbal task; (b) examining the effect of an additional load in the transition from a
lower to a higher sequence length in the reading span task; and (c) comparing the
effect of a low versus high memory load on grammatical reasoning task performance.
For each of these, it is expected that the effects of anxiety are stronger when the
additional load is greater. Prediction 2.3 presents some difficulties in evaluation in light
of the literature arguing for the fractionation of the CE. Specifically, anxiety may
differentially affect tasks due to the different storage and processing demands they
make, as suggested by the PET. Alternatively, it may be that certain processing
demands are not impaired by anxiety (cf. Dutke & Stöber, 2001).

Altogether, the present study aims to further evaluate the predictions of the PET, and
also to examine the extent of the role inhibition plays in the anxiety-working memory
relationship. These are the tenets that informed the design and analyses of the present
study.

6.8 Method

6.8.1 Participants
Participants were 64 undergraduate psychology students selected using criteria similar
to those outlined in Chapters 4 and 5. They were aged between 17 and 29 (M = 18.40,
SD = 1.88) and included 15 males. All were fluent in English and had normal or
corrected-to-normal vision and hearing.
6.8.2 Apparatus
All programs were presented on a Hyundai IBM-Compatible PC computer with a 35cm NEC MultiSync V500 MicroTouch monitor using MicroTouch Touchscreen Version 3.4. All programs were written in MetaCard 2.4.1, with the exception of the running verbal task which was written in MetaCard 2.2.

6.8.3 Mood Induction
Two mood induction procedures were used – Cognitive Mood Induction, and Music Mood Induction; these are identical to those utilised in the previous study.

6.8.4 Mood measures
The mood measures utilised in this experiment are identical to those described in Chapter 5. The measures were administered at three points in the experiment – Pre Mood Induction, Post Mood Induction, and Post Experiment, which is consistent with the study described in Chapter 4.

6.8.5 Tasks
6.8.5.1 Directed ignoring task. Sixteen stories were utilised in this task, each of 125 words in length, comprising between 7 and 10 sentences. The sentences were presented in italics (Arial 17-point italic). Interspersed within each story were four distractors, repeated 15 times each. The distractors were printed in regular (i.e. non-italicised) font. It was desired that each of the 16 stories could be paired with each of four sets of distractor types – Related, Unrelated, Control, and Threat. The latter category was additionally parsed into Cognitive Threat and Somatic Threat Distractor Types. Thus, half of all the pairings of the stories with Threat distractors were with Cognitive Threat distractors, and the other half with Somatic Threat distractors. It was therefore necessary to construct five sets of distractor types for each of the sixteen sets of stories.

With the exception of the Control Distractor Type, the distractor types comprised words selected based on ratings of an initial pool of 212 words. Related distractors were words that were semantically or thematically related to each story, Unrelated distractors were words that were neither semantically nor thematically related to each story, and
Threat distractors were words perceived to be threatening (these were neither semantically nor thematically related to the stories). Words within the latter category were parsed into words that were cognitive in nature (Cognitive Threat) and words that were somatic in nature (Somatic Threat). Altogether, 16 sets of Related Distractor Types (one for each story) were desired, along with four sets of Unrelated Distractor Types, and also four sets of Threat Distractor Types (within this, two each of the Cognitive and Somatic Threat Distractor Types). Four instances within each set of Distractor Types were needed.

All the word distractor types were composed such that: (a) word frequency counts (Kucera & Francis, 1967) and word lengths did not differ significantly across the different distractor types; (b) Threat distractors were rated as more threatening than non-threat (i.e. related and unrelated distractors), while Cognitive and Somatic Threat Distractor Types did not differ significantly in threat ratings; and (c) non-threat words were rated to be less somatic than Somatic distractors and less cognitive than Cognitive distractors, with the Cognitive and Somatic distractors equivalent in terms of relevance to their respective domains. Appendix D provides further detail regarding the selection of these stimuli.

For each of the 16 stories, five versions were constructed incorporating all Distractor Types (Related, Unrelated, Cognitive Threat, Somatic Threat, and Control). The Control distractors comprised strings of Xs that were composed as follows - each Related, Unrelated, Cognitive Threat, and Somatic Threat word was 'yoked' to a position (position 1-4). The length of Control distractors was then composed by averaging the word lengths of the four distractor words in that position. Overall, there were four sets of Unrelated distractors, sixteen sets of Related distractors, and two sets each of the Cognitive and Somatic threat distractors. The set of sixteen stories each participant was presented with was such that no set of distractors was repeated. The set of distractors paired with each story was counterbalanced across all participants (refer to Appendix E for an example). Each paragraph was followed by the presentation of four multiple-choice questions, each with four alternatives. These questions assessed comprehension of the paragraph. Appendix F presents the paragraphs utilised, the accompanying distractor word sets, and the multiple-choice questions.
Procedure. Participants were presented with a story on the computer screen and instructed to read aloud the italicised words at a pace that would allow them to answer comprehension questions based on the story while ignoring all words printed in regular font. They were instructed to not follow along with a marker (e.g. finger, mouse cursor) while reading. Participants indicated when they finished reading the story by touching a button on the computer monitor, following which they were presented with the multiple-choice questions and allowed to answer the questions at their own pace. The reading of the passages was tape-recorded and subsequently analysed for latency (reading time), and also for the number of intrusions (distractor items read aloud) made. Accuracy of response to the multiple-choice questions was recorded by the controlling software. This task was preceded by one practice trial.

6.8.5.2 Reading span task. Sixty sentences were employed in this task. These sentences were used to compose five sets of sentences, where the number of sentences in each set (i.e. set size) ranged between two and six sentences. There were three trials per set size. Sentences within a trial were not thematically related. Each sentence comprised twelve words, with the number of syllables in the sentences ranging from 16 to 19 (M = 17.63, SD = 1.06). The number of syllables in the sentences did not significantly differ between set sizes, F(4,55) = .62, n.s. The target to-be-recalled word was the terminal word of each sentence, and all terminal words were bisyllabic. Furthermore, terminal words within the one trial began with different letters and were not semantically related. Word frequency counts (Kučera & Francis, 1967) for the terminal words ranged from 9 to 181 (M = 69.77, SD = 42.86), and did not significantly differ between set sizes, F(4,55) = 1.10, n.s. An additional four sentences were utilised in the two practice trials; these were similar to the above sentences.

Each trial was followed by a question based on one of the sentences comprising the trial, with four multiple-choice alternatives. Appendix G presents the sentences for each trial and the accompanying multiple-choice questions.

Procedure. All participants received the sentences in the same order. Sentences were presented starting with a set size of two, and incrementing to a set size of six. Three trials were presented at each set size. The task was preceded by two practice trials.
For each trial (depicted visually in Figure 6.1), a "Ready for sentence" sign would appear centrally and remain onscreen for 1s. A sentence would then appear and remain for 4s, following which it disappeared and was replaced by an unrelated sentence. Participants were to read and comprehend each of the sentences for a subsequent comprehension task, and to remember the terminal word for later recall.

Following the last sentence of each trial, a "RECALL" sign appeared centrally, along with a number of blue ‘buttons’ (each 2.7cm x 2.7cm) that corresponded to the sequence length. The number of buttons indicated to participants the number of words to recall. The "RECALL" sign cued the recall of the terminal words, and participants were to successively press one of the buttons as they vocally recalled the terminal words in the order of presentation. Each button lit up in white when pressed, and remained illuminated for the remaining duration of the trial. When the final button was pressed, a multiple-choice question with four alternatives appeared after a 300ms interval. The question was based on one of the sentences in the trial, and participants were to press a button corresponding to the answer they thought was most applicable. When a response was made, 1s lapsed before the presentation of the "Ready for sentence" sign indicating the start of the next trial. Participants completed two practice trials at set size two to familiarise themselves with the task. Recall of the terminal words were taped and analysed after completion of the experiment. Responses to the comprehension task were recorded and scored by the computer.

6.8.5.3 Grammatical reasoning task. The grammatical reasoning task, which was almost identical in structure to the one used by C. MacLeod and Donnellan (1993), comprised two components – a reasoning subtask, and a memory load subtask. In the reasoning subtask, each stimulus display consisted of the letters X and Y, arranged either as XY or as YX, with a sentence below this describing a possible relationship between the two letters. The complete set of 16 stimulus displays is presented in Table 6.2. Half the sentences accurately described the spatial relationship, while the other half did not. Participants were required to verify the accuracy of the sentence by pressing one of two buttons marked ‘TRUE’ and ‘FALSE’ on the computer monitor.
Figure 6.1. Order of presentation of stimuli within one trial for the reading span task (set size = 2).
Table 6.2. Stimuli from the reasoning subtask of the Grammatical Reasoning task.

<table>
<thead>
<tr>
<th>XY</th>
<th>YX</th>
</tr>
</thead>
<tbody>
<tr>
<td>X is before Y</td>
<td>X is before Y</td>
</tr>
<tr>
<td>YX</td>
<td>XY</td>
</tr>
<tr>
<td>Y is before X</td>
<td>Y is before X</td>
</tr>
<tr>
<td>XY</td>
<td>YX</td>
</tr>
<tr>
<td>X is preceded by Y</td>
<td>X is preceded by Y</td>
</tr>
<tr>
<td>YX</td>
<td>XY</td>
</tr>
<tr>
<td>Y is preceded by X</td>
<td>Y is preceded by X</td>
</tr>
<tr>
<td>XY</td>
<td>YX</td>
</tr>
<tr>
<td>X is not before Y</td>
<td>X is not before Y</td>
</tr>
<tr>
<td>XY</td>
<td>YX</td>
</tr>
<tr>
<td>Y is not before X</td>
<td>Y is not before X</td>
</tr>
<tr>
<td>XY</td>
<td>YX</td>
</tr>
<tr>
<td>X is not preceded by Y</td>
<td>X is not preceded by Y</td>
</tr>
<tr>
<td>YX</td>
<td>XY</td>
</tr>
<tr>
<td>Y is not preceded by X</td>
<td>Y is not preceded by X</td>
</tr>
</tbody>
</table>

There were two parts to the concurrent memory load subtask. In the first part, participants were presented with the statement “MEMORY LOAD IS…” followed by a string of six digits. These digits were presented under either a low or high memory load condition. In the Low Memory Load condition, the digit string comprised all zeros. In the High Memory Load condition, the digit string comprised six random digits without repetition, with digits adjacent in the string not being consecutive ascending or descending numbers. This display remained on the screen for 2s before participants were presented with a stimulus display from the reasoning subtask.

The second part of the concurrent memory load subtask was presented 250ms following the participant’s response on the reasoning subtask. This comprised the statement “MEMORY TEST IS…” followed by a string of six digits. Half the trials displayed a string that was identical to that presented immediately prior to the reasoning task trial. On the other half, the digit string was different. Where the initial digit string was in the Low Memory Load condition (i.e. all zeros), the different test string was a
string of six random digits without repetition, and digits adjacent in the string were not consecutive ascending or descending numbers. Where the initial digit string was in the High Memory Load condition, the different test string was identical save for the transposition of two digits within the initial digit string (positions of the digits that were transposed were determined randomly by the controlling software). Participants were to press a button on the monitor labelled ‘TRUE’ if the digit string was the same as the initial string, and to press a button labelled ‘FALSE’ if it was different.

The order of presentation of stimuli within one trial on the grammatical reasoning task is depicted in Figure 6.2. Sixty-four experimental trials were presented in total, with successive trials separated by a 2s interval. The 64 trials comprised four presentations of each of the 16 stimulus displays. Of the four presentations, two were in the High Memory Load condition, and two in the Low Memory Load condition, and in each case, one presentation of the test digit string was identical to, and the other different from, the initial digit string. The order of the 64 trials was randomised for each participant.

Procedure. Participants were informed that they were to be presented with a reasoning task combined with a memory task. The importance of accuracy was stressed, and it was also stressed that accuracy was equally important in both the reasoning and memory tasks. Participants were presented with instructions that described the structure of a trial and were additionally instructed to recite the initial digit string out aloud, and to continue reciting it until the end of the trial. These instructions were followed by 16 practice trials which spanned the entire set of 16 stimulus displays, with half of these presented under the High Memory Load condition and half under the Low Memory Load condition. Within each of these, half the test digit strings were identical to the initial string, while the other half were not.

6.8.5.4 Running Verbal task. The stimuli and procedure of the Running Verbal task were identical to those utilised in the two previous studies.
Figure 6.2. Order of presentation of stimuli within one trial for the grammatical reasoning task.
6.8.6 General Procedure

Participants were tested individually. After reading an information sheet and completing a consent form pertaining to participation in the experiment, participants filled out the DASS-21, PSWQ, STICSA-Trait, STICSA-State, and POMS Anxiety and Depression questionnaires (Pre Mood Induction Phase). Participants then completed the practice trials of one of the tasks (the order of presentation of tasks was counterbalanced across all participants), followed by the cognitive and music mood induction procedures. Immediately after this, they completed the STICSA-State and POMS Anxiety and Depression questionnaires (Post Mood Induction Phase), followed by the task itself. Participants then completed the remaining tasks, with each task preceded by a mood induction phase comprising a two-minute music piece taken from the initial seven-minute piece and either ego threatening or ego non-threatening instructions. After the completion of all tasks, participants completed the STICSA-State, POMS Anxiety and Depression questionnaires, and also the CIQ (Post Experiment Phase). Participants were then fully debriefed. Assignment of participants into the various mood induction conditions followed the procedure outlined in the previous study (see Section 5.5.7).

6.9 Results

6.9.1 Overview of analyses

Four sets of analyses were conducted. The first evaluated participants' enduring (trait) mood levels and the efficacy of the mood induction procedures, as assessed by levels of state anxiety and depression. The second set of analyses assayed the effects of anxiety on inhibition. The third examined the impact of anxiety on working memory, and the fourth evaluated the relationships between anxiety, inhibition, and working memory. Where correlations are reported, each variable was first screened for univariate outliers, with any data points exceeding three standard deviations of the mean eliminated from analyses. Variables were then screened for bivariate outliers, with any data points exceeding Cook's $D = 1$ eliminated from analyses. All analyses were conducted using SPSS for Windows 11.0.
6.9.2 Participant mood levels and efficacy of mood induction procedures

6.9.2.1 Participant characteristics at testing time. It was desired that the more enduring mood characteristics of participants did not differ according to their allocation to the different mood induction conditions. However, it was expected that the low and high trait anxiety groups would differ on measures of trait anxiety, depression, and worry in a manner that is consistent with the findings of the preceding chapters. To this end, the trait measures (DASS Anxiety and Depression ratings, STICS Trait Anxiety Somatic and Cognitive ratings, and PSWQ ratings) were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) ANOVA. Prior to analyses, DASS scores were transformed to full-scale scores in the manner outlined in the previous chapters.

For each of these analyses, the only significant effects involved Trait Anxiety Group, with participants in the High Trait Anxiety Group endorsing higher ratings than their Low Trait Anxiety Group counterparts. Summary statistics for each Trait Anxiety Group are presented in Table 6.3. The absence of significant effects involving the Music Mood Induction and Cognitive Mood Induction factors indicates that the allocation of participants into the different mood induction conditions did not vary according to their trait mood at the time of testing.

Table 6.3 F values and means (and standard deviations in parentheses) for the main effect of Trait Anxiety Group on trait mood measures.

<table>
<thead>
<tr>
<th>Measure</th>
<th>F value</th>
<th>Trait Anxiety Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>DASS Anxiety</td>
<td>F(1,56) = 81.36a</td>
<td>2.88 (2.03)</td>
</tr>
<tr>
<td>DASS Depression</td>
<td>F(1,56) = 34.05a</td>
<td>4.63 (3.31)</td>
</tr>
<tr>
<td>PSWQ</td>
<td>F(1,56) = 13.81a</td>
<td>40.28 (12.12)</td>
</tr>
<tr>
<td>STICS-Trait Somatic Anxiety</td>
<td>F(1,56) = 20.24a</td>
<td>15.50 (3.53)</td>
</tr>
<tr>
<td>STICS-Trait Cognitive Anxiety</td>
<td>F(1,56) = 17.03a</td>
<td>17.88 (4.36)</td>
</tr>
</tbody>
</table>

a denotes p < .001
It is noted that the trait anxiety groups also differed on the depression measure, thus where trait anxiety is involved in effects on working memory performance, ‘blocking’ (i.e. introducing a trait depression variable) will be employed to examine the contribution of depression (cf. G.A. Miller & Chapman, 2001). This entailed the composition of Trait Depression Groups, with the Low Trait Depression Group comprising individuals whose DASS Depression rating ranged from 0 to 9 (inclusive), which corresponds with symptom severity in the normal range (S.H. Lovibond & P.F. Lovibond, 1995). The High Trait Depression Group comprised those individuals who endorsed DASS Depression ratings of 10 and above, which corresponds with symptom severity in the mild, moderate, severe, and extremely severe ranges (S.H. Lovibond & P.F. Lovibond, 1995).

It was also desired that participant allocation into the different Music Mood Induction and Cognitive Mood Induction conditions did not differ according to participants’ state mood at the initiation of testing. To this end, POMS Anxiety, POMS Depression, STICSA State Somatic Anxiety, and STICSA State Cognitive Anxiety ratings at the Pre Mood Induction Phase were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) ANOVA. STICSA State Somatic and Cognitive Anxiety ratings were obtained by summing across the respective subscales.

The only significant effects from these analyses involved main effects of Trait Anxiety Group, with higher ratings for the High Trait Anxiety Group than for the Low Trait Anxiety Group. Therefore, the allocation of participants into the mood induction conditions did not differ according to their mood at the time of testing. Summary statistics for each Trait Anxiety Group are presented in Table 6.4.
Table 6.4. F values and means (and standard deviations in parentheses) for the main effect of Trait Anxiety Group on state mood measures in the Pre Mood Induction Phase

<table>
<thead>
<tr>
<th>Measure</th>
<th>F value</th>
<th>Trait Anxiety Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>POMS Anxiety</td>
<td>$F(1,56) = 6.41^{c}$</td>
<td>10.56 (8.47)</td>
</tr>
<tr>
<td>POMS Depression</td>
<td>$F(1,56) = 10.36^{b}$</td>
<td>5.60 (5.84)</td>
</tr>
<tr>
<td>STICSA-State Somatic Anxiety</td>
<td>$F(1,56) = 4.73^{c}$</td>
<td>13.66 (3.23)</td>
</tr>
<tr>
<td>STICSA-State Cognitive Anxiety</td>
<td>$F(1,56) = 6.01^{c}$</td>
<td>14.91 (4.61)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>POMS Anxiety</td>
<td></td>
<td>17.77 (13.29)</td>
</tr>
<tr>
<td>POMS Depression</td>
<td></td>
<td>14.98 (14.64)</td>
</tr>
<tr>
<td>STICSA-State Somatic Anxiety</td>
<td></td>
<td>16.22 (5.71)</td>
</tr>
<tr>
<td>STICSA-State Cognitive Anxiety</td>
<td></td>
<td>18.28 (6.05)</td>
</tr>
</tbody>
</table>

$^{b}$denotes $p < .01$; $^{c}$denotes $p < .05$

6.9.2.2 Efficacy of mood induction procedures. As the POMS Anxiety and Depression measures and the STICSA State Somatic and Cognitive Anxiety measures were administered at three points in the experiment, these measures afforded an analysis of the immediate and more sustained effects of the mood induction procedures. These ratings were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) x 3 (Phase: Pre Mood Induction, Post Mood Induction, Post Experiment) mixed-design ANOVA. As there were more than two levels of the within-subjects variable, in instances where Mauchly’s test of the sphericity assumption was violated, Huynh-Feldt Epsilon-corrected values were reported. As the CIQ was administered only at the end of the experiment, the task-relevant ratings were subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) ANOVA. For all ANOVA analyses reported, where independent samples t tests were utilized to decompose significant interaction effects, in instances where violations of Levene’s test for equality of variances occurred, corrected values with equal variances not assumed were reported. This correction was applied in all subsequent analyses where it was pertinent.

POMS Anxiety ratings. There was a significant main effect of Trait Anxiety Group, $F(1,56) = 7.01$, $p < .05$, with higher ratings endorsed by the High Trait Anxiety Group, $M = 18.05$, $SD = 13.05$, than by the Low Trait Anxiety Group, $M = 10.74$, $SD =$
Also evident was a significant main effect of Music Mood Induction, $F(1,56) = 6.74$, $p < .05$, with higher ratings endorsed by those under Anxious Music Mood Induction, $M = 17.97$, $SD = 12.34$, than by those under Neutral Music Mood Induction, $M = 10.81$, $SD = 10.28$.

The analysis also yielded a significant Music Mood Induction x Phase interaction, $F(2,112) = 17.20$, $p < .001$. Means (and standard errors) for the Music Mood Induction conditions across the three phases of the experiment are presented in Figure 6.3. From this, it is apparent that the Anxious Mood Induction had an effect of increasing the ratings over the course of the experiment, with the converse pattern evident for the Neutral Mood Induction. There was no significant difference between the Neutral and Anxious Music Mood Induction groups in the Pre Mood Induction Phase, $t(62) = .26$, n.s., but the Anxious Music Mood Induction group endorsed higher ratings at the Post Mood Induction and Post Experiment Phases, $t(54.58) = 4.19$, $p < .001$, and $t(62) = 2.34$, $p < .05$, respectively, with this difference more pronounced in the Post Mood Induction Phase. These findings replicate those reported in Chapter 4.

Additionally, the Trait Anxiety Group x Cognitive Mood Induction x Phase interaction yielded $F(2,112) = 3.08$, $p = .05$, however when this effect was decomposed by examining two-way interactions at each level of each variable, no significant interactions emerged.

Altogether, the findings suggest that the Music Mood Induction affected the POMS Anxiety ratings substantially whereas the Cognitive Mood Induction did not.

**POMS Depression ratings.** The only significant effect from the ANOVA was a main effect of Trait Anxiety Group, $F(1,56) = 11.29$, $p < .01$, with higher ratings endorsed by the High Trait Anxiety Group, $M = 14.36$, $SD = 13.66$, than by the Low Trait Anxiety Group, $M = 5.28$, $SD = 5.33$. 
STICSA State Somatic Anxiety ratings. The ANOVA revealed a main effect of Phase, $F(2,112) = 10.25$, $p < .01$, but this was modified by a Music Mood Induction x Phase interaction, $F(2,112) = 7.76$, $p < .01$ (refer to Figure 6.4). Participants’ endorsements of ratings did not differ in terms of the Music Mood Induction condition at the Pre Mood Induction Phase, $t(62) = .52$, n.s., however Anxious Music Mood Induction participants endorsed higher ratings than did Neutral Music Mood Induction participants at the Post Mood Induction Phase, $t(41.30) = 3.20$, $p < .01$, but this difference was not sustained at the Post Experiment Phase, $t(62) = 1.61$, n.s. (see Figure 6.4). This pattern is similar to that of the POMS Anxiety ratings. Indeed, correlations between these two measures at the Pre Mood Induction, Post Mood Induction, and Post Experiment Phases were .66, .70, and .76 respectively (all $p$s < .001), suggesting good congruence between the two measures.
Figure 6.4. Means (and standard errors) of STICSA State Somatic Anxiety ratings for each Music Mood Induction condition at each phase of the experiment.

There was also a significant Trait Anxiety Group x Phase interaction, $F(2,112) = 4.95$, $p < .01$ (Figure 6.5). STICSA State Somatic Anxiety ratings were significantly higher for the High Trait Anxiety Group than for the Low Trait Anxiety Group at the Pre Mood Induction Phase, $t(49.01) = 2.2$, $p < .05$, and also at the Post Experiment Phase, $t(52.08) = 3.07$, $p < .01$. No significant difference between Trait Anxiety Groups was apparent at the Post Mood Induction Phase, $t(62) = 1.2$, n.s. (see Figure 6.5).

**STICSA State Cognitive Anxiety ratings.** The ANOVA revealed a main effect of Trait Anxiety Group, $F(1,56) = 9.46$, $p < .01$, with the High Trait Anxiety Group endorsing higher ratings, $M = 18.53$, $SD = 5.54$, than the Low Trait Anxiety Group, $M = 14.74$, $SD = 4.07$. 
There was also a Music Mood Induction x Phase interaction, $F(2,112) = 4.10, p < .05$. Interestingly, ratings did not differ between Neutral and Anxious Music Mood Induction conditions at any phase of the experiment, $t_s < 1.31$. Rather, the interaction reflects a reversal in the pattern of means for the Music Mood Induction conditions across the three phases. The Neutral Music Mood Induction condition served to decrease ratings, whilst the Anxious Music Mood Induction condition served to increase ratings across the experiment (see Figure 6.6). An unexpected finding from the analysis of STICSA State Cognitive Anxiety ratings was that there was an absence of any effects involving the Cognitive Mood Induction factor.
CIQ task-relevant ratings. There was a main effect of Trait Anxiety Group, \(F(1,56) = 5.39, p < .05\), with participants in the High Trait Anxiety Group endorsing higher ratings, \(M = 32.19, SD = 7.09\), than those in the Low Trait Anxiety Group, \(M = 28.53, SD = 5.69\). There was also a main effect of Cognitive Mood Induction, \(F(1,56) = 5.39, p < .05\), with higher ratings endorsed in the Ego Threat condition, \(M = 32.19, SD = 7.93\), than in the No Ego Threat condition, \(M = 28.53, SD = 5.63\).

In all, these analyses indicate that the High and Low Trait Anxiety Groups differed not only on several measures of trait and state anxiety, but also on worry, and trait and state depression ratings. Importantly, participants did not systematically differ on these variables as a function of their allocation to the different mood induction conditions (i.e. at the Pre Mood Induction Phase). Regarding the efficacy of the mood induction procedures, the POMS Anxiety and STICSA State Somatic Anxiety ratings (both measuring more somatic aspects of anxiety) were influenced by the Music Mood Induction procedure. Unexpectedly, the STICSA State Cognitive Anxiety ratings were influenced by the Music, but not the Cognitive, Mood Induction procedure. However,
the Ego Threat condition did, as expected, result in elevated reporting of task-relevant thoughts. It is important to note that, consistent with the findings of the study reported in Chapter 4, there was an absence of a Trait Anxiety Group x Mood Induction interaction (involving either the Music or Cognitive Mood Induction) for all the state anxiety ratings. This runs contrary to the notion that state anxiety is determined interactively by trait anxiety and mood induction (Eysenck & Calvo, 1992). The only exception was the Trait Anxiety Group x Cognitive Mood Induction x Phase interaction on the POMS Anxiety ratings, however it was difficult to obtain a clear interpretation of this effect.

6.9.3 Anxiety and inhibition – directed ignoring task

Reading time. Median reading times (in seconds) were calculated for each participant for Related, Unrelated, Control, and Threat Distractor Type paragraphs. For one participant, three stories (which were of different Distractor Types) were omitted from analyses due to equipment failure, thus median reading times were calculated across the remaining stories. There were no outliers for any of the Distractor Type medians.

To refresh, three comparisons were of particular interest in this task. The first concerned whether the lexical status of the distractor (i.e. words vs. strings of Xs) affected reading times. The second related to whether the relevance of the word to the content of the story (i.e. Related vs. Unrelated & Threat) affected reading times. The third examined whether threat words affected reading times more so than other unrelated words (i.e. Unrelated vs. Threat). In the event that threat words elicit lengthened reading times, these will be parsed into cognitive and somatic threat distractors for further analysis. Reading times were subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) x 4 (Distractor Type: Control, Related, Unrelated, Threat) mixed-design ANOVA, with the last factor a within-subjects variable. The Distractor Type factor was partitioned using Helmert contrasts into three orthogonal comparisons as outlined above: (a) Control versus Word (Related, Unrelated, and Threat Distractor Types) to examine the lexical status of the distractor; (b) Related versus Unrelated and Threat Distractor Types to examine relevance of the distractors;
and (c) Unrelated versus Threat Distractor Types to examine if emotional content affected performance.

The first of these comparisons, Control versus Word, yielded $F(1,56) = 297.76$, $p < .001$, with shorter reading times evident for the Control Distractor paragraphs, $M = 41.78$, $SD = 6.43$, than for Distractor paragraphs that comprised words, $M = 56.63$, $SD = 9.14$. Importantly, there was a significant Cognitive Mood Induction x Distractor Status interaction, $F(1,56) = 4.51$, $p < .05$. Reading times on the Control Distractor paragraphs did not differ between the No Ego Threat and Ego Threat conditions, $t(62) = .97$, n.s., however significantly longer reading times were evident under Ego Threat instruction on paragraphs comprising Word distractors, $t(62) = 2.36$, $p < .05$ (see Figure 6.7).

Figure 6.7 Means (and standard errors) of reading times for word and non-word Distractor Types under each Cognitive Mood Induction condition for the Directed Ignoring task.
The second comparison, investigating the semantic relevance of distractors (Related versus Unrelated and Threat Distractor Types), yielded, $F(1, 56) = 8.02, p < .01$, indicating longer reading times for Related Distractor Type paragraphs, $M = 57.84, SD = 10.62$, than for Unrelated and Threat Distractor Type paragraphs, $M = 56.03, SD = 8.79$. No interaction effects involving trait mood or mood induction variables were evident, $Fs < 1.79, n.s.$

The third comparison (Unrelated versus Threat Distractor Type) yielded a significant outcome, $F(1, 56) = 7.09, p < .05$. Here, longer reading times were apparent on Unrelated Distractor Type paragraphs, $M = 56.95, SD = 9.98$, than on Threat Distractor Type paragraphs, $M = 55.10, SD = 8.36$. Importantly, no interaction effect involving Distractor Type and a mood variable was observed, $Fs < 2.59, n.s.$ Consequently, no further analyses that parsed Threat Distractor Type into Cognitive and Somatic Threat Distractor Types were conducted.

Overall, the data suggest that participants exhibit longer reading times when the distractor is a word than when it comprises a string of letters. Within this, distractors that are semantically relevant to the paragraph elicited longer reading times than non-semantically relevant distractors. Surprisingly, unrelated distractors elicited longer reading times than threat distractors. Ego threat instructions elicited longer reading times when words were the distractors but the content of the distractor words did not modify this effect, suggesting that the deficit in inhibitory processing exhibited under ego threat is a general one.

**Distractors read out.** This analysis considered the number of distractors read out (either in part, or in entirety). The rates of intrusions were very low, and did not constitute sufficient data for meaningful analysis.

**6.9.3.1 State anxiety and inhibition.** As the state/trait anxiety distinction is also pertinent to the inhibition literature, correlations between state anxiety and inhibition measures were conducted. Along with reading times for the Control, Related, Unrelated, and Threat (parsed into Somatic and Cognitive Threat, as well as including an overall Threat index) Distractor Types, three additional indices were also of interest. The first, constructed for the comparison between Control and Word Distractor Types,
comprised the mean reading times for all paragraphs wherein the distractor was a word (Word Distractor Type). The second, constructed for the Related versus Unrelated and Threat Distractor Type, comprised the mean reading times for paragraphs in which the distractors were unrelated to the content of the paragraph and where the distractors were threat-related (Unrelated/Threat Distractor Type). The third index was derived in response to the findings reported in the preceding section suggesting that the only significant comparison implicating anxiety- or stress-linked effects on the directed ignoring task involved that between Control and Word Distractor Types (the first orthogonal comparison). Thus, a single index (degree of slowing) was derived from this comparison, obtained by subtracting reading times for paragraphs containing control distractors from reading times for paragraphs containing word distractors. In addition to the state anxiety ratings, state depression ratings were also included to examine a potential role for comorbid depression.

The results of the correlational analyses are reported in full in Appendix H (part a). Overall, no significant correlations were observed between state anxiety and any of the reading times, nor were there significant correlations between state depression ratings and reading times. The absence of significant correlations between state anxiety and the degree of slowing index was surprising in light of the interaction effect involving Cognitive Mood Induction and the comparison between control and word distractor types (the first orthogonal comparison) observed on the reading time analyses.

6.9.4 Anxiety and working memory

6.9.4.1 Reading span task. Reading span scores. Each trial was scored as correct if all terminal words were recalled correctly, position-respecting. Two methods of scoring were utilised. The first is a weighted scoring system (cf. Darke, 1988a) that considers the greater level of difficulty in recalling terminal words at the longer set sizes. Here, each correct trial is awarded the score of its set size (so a correct response on a trial comprising three sentences yields a score of three, for example) and scores are summed across all trials to produce the weighted reading span score. The second method, a fractional scoring method, is concordant with the scoring method employed in the running verbal task utilised in the previous two chapters such that the reading span score is calculated as a third of a point for each correct trial, plus one (to
accommodate the fact that testing started at set size two). The fractional and weighted span scores were highly correlated, \( r(63) = .99, p < .001 \), consequently subsequent analyses will consider only the fractional scores (hereafter referred to simply as reading span scores) as this method of scoring is consistent with that employed in the running verbal task.

Reading span scores were subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) ANOVA. There was a significant Cognitive Mood Induction x Trait Anxiety Group interaction, \( F(1,56) = 5.88, p < .05 \) (see Figure 6.8). Scores for participants in the Low Trait Anxiety Group did not differ as a function of Cognitive Mood Induction condition, \( t(30) = 1.43, n.s. \), while those in the High Trait Anxious Group under the Ego Threat Cognitive Mood Induction condition had lower span scores than those under the No Ego Threat Cognitive Mood Induction condition, \( t(30) = 2.07, p < .05 \). To verify that

![Figure 6.8](image_url)

Figure 6.8. Means (and standard errors) of reading span scores for each Cognitive Mood Induction x Trait Anxiety Group condition for the Reading Span task.
this finding is attributable to anxiety and not to depression, the reading span scores were reanalysed, this time with depression included as a variable in the analysis (G.A. Miller & Chapman, 2001; see Section 6.9.2.1 for details on the composition of the High and Low Trait Depression Groups). The reanalysis revealed that the Cognitive Mood Induction x Trait Anxiety Group x Trait Depression interaction was not significant, $F(1,49) = .24$, n.s, and the Cognitive Mood Induction x Trait Anxiety Group interaction remained significant, $F(1,49) = 4.90$, $p < .05$.

**Reaction time measures.** Only the reaction times for trials that were correct were considered. Reaction time was parsed into preparatory and inter-item intervals (cf. Chapters 4 & 5), obtained by calculating the median intervals for all valid (i.e. correct) trials. Approximately one-third of participants did not recall any trials correctly for set size three, consequently only trials of set size two were utilised. For the preparatory interval, two outliers were removed, and one was removed for the inter-item interval reaction times, for these data points exceeded three standard deviations beyond the mean.

Both the preparatory and inter-item intervals were subjected to the same ANOVA design as for the reading span scores. There were no significant effects for the preparatory intervals. For the inter-item intervals, there was a significant Cognitive Mood Induction x Trait Anxiety Group interaction effect, $F(1,55) = 7.34$, $p < .01$ (see Figure 6.9). For the Low Trait Anxiety Group, reaction times did not differ as a function of Cognitive Mood Induction condition, $t(30) = 1.42$, n.s. For the High Trait Anxiety Group, shorter reaction times were evident under the Ego Threat Cognitive Mood Induction condition than under the No Ego Threat Cognitive Mood Induction condition, $t(29) = 2.23$, $p < .05$. A noteworthy point is that under the Ego Threat Cognitive Mood Induction condition, the High Trait Anxiety Group exhibited shorter reaction times than did the Low Trait Anxiety Group, $t(28.20) = 2.35$, $p < .05$. As for the reading span scores, the inter-item interval reaction times were reanalysed, this time with trait depression included as a variable in the analysis. The Trait Depression factor was composed in the same manner as for the reading span scores analysis. The reanalysis revealed that the Cognitive Mood Induction x Trait Anxiety Group x Trait Depression interaction was not significant, $F(1,48) = 2.09$, n.s., and the Cognitive Mood Induction x Trait Anxiety Group interaction remained significant, $F(1,48) = 6.01$, $p < .05$. 
Figure 6.9. Means (and standard errors) of inter-item interval reaction times for each Cognitive Mood Induction x Trait Anxiety Group condition for the Reading Span task.

**Error analysis.** The proportion of errors in the comprehension task was obtained by calculating the number of errors across all attempted trials. These were then subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) ANOVA. This did not reveal any significant effects.

Altogether, the results of the reading span scores show that high trait anxious individuals were adversely affected by ego threatening instructions. However, where only correct trials were considered (i.e. performance accuracy was equated), these very same individuals exhibited faster response times. Also, the effects observed on the reading span task were attributed to anxiety rather than to depression.

**6.9.4.2 Grammatical reasoning task.** Proportion of errors. The proportion of errors was calculated for the memory and reasoning subtasks. For the memory subtask, the proportion of errors under Low Memory Load was very low and did not constitute sufficient data for meaningful analysis. Thus, only the proportion of errors
under High Memory Load was considered. This was subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) ANOVA. No significant effects were evident, $F_s < 2.88$.

For the reasoning subtask, the proportion of errors under both Low and High Memory Load conditions were subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) x 2 (Memory Load: Low, High) mixed-design ANOVA, where the last factor was a within-subjects variable and the rest, between-subjects variables. No significant effects were evident, $F_s < 2.82$.

**Reaction times.** Two reaction times were considered – one for the memory subtask, and one for the reasoning subtask. Reaction times were considered only for those trials on which participants responded correctly, and were obtained by calculating the median reaction times across such valid trials. Two outliers were removed from the memory subtask data (one from each Memory Load Condition), while three outliers were removed from the reasoning subtask data (two from the Low Memory Load condition, one from the High Memory Load condition). These data points exceeded three standard deviations of the mean. Both sets of reaction time data were subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) x 2 (Memory Load: Low, High) mixed-design ANOVA, where the latter factor was a within-subjects variable and the rest, between-subjects variables.

For the memory subtask, there was a main effect of Memory Load, $F(1,54) = 321.17$, $p < .001$, with longer reaction times evident under the High Memory Load condition, $M = 1869.71$, $SD = 405.63$, than under the Low Memory Load condition, $M = 1138.32$, $SD = 240.30$. There was also a significant Memory Load x Music Mood Induction interaction, $F(1,54) = 7.26$, $p < .01$ (see Figure 6.10). Reaction times were higher under the High Memory Load than the Low Memory Load for each Music Mood Induction condition, $t_s > 11.93$, $ps < .001$, with this difference more pronounced in the Anxious Music condition than in the Neutral Music condition.
For the reasoning subtask, there was a main effect of Memory Load, $F(1,53) = 60.11, p < .001$, reflecting longer reaction times under the High Memory Load condition, $M = 4689.84, SD = 1826.81$, than under the Low Memory Load, $M = 3484.43, SD = 804.62$. There was also a main effect of Cognitive Mood Induction, $F(1,53) = 8.72, p < .01$, with longer reaction times under the Ego Threat condition, $M = 4574.27, SD = 1245.89$, than under the No Ego Threat condition, $M = 3645.68, SD = 1112.78$. There was also a significant Cognitive Mood Induction x Memory Load interaction, $F(1,53) = 8.59, p < .01$ (see Figure 6.11). Although it appears, from Figure 6.11, that the Cognitive Mood Induction has an effect only under the High Memory Load, it is noted that those under Ego Threat instruction exhibited longer reaction times under each Memory Load condition compared with those under No Ego Threat instruction, $t > 2.32, ps < .05$.

Overall, reaction times were longer in the High Memory Load condition than in the Low Memory Load condition, $t > 3.87$, with this difference more pronounced for individuals.
in the Ego Threat Cognitive Mood Induction condition. That is, the degree of slowing under the High Memory Load condition relative to the Low Memory Load condition was greater for those under the Ego Threat Cognitive Mood Induction condition.

Figure 6.11. Means (and standard errors) of reaction times for the reasoning subtask under each Cognitive Mood Induction x Memory Load condition on the Grammatical Reasoning task.

Altogether, the results suggest that performance accuracy was equivalent for high and low anxious individuals. However, with increasing demands on working memory load, the reaction times on the memory subtask were considerably slowed under anxious music mood induction, whereas the reaction times on the reasoning subtask were considerably slowed under ego threat instruction.

6.9.4.3 Running Verbal task. Memory span scores. Memory span scores were calculated using the fractional scoring method employed in Chapters 4 and 5. There scores were then subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood
Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) ANOVA. No significant effects were evident.

Reaction times. Reaction times were considered only for correct trials, and were parsed into preparatory and inter-item intervals. These were calculated in the same manner as outlined in Chapters 4 and 5. Only those times for Sequence Lengths 2 and 3 were considered, as approximately a quarter of participants did not register a correct response for Sequence Length 4. For Sequence Length 2, one outlier was removed from the preparatory interval and one from the inter-item interval. These data points were more than three standard deviations from the mean. For Sequence Length 3, three participants failed to register any correct responses; furthermore one outlier was removed from the preparatory interval and another from the inter-item interval (criterion determining the removal of these data points was the same as above). Both the preparatory and inter-item intervals were subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Music Mood Induction: Neutral, Anxious) x 2 (Cognitive Mood Induction: No Ego Threat, Ego Threat) x 2 (Sequence Length: 2, 3) mixed-design ANOVA where Sequence Length was a within-subjects variable.

The analysis of preparatory intervals yielded a main effect of Sequence Length, $F(1,51) = 27.03$, $p < .001$, reflecting longer intervals for Sequence Length 3, $M = 2194.90$, $SD = 1426.21$, than for Sequence Length 2, $M = 1152.08$, $SD = 438.41$.

The analysis of inter-item intervals revealed a main effect of Music Mood Induction, $F(1,51) = 4.44$, $p < .05$, and also a significant Sequence Length x Trait Anxiety Group interaction effect, $F(1,51) = 4.35$, $p < .05$, however these were modified by a higher order Sequence Length x Trait Anxiety Group x Music Mood Induction effect, $F(1,51) = 5.16$, $p < .05$ (see Figure 6.12). When this higher order interaction was broken down, a significant Sequence Length x Trait Anxiety Group interaction was isolated to the Neutral Music Mood Induction condition, $F(1,27) = 8.42$, $p < .01$. This indicated that an increase in Sequence Length led to an increase in inter-item intervals for the Low Trait Anxiety Group, $t(14) = 2.79$, $p < .05$, but not for the High Trait Anxiety Group, $t(13) = 1.28$, n.s. To verify that this finding is attributable to anxiety and not to depression, the inter-item interval reaction times were reanalysed, this time with depression included as a variable in the analysis. With the inclusion of the Trait Depression factor in the
Figure 6.12. Means (and standard errors) of inter-item intervals for each Sequence Length x Trait Anxiety Group x Music Mood Induction condition for the Running Verbal task.
analyses, the Sequence Length x Trait Anxiety Group x Music Mood Induction interaction was altered, $F(1,44) = 3.79, p = .058$. The Sequence Length x Trait Anxiety Group x Music Mood Induction x Trait Depression interaction was not significant, $F(1,44) = .34, \text{n.s.}$

In all, these results suggest that anxiety did not adversely affect accuracy on the running verbal task. Furthermore, high anxious individuals do not appear to be disadvantaged by an increased memory load (as reflected in inter-item intervals for Sequence Lengths 2 and 3), which stands in contrast to the results of the grammatical reasoning task.

6.9.4.4 State anxiety and working memory performance. As with the studies reported in the previous two chapters, analyses of the state anxiety ratings did not yield significant trait anxiety x mood induction interaction effects (the exception was a trait anxiety x cognitive mood induction x phase interaction on the POMS Anxiety ratings, however this effect was difficult to interpret). It is, however, possible that state anxiety may still mediate performance on tasks of inhibition and working memory despite the absence of the trait anxiety x mood induction effect. This was examined by correlating state anxiety ratings with indices of performance on the working memory tasks (reading span, running verbal, and grammatical reasoning tasks). Indices of performance reflecting increasing load were also examined (cf. Chapter 5). State anxiety ratings comprised POMS Anxiety and STICS State Cognitive and Somatic Anxiety ratings, averaged across the Post Mood Induction and Post Experiment phases, as well as the CIQ task-relevant scores.

Correlations with state depression ratings were also obtain to address the possibility that state depression may mediate the relationship between anxiety and these performance variables. Where performance indices were correlated with both anxiety and depression ratings, partial correlations were conducted to isolate the effects of anxiety. State depression ratings comprised the POMS Depression ratings, averaged over the Post Mood Induction and Post Experiment phases.
Appendix H (parts b to d) presents the full set of correlational analyses. Overall, state anxiety did not appear to impair working memory performance. This was evident not only for indices of working memory performance per se, but also for indices reflecting increasing load. For the grammatical reasoning task, STICSA State Cognitive Anxiety ratings were negatively correlated with both the proportion of errors for the reasoning subtask under high memory load, as well as with the difference in the proportion of errors for the same subtask with increasing load (i.e. proportion of errors under high memory load – proportion of errors under low memory load). This suggests that elevated levels of cognitive anxiety actually enhanced performance. Similarly, in the reading span task, STICSA State Somatic Anxiety ratings were negatively correlated with preparatory intervals for Set Size 2, indicating shorter reading times with increasing levels of state somatic anxiety, and POMS Anxiety ratings were also negatively correlated with preparatory intervals for Sequence Length 3 of the Running Verbal task. Rather, all effects implicating state anxiety suggest that performance is actually enhanced with increasing levels of state anxiety. No other effects were significant. Importantly, state depression ratings were not linked with performance.

6.9.5 Anxiety, inhibition, and working memory

The role of inhibition in the anxiety-working memory relationship was investigated in two ways in the present study. First, an Inhibition factor was composed and included in the relevant ANOVAs to isolate the contribution of inhibition to the anxiety-related effects evident in the working memory task analyses conducted thus far. This factor was composed by conducting a median split on the degree of slowing index from the directed ignoring task (see Section 6.9.3.1) to yield Low and High Inhibitory Processing Ability levels of the Inhibition factor. Participants in the Low Inhibitory Processing Ability group were those with the higher degree of slowing index (indicating poorer inhibitory processing ability), while participants in the High Inhibitory Processing Ability group were those with the lower degree of slowing indices (reflecting better inhibitory processing ability). Each of the working memory indices that yielded effects involving anxiety (or stress, as is the case in the grammatical reasoning task) were subsequently reanalysed, this time with inhibition included as a factor. For the grammatical reasoning task, this included analyses of reaction times for both the memory and reasoning subtasks. For the reading span task, this included analyses of reading span scores and
inter-item intervals. Finally, for the running verbal task, this included the analysis for inter-item intervals. Results pertaining to these analyses are reported next.

For the reading span task, there was a main effect of Inhibition for the reading span scores, $F(1,48) = 8.83, p < .01$, reflecting higher scores attained by the Low Inhibitory Processing Ability group, $M = 2.68, SD = .63$, than by the High Inhibitory Processing Ability group, $M = 2.28, SD = .46$. However, there was an absence of a significant Cognitive Mood Induction x Trait Anxiety Group x Inhibition interaction, $F(1,48) = 2.02$, n.s., indicating that inhibition did not alter the interaction summarised in the original analysis. The Cognitive Mood Induction x Trait Anxiety Group interaction remained significant, $F(1,48) = 8.49, p < .01$. Analysis of the inter-item intervals for this task indicated revealed an absence of a significant Inhibition effect, $F(1,47) = .37$, n.s., nor was there a significant Cognitive Mood Induction x Trait Anxiety Group x Inhibition interaction, $F(1,47) = .90$, n.s., indicating that inhibition did not alter the interaction summarised in the original analysis. The Cognitive Mood Induction x Trait Anxiety Group interaction remained significant, $F(1,47) = 5.71, p < .05$.

For the grammatical reasoning task, there was an absence of main effects involving Inhibition on reaction times for the memory and reasoning subtasks, $F_s < 1.33$, n.s. There was also an absence of a Memory Load x Inhibition effect for both memory and reasoning subtask reasoning times, $F_s < 1.63$, n.s. Additionally, the Music Mood Induction x Memory Load x Inhibition effect was not significant for the memory subtask, $F(1,46) = 1.52$, n.s., and the Music Mood Induction x Memory Load interaction effect remained significant, $F(1,46) = 6.83, p < .05$. The Cognitive Mood Induction x Memory Load x Inhibition effect was not significant for the reasoning subtask, $F(1,45) = .14$, n.s., and the Cognitive Mood Induction x Memory Load interaction remained significant, $F(1,45) = 7.04, p < .05$. Altogether, these findings suggest that inhibition did not affect performance on this working memory task.

Finally, for the running verbal task, there was no significant effect of Inhibition, $F(1,43) = .32$, n.s. Additionally, the Trait Anxiety x Music Mood Induction x Sequence Length x Inhibition effect was also not significant, $F(1,43) = .24$, n.s., and the Trait Anxiety x Music Mood Induction x Sequence Length interaction remained significant, $F(1,43) =$
4.94, \( p < .05 \). The absence of effects involving Inhibition suggests that this factor does not affect performance on the running verbal task.

The second manner of examining the anxiety-inhibition-working memory relationship utilised in the present study was to employ correlational analyses between the various indices of working memory performance, and also between these indices and the single index of inhibition (degree of slowing index from the directed ignoring task). If inhibition underpins CE resources as asserted by Miyake et al. (2000), this was expected to be manifest in significant correlations between all indices of performance, and between the degree of slowing index and all indices of working memory performance. Only those indices of performance on which anxiety- or stress-linked effects were evident were included in analyses for the focus of the present programme of research was on the anxiety-working memory link, and these included the indices of performance per se as well as indices of increasing load.

Table 6.5 presents the relationships between the indices of working memory performance. From this, it is evident that within each working memory task, indices of performance were often correlated (with the exception of the reading span task). However, the correlations of interest concerned those computed between indices from different working memory tasks. Overall, performance on the running verbal task was not strongly related to performance on the other two tasks, while a clear pattern emerged wherein reading span scores of the reading span task were related to performance on the grammatical reasoning task.

Regarding the relationships between the index taken from the directed ignoring task and all indices of working memory performance, the correlational analyses revealed a significant relationship between the degree of slowing index and reading span scores, \( r(64) = -.31, p < .05 \). This is consistent with the results reported for the reanalyses incorporating the Inhibition factor reported earlier in this section, wherein the Inhibition factor was found to affect reading span score performance. Importantly, no other significant effects emerged from this analysis (\( r_s < .25, \text{n.s.} \)).
Table 6.5. Correlations between indices of working memory performance on which anxiety- or stress-linked effects were significant.

<table>
<thead>
<tr>
<th>Running verbal</th>
<th>Reading span</th>
<th>Grammatical reasoning</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>.29&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>-.61&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>-.22</td>
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<tr>
<td>5</td>
<td>.06</td>
<td>.27&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>-.02</td>
<td>.10</td>
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<td>7</td>
<td>.15</td>
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<td>.29&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>11</td>
<td>-.03</td>
<td>.22</td>
</tr>
</tbody>
</table>

Note: 1 = Inter-item interval for Sequence Length 2  
2 = Inter-item interval for Sequence Length 3  
3 = 2 - 1  
4 = Reading span score  
5 = Inter-item interval for Set Size 2  
6 = Reaction times under Low Memory Load, memory subtask  
7 = Reaction times under High Memory Load, memory subtask  
8 = 7 - 6  
9 = Reaction times under Low Memory Load, reasoning subtask  
10 = Reaction times under High Memory Load, reasoning subtask  
11 = 10 - 9  
<sup>a</sup> denotes p < .001; <sup>b</sup> denotes p < .01; <sup>c</sup> denotes p < .05

Altogether, the analyses reported in this section indicate that inhibition contributes to performance only on the reading span task. However, performance on the reading span task and on the grammatical reasoning task were correlated despite an absence of contribution of inhibition to the latter task. This suggests that although impairments in working memory performance due to anxiety or stress are mediated by inhibition, there are clearly other factors that are also implicated.

6.10 Discussion

Although the present chapter was initially motivated by the lack of a robust anxiety-working memory performance link in the preceding chapter, evolving research into the fractionation of the CE (e.g. Baddeley, 1996a; Bull & Scerif, 2001; Miyake et al., 2000),
the demonstration that the CE process of updating may not be impaired by elevated levels of anxiety (Dutke & Stöber, 2001), and the identification of inhibition as a potential process unifying CE processes (Miyake et al.) together with a demonstrated anxiety-inhibition link (Dalgleish, 1995; Fox, 1994; Hopko et al., 1998; Linville, 1996), led to a shift in the focus of the chapter. Specifically, a consideration of the above body of research questioned whether greater specification of the CE component of working memory is necessary within the PET, or whether the current conceptualisation of a unified CE system is adequate. Altogether, these considerations led to the identification of four aims. The first centred on establishing an anxiety-working memory link and the implications of the present programme of research for the predictions of the PET. The second aim was to examine the relationship between anxiety and inhibition. The third aim concerned whether state or trait anxiety, or situational stress, is responsible for anxiety-linked impairments in working memory and inhibitory processes. Regarding the anxiety-working memory relationship, additional mediating factors discussed in Section 1.6 (i.e. comorbid depression, cognitive versus somatic anxiety) will be explored in the discussion that follows. The fourth aim was focused on evaluating the extent to which inhibition mediates the relationship between anxiety and working memory. Prior to reviewing outcomes with respect to these aims, participants’ trait mood and the efficacy of the mood induction procedures will be discussed, for these set the context within which these aims may be evaluated.

6.10.1 Trait mood and efficacy of mood induction procedures

High trait anxious individuals differed from their low trait anxious counterparts not only on all ‘types’ of trait anxiety (somatic, cognitive, and also general), but also on measures of trait depression and trait worry. Trait anxiety levels were also strongly linked with state anxiety levels.

Regarding the mood induction procedures, the music mood induction procedure employed was effective in that the anxious music elevated anxiety ratings while the neutral music decreased (as in the case of the POMS Anxiety ratings) or did not elevate (in the case of the STICSA State Somatic Anxiety ratings) state anxiety levels, findings that replicate those of Chapter 4. Together, these results strongly suggest that the absence of an effect of the music mood induction manipulation on state anxiety variables recorded in the two phases of the experiment reported in Chapter 5 was
probably due to the exclusion of the administration of mood measures in the post mood induction phase. The results of the cognitive mood induction suggest that while it had an effect on CIQ task-relevant scores, no effect was evident on the STICSA State Cognitive Anxiety ratings. Instead, there was an effect of the music mood induction procedure on the STICSA State Cognitive Anxiety ratings. Additionally, the music mood induction analyses also concur with those of Chapter 4 in that anxious music appears to be selective in its effects on mood, with no effect on state depression ratings evident.

For the analyses examining the efficacy of the mood induction procedures, an important finding was that there was an absence of interactions involving trait anxiety and cognitive mood induction on measures of state anxiety (with the exception of the POMS Anxiety ratings, however this finding also involved experimental phase and was not easily interpreted). The overall absence of interactions involving trait anxiety and cognitive mood induction on state anxiety ratings is important because the PET states that it is state cognitive anxiety (specifically, worry) that is responsible for impaired working memory performance, and cognitive anxiety is presumed to be manifest by high trait anxious individuals placed under evaluative stress. While effects were manifest on CIQ task-relevant ratings, these reflected independent effects of experiencing the ego threat instructions, and trait anxiety. That is, no interaction of these two factors was observed.

### 6.10.2 Anxiety and working memory: Evaluating the PET

According to the PET, anxiety-linked impairments are expected to be more pronounced on measures of efficiency than on measures of effectiveness. Furthermore, these impairments are purported to become more pronounced for high than for low anxious individuals with increasing task complexity. This chapter sought to build on the findings of the previous chapter in relation to the specific predictions of the PET (Predictions 1.4, 1.5, and 2.3) as well as evaluating the additional predictions regarding secondary task performance (Predictions 1.2) and the interference of a concurrent load on performance (Prediction 2.1). Prior to discussing the results of this study for the specific predictions of the PET, the findings from this study regarding working memory task performance will be briefly summarised.
The present study utilised several working memory tasks in a bid to determine if the absence of effects observed in the previous chapters was due to the tasks utilised. One task from the previous two studies – the running verbal task which, of the four span tasks, would be the one expected to reveal anxiety-linked performance impairments – was retained in this present study. Performance on this task in this study contrasted with the findings reported in Chapter 5. In the previous study, there was an effect of cognitive mood induction on reaction times on the same running task (i.e. running verbal, see Figure 5.8). The experience of ego threat instructions elicited a greater increase in preparatory intervals with increasing sequence length (denoting an increase in demands on working memory), and also yielded faster inter-item intervals under the lower sequence length (lower memory load condition). In the present study, however, anxiety-linked impairments were restricted only to the inter-item intervals (see Figure 6.12), moreover it was the operation of trait anxiety, in conjunction with music mood induction – rather than the cognitive mood induction alone as was the case in Chapter 5 – that elicited this difference. Altogether, the contrasting findings observed on the same task across the two studies reported here and in Chapter 5 suggest that the running verbal task may not be sensitive to anxiety-linked decrements in cognitive performance.

The results of the reading span and grammatical reasoning tasks were more promising. Consistent with the findings of Darke (1988a) and Sorg and Whitney (1992), anxiety-linked impairments were observed on reading span scores. While these studies assessed performance using only accuracy (span) scores, the present study also utilised reaction times (which were parsed into preparatory and inter-item intervals). The reading span scores and inter-item intervals both revealed interactions involving cognitive mood induction and trait anxiety group. Reading span scores for the low trait anxious individuals did not differ according to cognitive mood induction condition, however the experience of ego threat instruction resulted in lower span scores for high trait anxious individuals (see Figure 6.8). Interestingly, where accurate responses alone were considered – as in the case of the inter-item interval analyses – the experience of ego threat instructions actually resulted in shorter reaction times for high trait anxious individuals (see Figure 6.9). Thus, ego threat appeared to effect a shift in speed-accuracy trade-off for the high trait anxious participants – they responded faster, but less accurately. No effect of cognitive mood induction was evident for low trait anxious individuals on the same measure.
The results of the grammatical reasoning task in this study were consistent with the findings of Derakshan and Eysenck (1998) and C. MacLeod and Donnellan (1993), who found anxiety-linked impairments on performance on the reasoning subtask. Whereas Derakshan and Eysenck attribute this to elevated levels of state anxiety (trait anxiety interacting with ego threatening instruction), C. MacLeod and Donnellan attribute this to elevated levels of trait anxiety. Both of these interpretations, however, run contrary to the findings reported here. In the present study, it was the experience of ego threat instruction – rather than elevated state anxiety levels – that resulted in a greater increase in reaction times under increasing memory load on the reasoning subtask (see Figure 6.11; see also Section 6.9.4.4 reporting correlations between state anxiety and indices of working memory performance). A similar effect was also evident on the reaction times for the memory subtask, however this was attributed to the music mood induction, rather than the cognitive mood induction (see Figure 6.10). In this regard, it appears that the debilitating effects of anxiety may not be specific to cognitive anxiety.

The findings reported above provide only mixed support for assumptions and specific predictions evaluated in this chapter (Predictions 1.2, 1.4, 1.5, 2.1 and 2.3). At the outset, the effectiveness/efficiency distinction made by the PET was examined by considering measures of accuracy (e.g. memory span scores, proportion of errors) and reaction times. As in the previous chapter, it is acknowledged that although reaction time measures are commonly adopted in the anxiety and working memory literature as an index of processing efficiency, this is an untested prediction of the theory (Prediction 1.6), and the broader cognition literature often interprets accuracy and reaction time as alternative indices of task difficulty (Allen Osman et al., 2000). Anxiety-linked impairments in performance were evident on both accuracy (reading span task, see Figure 6.8) and reaction times (grammatical reasoning task, see Figures 6.10 and 6.11).

The PET also states that worry, a cognitive component of state anxiety, is responsible for anxiety-linked impairments in performance, and it would therefore be expected that anxiety-linked impairments in performance would implicate a trait anxiety x cognitive mood induction interaction. There was some support for this contention in the reading span task analyses (see Figure 6.8). The reading span scores indicated that the
cognitive mood induction manipulation did not affect the performance of low
trait anxious individuals, but high trait anxious individuals were disadvantaged when under
ego threat instruction compared to no ego threat instruction. However, a contrary
pattern was observed in the analyses for inter-item interval reaction times for the same
task, where high anxious individuals actually benefited from ego threat instruction,
exhibiting shorter reaction times on task performance. This was observed where
performance accuracy was equated between high and low anxious individuals (as only
trials that were answered correctly were considered), suggesting that if reaction times
were indeed an index of efficiency, then high anxious individuals may actually be more
efficient than low anxious individuals. This finding contrasts with the prediction of the
PET (Prediction 1.6), which states that high anxious individuals are characterised by
lower efficiency.

The utilisation of the reading span and grammatical reasoning tasks permitted an
analysis of Prediction 1.2, which states that anxiety typically affects secondary task
performance. There was mixed support for this prediction from the reading span task
analyses. While the proportion of errors was equivalent across groups, and
performance impairments were observed on the memory component of this task, it is
noted that the inter-item interval analysis yielded a pattern opposite to that predicted by
the PET.

Prediction 1.4 concerns motivational factors that enhance effort, specifically that such
factors benefit the performance of low anxious individuals to a greater extent than they
do the performance of high anxious individuals. This prediction was not supported. In
the reading span analyses, the cognitive mood induction procedure did not differentially
impact on the reading span scores or reaction times of low trait anxious individuals.
Again, it is acknowledged that the ego threat instruction procedure can engender worry
which may complicate an interpretation of this effect.

Prediction 1.5, that an additional load would adversely affect performance on central
tasks to a greater extent in high anxious than low anxious individuals, was evaluated in
two ways in this study. The first compared the impact of increasing sequence length on
the running verbal task. This revealed an interaction in the inter-item interval reaction
times involving sequence length, trait anxiety, and music mood induction that,
unexpectedly, involved differences restricted to the neutral music mood induction condition (see Figure 6.12). In this condition, high anxious individuals, unlike low anxious individuals, were not impaired by an additional load. This finding contradicts the PET, which states that high anxious individuals should be more impaired by the imposition of an additional load than should low anxious individuals. The second way of evaluating Prediction 1.5 contrasted the effects of high and low memory load on the performance of the reasoning subtask of the grammatical reasoning task (see Figure 6.11). This revealed that an additional load did disproportionately impair performance when participants experienced cognitive stress. However, this effect did not appear to involve state anxiety (refer to Section 6.9.4.4), as would be expected if the effect involved trait anxiety and situational stress. Thus, this prediction of the PET received partial support.

Prediction 2.1 states that the effects of anxiety on performance is contingent on the demands a task makes on resources, and that this is examinable using a concurrent load. The grammatical reasoning task, which requires participants to retain a string of digits imposing either a low or high memory load while concurrently performing a reasoning subtask, is an exemplar of this experimental paradigm. The findings from this study indicated that the experience of cognitive stress had the impact of affecting performance on the reasoning subtask (as reflected in reaction times) such that those under ego threat instruction were slower than those not under ego threat instruction. Furthermore, with a greater concurrent load imposed, this impairment was more pronounced (see Figure 6.11). This result perhaps presents the most convincing outcome in favour of the PET, however it must be noted that the correlations reported in Appendix H suggest that this effect was not mediated by state anxiety.

Prediction 2.3 states that anxiety-linked impairments will be more pronounced on tasks with high storage and processing demands. One of the concerns raised in Chapter 5 was that the running memory tasks were possibly not sufficiently demanding on resources to reveal anxiety-linked impairments. Adopting this approach, it may be argued, then, that anxiety-linked impairments evident on the reading span and grammatical reasoning tasks but not on the running verbal task reflect the greater demands the former two tasks impose. In this regard, this prediction of the PET is supported. However, the argument is somewhat circular (the reading span and
grammatical reasoning tasks are argued to be more demanding because they show the anxiety- and stress-linked impairments). Furthermore, an alternative interpretation that cannot be ruled out is that the absence of effect on the running task may be due to the fact it engages a different CE process (updating) and that this process may not be impaired by anxiety (Dutke & Stöber, 2001).

Regarding the mood factors that complicate an interpretation of the anxiety-working memory relationship (i.e. comorbid depression, state versus trait anxiety, and cognitive versus somatic anxiety), it may be concluded that (a) trait depression generally did not alter those interaction effects involving trait anxiety (the exception was the inter-item interval analyses for the running verbal task), neither were state depression ratings linked with working memory performance; (b) while there was some suggestion that state anxiety – as indicated by interactions involving trait anxiety and situational stress – was the source of impairment, correlational analyses of state anxiety ratings with indices of working memory performance failed to support this observation; and (c) it appears that the experience of stress – particularly that which is cognitive in form – is linked with impairments in performance either alone or in interaction with trait anxiety, and these effects are not mediated by state anxiety.

Altogether, the findings of the present study provide only limited support for the predictions of the PET. Furthermore, the findings also question some of the assumptions of the PET pertaining to the state/trait anxiety distinction. Specifically, while there were observations of trait anxiety x cognitive mood induction interactions on indices of working memory performance, this was not actually reflected in the state anxiety scores, moreover cognitive stress alone was often implicated in effects on working memory performance.

6.10.3 Inhibition – mediating the anxiety-working memory relationship?

The second aim of the study was to investigate whether elevated levels of anxiety are associated with impaired inhibitory processing. The results of the directed ignoring task provide support for this relationship. The relationships between trait anxiety, mood manipulations, and three specific comparisons – the lexical status of the distractor (i.e. word vs. strings of Xs), semantic relevance of the distractor, and emotionality of distractor – were of particular interest. The results revealed that the cognitive mood
manipulation interacted with the first comparison, such that equivalent paragraph reading times for the two mood conditions were apparent on X-strings, however longer reading times were evident under ego threat instruction than under no ego threat instruction on word distractors. The other comparisons did not interact with mood manipulations or trait anxiety, suggesting a general deficit in inhibitory processing, which is consistent with the findings of Hopko et al. (1998) and Sachse (2000). The findings of a general deficit in inhibitory processes contrast with the tendency for high anxious individuals to be disproportionately affected by threatening stimuli as evidenced in some studies employing the emotional Stroop (e.g. C. MacLeod & E.M. Rutherford, 1992; Mogg et al., 1990). It is not entirely clear why threatening stimuli affect inhibitory processing on the emotional Stroop and not other tasks, although factors such as the subliminal versus supraliminal presentation of stimuli studied within the emotional Stroop literature are possible explanations.

A related topic that formed the third aim of this study is whether state or trait anxiety is responsible for any observed impaired inhibitory processing. The review of the emotional Stroop and negative priming literature thus far is inconclusive. As for the directed ignoring studies, Hopko et al. (1998) found an effect of trait mathematics anxiety and Sachse (2000) also implicated trait anxiety in impaired inhibitory processing, however the latter utilised evaluative stress whereas the former did not. As Sachse (2000) subjected all participants to evaluative stress, it remains possible that the results of this study may have reflected a trait x stress interaction. In contrast, the findings of this study suggest that it is the presence of evaluative stress alone, rather than trait anxiety alone or the interaction of trait anxiety and stress, that is responsible for impaired inhibitory processing. Differences between the three studies may reflect the methodology employed – Hopko et al. examined trait mathematics anxiety but did not examine evaluative stress, Sachse examined trait anxiety and all participants experienced evaluative stress, whereas the present study examined trait anxiety and systematically manipulated evaluative stress.

The fourth aim of the study was to investigate the extent to which inhibition mediates anxiety-linked impairments in working memory performance. Integrating the PET with Hasher and Zack’s (1988) inhibition theory, Hopko et al. (1998) suggested that inhibition affects the anxiety-working memory relationship such that it is not the degree
to which the individual experiences non task-focused thoughts that determines performance, but rather the ability to minimise the impact of such distracting thoughts by preventing their access to working memory. This integrative account received some support, with the demonstration that inhibition accounted for some of the variance on reading span scores.

However, it is important to note that inhibition does not appear to provide a complete account of the relationship between anxiety and working memory. Although inhibition itself accounted for some variance on reading span performance, the trait anxiety x cognitive mood induction x inhibition interaction was not significant and the trait anxiety x cognitive mood induction interaction remained significant. Furthermore, inhibition was not correlated with indices of performance on the grammatical reasoning and running verbal tasks, and reading span scores were correlated with grammatical reasoning task performance despite an absence of relationship between indices of performance on the grammatical reasoning task and inhibition. These findings shed light on the contradiction that exists between Dutke and Stöber’s (2001) hypothesis that anxiety does not affect the process of updating, and Miyake et al.’s hypothesis that inhibition underpins CE processes. These contradictory hypotheses led to one of two possibilities – either (a) anxiety does not affect inhibition and, consequently, does not affect updating; or (b) inhibition is not linked with the process of updating, thereby permitting a link between anxiety and impaired inhibitory processes, but not one between anxiety and updating. The findings of this study support the latter contention that inhibition does not underlie performance on all working memory tasks that engage the CE, with no effects of inhibition on the running verbal task. Thus, fractionable CE processes are supported, but inhibition as a unifying strand between these fractionated processes is not.

6.10.4 The PET – A need for greater specification?

Altogether, the findings of the present study have implications for the PET, and also the anxiety-working memory literature more generally. Importantly, this study makes the recommendation that greater specification of the CE component of the working memory be sought within the PET to delineate fractionable CE processes. It was established (see Section 6.9.5) that although inhibition was linked with some indices of working memory performance (reading span task), it did not underpin performance on all of the
working memory tasks that engage the CE (i.e. no effect on the updating and grammatical reasoning tasks). Furthermore, performance on the reading span task was linked with performance on the grammatical reasoning task despite the latter itself not being linked with inhibition (refer to Table 6.5). Together, these findings make a clear argument for fractionable CE processes, refuting the conceptualisation of the CE as a unified system (Baddeley, 1986).

In supporting fractionable CE processes, the next logical step would be to identify which processes may be fractionated and, more importantly for the purpose of the present programme of research, which processes are affected by anxiety. The findings of the present study, together with literature into the inhibition-working memory relationship (e.g. May et al., 1999), have identified inhibition as one such process. Importantly, for the PET, the available evidence suggests that this CE process is adversely affected by anxiety (Hopko et al., 1988) or stress (see Section 6.9.3 of this chapter). Updating is another fractionable CE process, however it seems to be unaffected by stress or by anxiety (Dutke & Stöber, 2001; see also Section 6.9.4.3).

What other fractionable CE processes may be delineated? The correlational analyses presented in Table 6.5 indicates that reading span scores were correlated with performance on the grammatical reasoning task in spite of an absence of effect of inhibition on performance on the latter task. This finding suggests that there is a common source of variance in the performance of these two working memory tasks that is not tapped by inhibition, furthermore that this underlying process is susceptible to anxiety. It is interesting to speculate what this underlying process that is common to both the reading span and grammatical reasoning tasks may be. The obvious candidates would be shifting and dual tasking, for both these tasks require the coordination of two distinct components (i.e. processing sentences and remembering words in the reading span task, and remembering digit strings and verifying relational statements in the grammatical reasoning task). This is apparent in the grammatical reasoning task where switching between the memory subtask and the reasoning subtask is required, however it may be less clear in the reading span task where the two components of task performance are more intimately linked.
Distinguishing between shifting and dual-tasking, however, is not an easy process, because there are obvious commonalities between the two (Collette & Van der Linden, 2002). Engle, Kane, and Tuholski (1999) suggest that reading span task may actually be a form of dual-tasking, which appears to be analogous to the CE process that Miyake et al. (2000, p. 55) identify as ‘shifting’, for this process involves shifting “back and forth between multiple tasks, operations, or mental sets”. Despite the similarities between the two processes, Miyake et al. unexpectedly found that shifting did not contribute to dual task performance.

Clearly, the CE processes outlined above may only be a few of many fractionable processes (Miyake et al., 2000), and it is with evolving research into the fractionation of CE processes that a greater number of such processes may be identified. It is recommended that the anxiety-working memory literature be closely aligned with research into the fractionation of CE processes, for this permits a more comprehensive picture of the mechanisms via which anxiety affects working memory performance. For instance, the findings of the present study suggest that the process of updating (as assessed by the running verbal task) may not actually be impaired by elevated levels of anxiety, whereas inhibition (as assessed by the directed ignoring task) is impaired. It will be interesting to observe, with greater fractionation of the CE, which other processes may mediate the relationship between anxiety and working memory. An investigation of the role these processes play in mediating the anxiety-working memory relationship stands to benefit from adopting the approach utilised in the present study – that is, establishing a link between anxiety and the processes of interest and, in turn, establishing a link between the processes of interest and working memory performance.

6.10.5 Chapter summary

To conclude, while the present study was initially motivated by an absence of robust anxiety-linked impairments in working memory performance in the previous study, it has evolved considerably into a study that explores the adequacy of the current PET model. The most important contribution this chapter makes to the anxiety-working memory literature is in arguing for greater specification of CE processes within the working memory system of the PET, and this has arisen from contrasting findings concerning how anxiety affects different CE processes. Specifically, the updating processes does not appear to be impaired by anxiety (consistent with the absence of robust effects in
the previous chapter) whereas the process of inhibition is susceptible to anxiety. Additionally, the findings of this chapter suggest that although a relationship between anxiety and working memory performance was evident, this was not entirely consistent with the predictions of the PET. Most notably, stress, rather than anxiety, was predominantly implicated in effects on working memory performance. Stress was also implicated in impaired inhibitory processes, and while this impairment accounted for some variance in working memory performance, it is clear that there are other factors at play in the anxiety-working memory relationship. Directions for future research were recommended, suggesting a closer alignment with literature on the fractionation of CE processes in order to evaluate which of these processes serve to mediate the anxiety-working memory relationship.
CHAPTER 7: GENERAL DISCUSSION

7.1 Overview

The initial focus of this thesis was to evaluate the PET in its account of the anxiety-working memory relationship, and to also address factors mediating this relationship. The evaluation of these aims is reviewed in the present chapter, which comprises five sections. In the first section, the theoretical underpinnings of the anxiety-working memory literature are briefly recounted. This has a focus on the predictions of the PET. However, in the evolution of the present programme of research, it became apparent that the current model of the PET may be insufficiently detailed regarding the CE component of working memory, and this is discussed briefly in this section. In the second, the empirical studies conducted in the present programme of research – and their implications for the PET – are discussed. This encompasses: (a) methodological considerations raised in Chapters 2, 3, and 4; (b) evaluation of the PET on the basis of the studies reported in Chapters 5 and 6, together with a discussion of factors mediating the anxiety-working memory relationship; and (c) evaluation of the role of inhibition in mediating this relationship. The third section reconciles the results of the present programme of research with the PET. The fourth section revisits the issue of comorbid depression, and provides a more in-depth consideration of the implications this holds for the anxiety-working memory relationship. The fifth section makes suggestions for future research. Finally, the discussion regarding the relationships raised in the preceding sections is concluded.

7.2 Summary of the theoretical underpinnings of the anxiety-working memory literature

As introduced in Chapter 1, a dominant theory in the conceptualisation of the anxiety-working memory relationship, the Processing Efficiency Theory (PET), was proposed by Eysenck and Calvo (1992). The PET is premised on Baddeley and Hitch’s (1974) tripartite working memory model. The tripartite working memory model posits that working memory is comprised of a modality-free central executive, which coordinates information from two slave systems – one responsible for the storage of verbal information (the PL), the other responsible for the storage of visuospatial information (the VSSP).
According to the PET, anxiety affects working memory via worry, or the cognitive component of state anxiety. Worry has two effects. First, it serves to pre-empt capacity in the CE and, to a lesser extent, the PL, of the tripartite model of working memory. Second, worry can initiate additional effort and/or processing strategies to counter the negative effects of itself. The PET draws a distinction between effectiveness and efficiency as indices of performance. It is proposed that anxiety impacts on working memory such that (a) processing efficiency is impaired to a greater extent than is performance effectiveness; and (b) impairments in performance are more pronounced with increasing demands on working memory capacity. Central to the relationship between efficiency and effectiveness is the notion of effort. Eysenck and Calvo (1992) propose that efficiency may be conceptualised as effectiveness divided by effort.

Several factors mediating the anxiety-working memory relationship were also identified. These related to distinctions between state and trait anxiety, and between cognitive and somatic anxiety. The issue of comorbid depression was also considered. Also under scrutiny was the nature of the working memory tasks employed to investigate the anxiety-performance relationship.

As the present programme of research evolved, a pertinent question raised concerned whether the PET, which currently conceptualises the CE as a unitary system, is sufficiently detailed, or whether greater specification regarding the CE component of the working memory model was required within the PET. This arose from the absence of anxiety-linked deficits in working memory performance in Chapter 5, along with evolving literature into the fractionation of CE processes (e.g. Miyake et al., 2000) and research suggesting that not all CE processes are impaired by anxiety (Dutke & Stöber, 2001). Together, these findings queried the need for greater specification of what CE processes are expected to be impaired by anxiety.

7.3 Review of empirical studies

There are three distinct phases in discussing the empirical studies that comprised this research programme. First, methodological considerations relating to working memory tasks and measures of anxiety were addressed in Chapters 2, 3, and 4. Chapter 4 also explored a role for somatic anxiety in the anxiety-working memory relationship. Second, the relationship between cognitive anxiety and working memory was directly
assessed in Chapters 5 and 6. Third, and finally, the mediating role of inhibition in the anxiety-working memory relationship was additionally evaluated in Chapter 6.

### 7.3.1 Methodological considerations

Several methodological considerations were apparent in the existing anxiety-working memory literature. The first methodological consideration concerned the role of comorbid depression in this relationship. This is problematic as depression itself has been linked with impaired working memory performance in a manner similar to the link suggested between anxiety and working memory (see Section 1.6.2). The first step towards isolating the effects of anxiety was to identify measures that maximised the distinction between anxiety and depression at the trait level. This formed the focus of Chapter 2, which identified the DASS Depression and Anxiety scales as suitable tools.

The second methodological consideration regarded the nature of the working memory tasks. Specifically, Chapter 1 identified tasks for assessing all three working memory systems that were comparable in nature (i.e. verbal and visuospatial span tasks, and fixed and running versions of each). Chapter 3 sought to further explore the suitability of the verbal and visuospatial span tasks, and to develop task formats that minimise differences in task characteristics. The results of this study supported the utility of the spatial span task and a visual/manual format of the verbal span task.

Two additional considerations were raised in the literature review presented in Chapter 1. One concerned the distinction between state and trait anxiety that is often not the focus of empirical scrutiny. Often, the presence of a trait anxiety x mood induction interaction on measures of performance is taken to reflect the involvement of state anxiety, without necessarily measuring this (e.g. Darke, 1988a). The state/trait relationship was examined in the context of the cognitive/somatic distinction, with the latter forming the fourth consideration raised in the literature review. Chapter 4 then reported an exploratory study into a possible role for somatic anxiety in the anxiety-working memory relationship. The results of this study indicated a trait anxiety x music mood induction interaction in affecting working memory performance, however this was in a direction contrary to that expected (i.e. fixed tasks, rather than running tasks, were affected). Additionally, the results of this study (and also the studies reported in Chapters 5 and 6, where the state/trait distinction was further evaluated) suggested that
state anxiety levels are not necessarily affected by the trait anxiety-mood induction interaction. The cognitive/somatic distinction was explored more fully in Chapters 5 and 6, where manipulations to engender both forms of anxiety were employed.

**7.3.2 Evaluating the PET**

The predictions of the PET were explored empirically in Chapters 5 and 6. The two central predictions of the PET – that (a) processing *efficiency* is impaired to a greater degree than is performance *effectiveness*; and (b) impairments in performance are more pronounced with increasing demands on working memory capacity – received partial support. Under each of these tenets, several specific predictions were delineated, and the findings in relation to the predictions evaluated in this programme of research are presented in Table 7.1. What follows is an overall interpretation of these findings in relation to the PET.

The PET suggests that processing efficiency (i.e. effectiveness divided by effort) is impaired to a greater extent than is performance effectiveness (i.e. quality of output). Indeed, the PET was developed to account for inconsistencies in the existing literature wherein some studies found anxiety-linked impairments, while others found equivalent performance between high and low anxious individuals and even instances where anxiety enhanced performance. Eysenck and Calvo (1992) argued that these inconsistencies arise due to the focus on effectiveness as an index of performance, and suggested that anxious individuals may enhance effort to offset an already reduced working memory capacity in order to attain a comparable level of effectiveness. Thus, while effectiveness may be equivalent with the application of extra effort, this comes at a cost, as reflected in lower processing efficiency. The pattern of results on accuracy and span scores – which may be regarded as indices of performance effectiveness – in this present programme of research are consistent with this observation. In one instance, elevated levels of anxiety impaired performance (as reflected in the reading span scores reported in Chapter 6; see Figure 6.8), but in other instances it resulted in equivalent or superior performance (see fixed span scores reported in Chapter 5, and Figure 5.6; accuracy scores for the grammatical reasoning and reading span tasks in Chapter 6).
Table 7.1 Summary of findings from the present programme of research in relation to the predictions of the Processing Efficiency Theory

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Evaluated in</th>
<th>Outcome</th>
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</table>
| 1.2 Anxiety typically impairs secondary task performance. | Chapter 6 | - *Reading span task*. Anxiety affected some aspects of performance (e.g. reading span scores, and inter-item reaction times). The patterns of interactions were such that they involved both the cognitive stressor and trait anxiety. Reading span scores were equivalent for low trait anxious individuals irrespective of cognitive mood induction condition, however for high trait anxious individuals, ego threat instruction resulted in lower span scores (see Figure 6.8) which is consistent with Prediction 1.2. For the inter-item reaction times, no differences for cognitive mood induction were evident for low trait anxious individuals, however high trait anxious individuals were faster under ego threat instruction than under no ego threat instruction (Figure 6.9), thus performance was actually enhanced in this instance.

- *Grammatical reasoning task*. On the reasoning task component of this task, reaction times were longer under ego threat instruction than under no ego threat instruction. There was also an interaction effect involving cognitive mood induction and memory load – indicating that performance under ego threat and no ego threat conditions was equivalent when demands on the CE were minimised, but with greater demands on the CE, longer reaction times were evident for those under ego threat instruction (Figure 6.11). This is partly consistent with Prediction 1.2, for it is noted that the effects involved cognitive stress rather than anxiety *per se*. |
Table 7.1 (continued)

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Evaluated in</th>
<th>Outcome</th>
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</table>
| **1.4** Motivation-enhancing manipulations benefit high anxious individuals to a lesser extent than they do low anxious individuals. **Chapters 5 & 6**, where ego threat instructions were utilised. | - Accuracy was equivalent for individuals under ego threat and no ego threat conditions in several instances (e.g. running verbal span scores in Chapter 6, accuracy on the reasoning task component of the grammatical reasoning task in Chapter 6). In some situations (e.g. memory span scores on fixed span tasks in Chapter 5) the accuracy scores were higher for participants under ego threat conditions than for those not under ego threatening conditions (see Figure 5.2), however this effect did not implicate trait or state anxiety. Finally, ego threat instructions did not enhance the performance of low trait anxious individuals on the reading span task (see Figure 6.8).  
- On reaction time measures, it was evident in several situations that ego threat instructions resulted in participants performing faster (where reaction time is taken as an index of efficiency, e.g. inter-item reaction times for running verbal task in Chapter 5, see Figure 5.9). Again, trait anxiety group was not implicated. Also, ego threat instructions did not enhance the performance of low trait anxious individuals on the reading span task (Figure 6.9). | |
| **1.5** Impairments in performance are more pronounced under conditions of increasing load for high anxious than low anxious individuals. **Chapters 5** | - Accuracy on the span tasks was not impaired for high anxious individuals.  
- Regarding reaction times, it is noted that in some situations, high anxious individuals were not impaired on central executive tasks to a greater extent than were low anxious individuals, however there was some support for increasing task complexity engendering greater impairments for high anxious individuals (see Figure 5.5).  
- No evidence of greater impairment for anxious individuals on measures of accuracy. It does appear that on the more complex working memory tasks (e.g. grammatical reasoning task) there is some evidence that high anxious individuals are more impaired on reaction times (see Figure 6.11). | }
Table 7.1 (continued)

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Evaluated in</th>
<th>Outcome</th>
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<tbody>
<tr>
<td>2.1  The degree of anxiety impairment is contingent on the demands the task makes on processing resources, which may be assessed using a concurrent load paradigm.</td>
<td>Chapter 6</td>
<td>- This prediction was partially supported by the results from the grammatical reasoning task, wherein the retention of strings of digits impaired the performance of individuals under ego threat instruction on the reasoning subtask. This impairment was more pronounced when the digit strings imposed a high memory load. Note: it was ego threat instruction, rather than state anxiety, which was involved in this effect.</td>
</tr>
<tr>
<td>2.2  Anxiety limits the available storage capacity.</td>
<td>Chapters 4 &amp; 5</td>
<td>- No evidence that anxiety adversely affected verbal storage capacity (specifically, the fixed verbal span task).</td>
</tr>
<tr>
<td>2.3  Anxiety-linked impairments in performance will be most pronounced on tasks with heavy storage and processing demands.</td>
<td>Chapter 6</td>
<td>- Similar to that noted for Prediction 2.1, anxiety did not have equivalent effects on the working memory tasks utilised in Chapter 6 (greatest impairment on grammatical reasoning task, least impairment on running verbal span task). This could reflect differing demands these tasks make on storage and processing resources (although see Section 7.3.2.1).</td>
</tr>
<tr>
<td>2.4  Anxiety-linked impairments are not typically observed on tasks that tap neither the CE nor PL.</td>
<td>Chapter 5</td>
<td>- Generally, there was an absence of a relationship between anxiety and performance on tasks that tap neither the CE nor PL (i.e. on the fixed spatial span task which is expected to tap the VSSP).</td>
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</tbody>
</table>
Eysenck and Calvo (1992) suggest that the distinction between effectiveness and efficiency may be tested when effectiveness is equated for high and low anxious individuals. In such an instance, it is expected that the former have expended increased effort in order to attain an equivalent level of performance. Eysenck and Calvo propose that this may be examined by employing a variety of methods, including assessing subjective effort, utilising a secondary task, utilising a loading paradigm, manipulating the level of motivation (for this is related to effort and, in turn, efficiency), as well as recording processing times. The latter is considered to be a measure of efficiency because one manner in which high anxious individuals can overcome a restricted working memory capacity is to increase the amount of time taken to process information. Thus, while effectiveness may be comparable for high and low anxious individuals, high anxious individuals may actually take longer to attain this (Prediction 1.6).

Processing time has been readily adopted as an index of efficiency in most of the anxiety-working memory studies published subsequent to this theory (e.g. Calvo et al., 1994; Derakshan & Eysenck, 1998; Elliman et al., 1997; Ikeda et al., 1996). Employing this measure of processing efficiency in the present programme of research, it is interesting to note that this specific prediction of the PET (Prediction 1.6) was not well supported. There were several instances where elevated levels of anxiety were not linked with disproportionately longer reaction times (see the absence of effects involving mood in Chapter 4; also preparatory intervals did not differ between ego threat and no ego threat conditions on fixed and running tasks in the study reported in Chapter 5, see Figure 5.5). In some instances, the ego threat instructions resulted in shorter reaction times (e.g. for the inter-item intervals on running span tasks in Chapter 5, see Figures 5.9, 5.10). Again, it is important to reiterate that interpreting reaction time as a measure of processing efficiency is a feature of the PET (Prediction 1.6), and it has become commonplace to interpret reaction time effects in the anxiety-working memory literature in terms of processing efficiency. The interpretation of accuracy and reaction time as reflecting distinct aspects of performance (i.e. effectiveness and efficiency, respectively) is not accepted uniformly in the cognition literature, and it is critical to note that some researchers view these two measures as complementary (e.g. entering into a speed-accuracy trade-off; Allen Osman et al., 2000).
The PET also predicts that anxiety-linked impairments in performance will be more evident with increasing demands on working memory capacity, and this prediction received limited support from the present research. Increasing demands on working memory capacity were operationalised in several different ways on the tasks utilised in the present programme of research. For the span tasks, comparisons were made between performances on the fixed and running versions of the same task and at the same sequence length (with the running version proposed to be more taxing on processing resources). In the preparatory interval analyses conducted in Chapter 5, a task status x cognitive mood induction interaction revealed that the increment in reaction times when comparing fixed to running tasks was greater for those under ego threat instruction than those not under ego threat instruction (see Figure 5.5). It is important to note that reaction times did not differ between the groups for either the fixed or running tasks. This is important because the PET states that where effectiveness is equated (which is the case here as the reaction time analyses considered only the trials on which participants responded correctly), the high anxious participants are already expending more effort to attain an equivalent level of effectiveness, thus processing efficiency should be lowered and, hence, lengthened reaction times would be expected.

Increasing demands on working memory may also be observed when comparing the effects of increasing sequence length on the same task. For example, the preparatory interval analyses in Chapter 5 also revealed a sequence length x cognitive mood induction interaction on the running verbal span task (see Figure 5.8b). This reflected a greater increase in reaction times under increasing sequence length for the ego threat instruction group than for the no ego threat instruction group. Again, contrary to the expectation that elevated levels of anxiety would result in lower processing efficiency, the effect reflected shorter reaction times at the lower sequence length for the ego threat group, rather than lengthened reaction times at the higher sequence length for the same group.

A final way of evaluating the impact of anxiety on the capacity to cope with increasing task demands is presented by the grammatical reasoning task in Chapter 6, which utilised conditions of low memory load (string of six zeros) and high memory load (string of six random digits) performed concurrently with the reasoning subtask. Reaction times under conditions of increasing memory load on the reasoning subtask were disproportionately longer for those under ego threat instruction than those under no ego threat instruction (see Figure 6.11). This finding
perhaps represents the only unequivocal evidence in support of this particular PET prediction, although it is noted that this effect involves ego threat rather than state anxiety, which would be predicted by the PET.

Factors complicating an interpretation of the anxiety-working memory relationship were raised in Section 1.6. These related to: (a) suitability of tasks evaluating the working memory systems; (b) state versus trait anxiety; (c) cognitive versus somatic anxiety; and (d) comorbid depression.

### 7.3.2.1 Working memory tasks

Regarding the suitability of working memory tasks, it was identified in Chapter 1 (Section 1.6.1) that span tasks are ideal for the purpose of assessing the three components of Baddeley and Hitch’s (1974) working memory model, for the tasks can be equated on several dimensions save for the process of interest. The suitability of the verbal and spatial fixed span tasks was verified in the preliminary study conducted in Chapter 3. However, the findings reported in Chapters 4 and 5 questioned whether this set of tasks, in particular the running verbal task (because according to the PET, anxiety is proposed to affect both the CE and PL, which this task is proposed to engage), were suitable for the purpose of investigating anxiety-related impairments in working memory performance. This question arose due to the absence of robust anxiety-linked effects in Chapters 4 and 5, which contrasted with the existing literature which has documented anxiety-linked impairments on various working memory tasks (e.g. Darke, 1988a,b; MacLeod & Donnellan, 1993; Markham & Darke, 1991; Tohill & Holyoak, 2000; A.M. Williams et al., 2003).

The question surrounding the suitability of the updating tasks had implications at a more theoretical level, querying the suitability of the current PET model. Presently, the PET, which was developed in 1992, is premised on Baddeley’s 1986 tripartite working memory model. In this earlier model of working memory, the CE was considered a unitary system resembling attention that was capable of performing a variety of processes (Baddeley, 1986; Eysenck & Calvo, 1992). However, since the development of the PET, there has been an increasing focus on identifying fractionable CE processes, with some such processes identified by the literature including inhibition, updating, shifting, dual tasking, activation of long term memory, and the coordination of the slave systems (e.g. Baddeley, 1996a; Bull & Scerif, 2001; Collette & Van der Linden, 2002; Miyake et al., 2000). In spite of this, studies
examining the anxiety-working memory relationship published subsequent to the research into the fractionation of the CE generally appear to still adopt the unified CE system (e.g. A. Richards et al., 2000; Murray & Janelle, 2003; Tohill & Holyoak, 2000; A.M. Williams et al., 2002).

Research into the fractionation of CE processes potentially poses problems for the current conceptualisation of the PET. In particular, a study by Dutke and Stöber (2001) suggests that elevated levels of anxiety may not actually impair the process of updating, which is the CE process proposed to be engaged by the span tasks utilised in Chapters 4 and 5 of the present programme of research (see Morris & Jones, 1990). Adopting a task-based approach to examining the anxiety-working memory relationship, Dutke and Stöber (2001) suggest that complex working memory tasks engage a mixture of coordinative and sequential demands. Tasks high in coordinative complexity require integration between processing steps, whereas tasks high in sequential complexity require the contents of working memory to be frequently updated. Dutke and Stöber propose that tasks that are sequentially demanding serve to alleviate the working memory system of the roles of monitoring and refreshing the contents of working memory by providing external prompts to do so. This serves to free up resources, and high anxious individuals are expected to benefit from this to a greater extent because worry already consumes some of the fixed-capacity system.

Dutke and Stöber’s (2001) findings served to shed light on the failure to replicate robust anxiety-linked impairments in working memory performance in Chapters 4 and 5. Specifically, the running memory tasks utilised in these chapters engaged the CE process of updating (Morris & Jones, 1990), which may be viewed to be a task high in sequential complexity. To verify that it was task limitations, rather than other aspects of the experimental design that accounted for the absence of robust anxiety-linked impairments on the updating tasks, Chapter 6 examined the impact of anxiety on a variety of working memory tasks. These tasks included the running verbal task from Chapters 4 and 5 (which would be expected to be most susceptible to the effects of anxiety for this task is proposed to engage both the CE and PL), as well as two tasks on which anxiety-linked performance impairments have been documented – the reading span task (Daneman & Carpenter, 1980) and the grammatical reasoning task (C. MacLeod & Donnellan, 1993). If the absence of robust effects observed in Chapters 4 and 5 was attributable to the running verbal
task and not to other limitations in the experimental design (e.g. pertaining to the selection of trait anxious individuals or to the mood induction technique employed), then it was expected that anxiety-linked impairments would be evident on the reading span and grammatical reasoning tasks but not the updating task. This argument was weakly supported by the findings of Chapter 6. Thus, it appears that anxiety does not affect all CE processes equally.

Clearly, the fractionation of CE processes, and the finding that anxiety does not affect all CE processes equally, has implications for the selection of working memory tasks suitable for assaying anxiety-linked impairments in performance. Specifically, it suggests a greater need for the careful selection of working memory tasks. Presently, the degree of specification of tasks on which anxiety-linked impairments are predicted extends to those tasks that make heavy processing and storage demands (Eysenck & Calvo, 1992). This explains why studies utilise a wide variety of working memory tasks (e.g. grammatical reasoning, analogical reasoning, syllogistic reasoning, and the reading span task). The findings reported in Chapter 6 regarding the differential impact of anxiety on the various working memory tasks, together with Dutke and Stöber’s (2001) suggestion that anxiety does not impair the process of updating, permits more specific predictions regarding the types of tasks on which anxiety-linked impairments may be evident.

7.3.2.2 State versus trait anxiety. Another factor complicating the interpretation of the anxiety-working memory relationship is whether state or trait anxiety accounts for impairments in performance. Eysenck and Calvo (1992) pinpoint state anxiety as the source of impairment, but view it to be determined interactively by trait anxiety and situational stress, and concede that trait and state anxiety are difficult to distinguish on an empirical basis. The literature review presented in Section 1.6.3 did not serve to clarify these complex relationships, but instead found evidence for an impact of trait anxiety (e.g. MacLeod & Donnellan, 1993), of situational stress (e.g. Tohill & Holyoak, 2000), and of a combination of the two (e.g. Sorg & Whitney, 1992) on working memory performance.

Part of the difficulty in extricating trait or state effects in the existing literature may be attributed to the piecemeal approach adopted by several studies to investigating these relationships. One study that did attempt to systematically examine the state/trait distinction selected participants on the basis of trait anxiety levels,
subjected these participants to situational stress, and measured the ensuing effects on state anxiety levels (Murray & Janelle, 2003). This was the same approach adopted in the present programme of research to assay the state/trait anxiety distinction.

Several patterns emerged from the present programme of research. First, contrary to the findings of C. MacLeod and Donnellan (1993), trait anxiety alone did not adversely affect performance, although it is acknowledged that stress was not a factor examined in their study. Second, the experience of stress alone (predominantly cognitive in nature, although there were some effects of the music stressor) served to impair performance (see Figures 5.5, 5.8, 6.10, 6.11). Third, there were several instances in which trait anxiety interacted with situational stress to affect working memory performance (see Figures 6.8 & 6.9), although these effects were not always in a consistent direction. While such interactions would theoretically be expected to reflect the operation of state anxiety, it is noted that analyses of the state anxiety measures in Chapter 4, 5, and 6 did not reveal trait anxiety x stress (mood induction) interactions but rather uncovered independence of the effects these two variables had on state anxiety ratings. Furthermore, correlational analyses examining state anxiety ratings with indices of working memory performance indicate an overall absence of such relationships (see Sections 4.8.3.3, 5.6.3.3, & 6.9.4.4). The absence of state anxiety-working memory performance relationships is vitally important, as many studies within the anxiety-working memory literature view a significant trait anxiety x stress interaction on working memory indices as being indicative of the influence of elevated levels of state anxiety. In this regard, the findings of this present programme of research caution against such an assumption, and suggest that future studies measure state anxiety levels to verify the efficacy of their experimental manipulations in engendering elevated levels of state anxiety.

Unexpectedly, the relationships between trait anxiety, stress, and state anxiety and the ensuing effect on working memory performance reported in this programme of research were often contrary to those evident in the anxiety-working memory literature. The source of this difference is likely to be attributable to the seemingly piecemeal approach studies have adopted in examining the effects of trait and state anxiety on working memory thus far. Recently, Meijer (2001) has suggested that the relationship between trait anxiety and state anxiety differs under stressful versus reassuring (i.e. non-stressful) conditions, while the relationship between state
anxiety and performance actually does not vary across the differing conditions of stress. Together with the findings of the present thesis, it is apparent that future research in the anxiety-working memory literature needs to adopt a systematic approach to delineating the relationships between trait anxiety, stress, and state anxiety. An ideal starting point is the methodology utilised in the present study and by Murray and Janelle (2003) wherein high and low trait anxious individuals were selected, mood induction (i.e. stress) formed a variable of interest, and where state anxiety levels were measured.

7.3.2.3 Cognitive versus somatic anxiety. The vast majority of the studies prior to this programme of research have focused on the impact of cognitive anxiety on working memory performance (e.g. Calvo et al., 1994; Darke, 1988a,b; Ikeda et al., 1996; Leon & Revelle, 1984; Markham & Darke, 1991). This is largely attributable to Liebert and Morris’ (1967) identification of worry – and not emotionality – as the critical component affecting working memory performance. Potential mechanisms by which somatic anxiety, the less-studied component of anxiety in the anxiety-working memory relationship, may affect performance were hypothesised in Section 1.6.4. Chapter 4 presented an exploratory investigation into a tenable link between somatic anxiety (influenced by a music mood induction manipulation) and working memory performance. This study did not reveal a strong relationship, although it is acknowledged that, in light of Chapter 6 and Dutke and Stöber's (2001) findings, it may be that anxiety was not likely to adversely affect performance on the updating task in any event.

Chapters 5 and 6 additionally adopted manipulations of cognitive anxiety (ego threatening instructions). The findings of Chapters 5 and 6 demonstrated a role of cognitive anxiety in working memory performance, however these effects were often contrary to the predictions of the PET. One possible explanation is that the ego threat mood manipulation was not sufficient to elicit the necessary conditions for strong anxiety-linked impairments to be evident. However, as this manipulation is employed within much of the anxiety-working memory literature (Darke, 1988a;b; Derakshan & Eysenck, 1998; Leon & Revelle, 1985; Markham & Darke, 1991), this is an unlikely explanation. While an impact of the music mood induction was evident on several occasions (e.g. for reaction times on the memory load component of the grammatical reasoning task, and for preparatory intervals on the fixed span tasks in Chapter 5), these effects were not consistent. Thus, a role for cognitive anxiety is supported, with the possibility that a smaller role for somatic anxiety exists.
7.3.2.4 Comorbid depression. One of the greatest difficulties facing an interpretation of the anxiety-working memory relationship is the issue of comorbid depression. This is because most of the studies investigating this relationship have not included measures of depression to ascertain if the adverse effects on performance are attributable to anxiety or to depression. This issue was investigated in the present programme of research via the inclusion of both state and trait measures of depression (POMS Depression and DASS Depression respectively), and statistical analyses were employed to examine the contribution of anxiety and depression where anxiety-linked deficits in performance were evident. Overall, it was observed that elevations in trait anxiety scores were accompanied by elevations in trait depression scores, although elevations in state anxiety scores in response to the mood induction procedure were not accompanied by elevations in state depression scores (suggesting specificity of the mood manipulation techniques utilised). For the reanalyses incorporating trait depression as a variable of interest where trait anxiety was implicated in effects on working memory, it was noted that depression generally did not affect performance (but see the inter-item interval analyses for the running verbal task reported in Chapter 6). Where state anxiety was implicated in effects on working memory, these were largely unaccompanied by significant correlations between state depression ratings and these same working memory variables (with the exception of inter-item intervals on Sequence Length 3 on the fixed verbal task in Chapter 4). Overall, the prevailing trend was for effects on working memory performance – and, more specifically, impairments in performance – to arise from elevated levels of anxiety rather than depression.

At a more theoretical level, the distinction between anxiety and depression may have critical bearing on understanding working memory performance. As identified in Section 1.6.2, both the anxiety-working memory relationship, and the depression-working memory relationship have been proposed to arise through similar mechanisms via which working memory is impaired due to increased levels of mood. The possible operation of common mechanisms is explored more fully in a subsequent section (Section 7.5.3). To foreshadow, the section explores common and also distinct mechanisms of anxiety and depression that may impact on working memory performance. This is followed by an exploration of potential ways to differentiate the impact of these two types of mood on working memory performance.
Chapter 5 provided only limited support for the PET, and the absence of robust anxiety-linked impairments in working memory performance was attributed to the utilisation of the running memory tasks. It was discussed in Section 7.3.2.1 that research into the fractionation of CE processes (e.g. Lehto, 1996; Miyake et al., 2000), together with Dutke and Stöber’s (2001) findings, meant that not all CE processes were impaired by elevated levels of anxiety. One CE process that has been implicated in the anxiety-working memory relationship is that of inhibition (Hopko et al., 1988). The mediating role that inhibition may play was explored more fully in Chapter 6, which examined the relationships between performances on several tasks, namely, a working memory task that has been demonstrated to implicate inhibitory processes (the reading span task; cf. Lustig et al., 2001), the running verbal task utilised in Chapters 4 and 5, another working memory task on which anxiety-linked impairments in performance have been reported (grammatical reasoning task), as well as a measure of inhibitory processing (the directed ignoring task).

Chapter 6 presented findings that supported a role for inhibition in the anxiety-working memory relationship, which is consistent with Hopko et al.’s (1998) findings, although it must be noted that inhibition does not entirely explain the anxiety-working memory link. A general deficit in inhibitory processes was evident for those under ego threat instruction, as indicated by performance on the directed ignoring task. The relationships between anxiety, inhibition, and working memory were addressed in two ways. First, an analysis of working memory performance incorporating inhibition as a variable of interest (see Section 6.9.5) in the ANOVAs indicated that inhibition accounted for some variance in the performance of the reading span task, which is congruent with existing studies suggesting this link (Hopko et al., 1998; Lustig et al., 2001; May et al., 1999). However, there were clearly factors other than inhibition that determine performance on this task for inhibitory processes were not implicated in performance on the grammatical reasoning and running verbal tasks (on which anxiety- and stress-linked impairments were observed).

The second way of assaying the relationships between anxiety, inhibition, and working memory was to examine correlations between those indices of working memory performance on which anxiety-linked effects were evident, as well as examining correlations between these indices and an index of inhibition. The rationale underlying this approach was that if inhibition does underpin CE processes
(as stated by Miyake et al., 2000), then all such indices were expected to be correlated with one another. These correlations, reported in Section 6.9.5, indicated that the only clear pattern to emerge was that reading span scores were correlated with performance on the grammatical reasoning task. As performance on the grammatical reasoning task was not affected by inhibition, it suggests that these two tasks tap a common process that is not inhibition. Thus, while cognitive stress impacts on inhibition, which in turn affects performance, it also affects another component of performance unrelated to inhibition.

Potential processes apart from inhibition that may mediate the anxiety-working memory link – specifically, shifting and dual tasking – were considered in Chapter 6 (see Section 6.10.4), where recommendations for future research investigating the role of these processes were suggested. At a more global level, it is interesting to speculate how these additional processes, along with the inhibition findings, may be incorporated with the PET. Research into the fractionation of the CE, together with the studies comprising this present programme of research, and the findings of Hopko et al. (1998) and Dutke and Stöber (2001), clearly argue for greater specification of which CE components are affected by anxiety. Certainly, it appears that the various CE processes are not affected to the same extent by anxiety – whereas inhibition appears to be affected, updating does not, and it may be that anxiety affects shifting and dual tasking (however these effects need to be empirically validated). It is important to note that Miyake et al. (2000) concede that this is not an exhaustive list of this system's fractionable components. It is only with the comprehensive identification of other CE processes that it will be possible to identify those processes that are susceptible to anxiety.

### 7.4 A reconceptualisation of the PET

For now, a revision of the PET incorporating the findings of this present programme of research is proposed. In contrast to the original theory (represented diagrammatically in Figure 1.1), the CE/Control system has greater specification. Specifically, the four CE processes discussed in Chapter 6 – inhibition, updating, shifting, and dual-tasking – should be incorporated into the CE system within the PET. Within the CE system, inhibition is identified as one process mediating the anxiety-working memory link, whereas updating is not accorded such a role. Shifting and dual-tasking may also be affected by anxiety, however this is subject to
empirical validation by future research (see Section 6.10.4 for a more detailed discussion regarding the specification of the CE component within the PET).

The greater specification of CE component of working memory within the PET equips this theory with greater explanatory power in accounting for existing contradictions within the anxiety-working memory literature. For instance, it provides an explanation for Elliman et al.'s (1997; see Table 1.1) study wherein no overall effect of anxiety was observed on the BAKAN sustained attention task (anxiety did affect reaction times, but only in the later stages of the experiment, suggesting that other factors such as fatigue may have had an effect). In the BAKAN task, participants were required to monitor a stream of digits and indicate when three consecutive odd or even numbers were present. The requirements of this task can be viewed as invoking the process of updating. Specifically, the first digit in the stream is held in memory, and when the second digit is presented, a decision is made regarding whether the second digit is similar (i.e. odd or even) to the first. If the second digit belongs to the same odd/even category as the first digit, the second digit is held in memory together with the first, with a judgement to be made regarding the third digit in relation to the first and second. If the second digit does not belong to the same category as the first, the first digit is discarded from memory. The second digit then becomes the only digit held in memory, with which the third digit is compared. As the process engaged in the successful completion of the task bears similarities with that of updating (cf. Morris & Jones, 1990; see also Section 1.6.1), it is not surprising that there was an absence of anxiety-linked effects on this task.

The findings of this programme of research also suggest a revision of the relationships between trait anxiety, stress, and state anxiety. Presently, within the PET, anxiety-linked effects on working memory performance are attributed to state anxiety, which is deemed to be determined interactively by trait anxiety and situational stress (Eysenck & Calvo, 1992). Within the present programme of research, there was no evidence of such an interaction on state anxiety scores; instead, trait anxiety and situational stress (both of a cognitive and somatic nature) made independent contributions to state anxiety levels. State anxiety levels were generally not related to working memory performance as demonstrated in correlational analyses, even though trait anxiety x stress (mood induction) interactions were found (see Figures 6.8 & 6.9). Rather, working memory performance appeared to be affected by situational stress itself, although again this
was not mediated by state anxiety levels. It is noted that the findings of the research reported in this thesis run contrary to a large body of literature acknowledging state anxiety as being determined interactively by trait anxiety and situational stress, and must thus be interpreted with caution at this stage. Future research examining the anxiety-working memory relationship should measure state anxiety levels in order to obtain a clearer picture of these relationships.

Altogether, the present programme of research suggests that the PET be revised to include greater specification of the CE component of working memory within the PET, and also for a reconsideration of the relationships between trait anxiety, stress, and state anxiety. In incorporating these recommendations, the PET becomes a more powerful model in explaining the anxiety-working memory literature.

7.5 Anxiety and depression – comorbidity, and implications for working memory

Thus far, the relationship between anxiety and depression, and the ensuing impact on working memory performance, has been restricted to discussing the steps taken in this programme of research to control for the effects of depression so as to obtain a clearer picture of the anxiety-working memory link. This was a conscious decision due, in part, to the firm focus of this research on anxiety and working memory. The findings of the present programme of research suggested that depression may play a role in the anxiety-working memory link, although this was not a robust finding (compare correlations reported in Section 4.8.3.3 with the findings reported in Chapter 6). This suggests that future research into the relationship between anxiety and working memory should also investigate the role depression in order to explicate the relationships between these three constructs.

While some studies have addressed the relationships between anxiety, depression, and working memory using statistical analyses to isolate the contributions of anxiety and depression, as utilised in the present programme of research and by C. MacLeod and Donnellan (1993), it is important to consider these relationships within a wider context. In particular, it is important to examine how the PET is nested within other accounts of the relationship between mood and working memory. Similarities between the PET and the RAM (Ellis & Ashbrook, 1988), which addresses the depression-working memory relationship, have been discussed elsewhere (see Section 1.6.2). The current section is devoted to a further
exploration of the commonalities and distinctions between anxiety and depression, which encompasses a discussion of the tripartite model of anxiety and depression. Following this, the implications of this model for working memory are considered.

7.5.1 Anxiety and depression – commonality and specificity

It was noted in Section 1.6.2 that there is a significant degree of overlap in the symptoms that constitute anxiety and depression. Gotlib and Cane (1989) identified these to include irritability, impaired concentration, and fatigue. The authors also identified symptoms that were unique to anxiety and others unique to depression. Under the specific anxiety construct, they identified the symptoms of excessive worry (although see Starcevic, 1995, who argues that worry is also a feature of major depression), hyperactivity of the autonomic system, muscle tension, and an exaggerated startle response. Symptoms comprising the specific depression construct included dysphoric mood, fluctuations in weight, loss of interest, motor retardation, poor appetite, and feelings of worthlessness or guilt.

Further support for specificity within anxiety and depression is derived from Tellegen (1985), who identified the constructs of positive and negative affect. Positive affect, in this context, refers to an enthusiasm for life. Research has indicated that an absence of positive affect is a hallmark of depression. This stands in contrast to the construct of negative affect, or the variety of unpleasant affective states such as anger, guilt, sadness, and fear (L.A. Clark & Watson, 1991b). Whereas high levels of negative affect are evident in both anxiety and depression, only depression is associated with low positive affect. Similarly, negative affect is correlated with diagnoses of both anxiety and depression, but positive affect is related only to a diagnosis of depression (Watson, L.A. Clark, & Carey, 1988). Thus, positive affect plays a role in separating the constructs of anxiety and depression. What the positive-negative affect dichotomy fails to do, however, is to provide evidence for a distinct anxiety construct – this was subsequently addressed by L.A. Clark and Watson (1991a) in their tripartite model of anxiety and depression.

7.5.2 The tripartite model of anxiety and depression

The central tenet of the tripartite model is that anxiety and depression share a large degree of overlap in symptoms – negative affect – yet these constructs are also differentiable despite this commonality (L.A. Clark & Watson, 1991b; Frances et al., 1992). Although the negative affect factor accounts for a significant amount of
overlap between anxiety and depression, there is evidence (L.A. Clark & Watson, 1991a,b; Gotlib & Cane, 1989; Tellegen, 1985; Watson et al., 1988) to suggest that separate anxiety and depression factors are present. Items unique to depression, but not anxiety, include feelings of loneliness, hopelessness, and loss of interest, as well as loss of pleasure. This “depression” factor is analogous to Tellegen’s lack of positive affect factor. L.A. Clark and Watson (1991a) extend Tellegen’s findings and postulate a specific anxiety factor characterised by physiological hyperarousal, and encompassing panic symptoms as well as feelings of tension and nervousness (although see Watson et al., 1995b, and Mineka, Watson, & L.A. Clark, 1998, who argue that anxiety may reflect a broader range of somatic symptoms).

The tripartite model has been validated by several factor analytic studies utilising a variety of clinical and non-clinical adult samples (e.g. Bieling, 1998; D.A. Clark, Steer, & A.T. Beck, 1994; Joiner, 1996; Steer, D.A. Clark, A.T. Beck, & Ranieri, 1995; Watson et al., 1995b). It has also been validated in inpatient child and adolescent populations (Joiner, Catanzaro, & Laurent, 1996). These studies all adopt a similar methodology – the three-factor tripartite model is compared with alternative models (e.g. one factor designating a general distress factor, or two factors designating positive and negative affect factors) in fitting data collected from measures of anxious and depressive symptoms. This clearly is a phenotypic approach to delineating the common and specific components of anxiety and depression, and has certainly evolved from the theoretical underpinnings of the tripartite model. However, the model has also been validated in studies adopting genotypic and cognitive approaches (see Mineka et al., 1998, for a review).

7.5.3 Implications of the tripartite model for anxiety-working memory research

Altogether, the research cited above provides strong support for the tripartite model. Furthermore, it argues for the need to identify symptoms constituting each of the components of the model, for this has bearing on diagnoses of mood disorders (see Joiner, 1996, for an in-depth discussion). Clearly the implication of the tripartite model for the diagnoses of mood disorders is an important area of research in its own right. However, the question of relevance to this thesis is what impact the tripartite model has on conceptualising the relationship between anxiety and working memory. At first glance, the model appears to be at odds with the PET. Whereas the PET identifies worry as an integral route via which anxiety affects working
memory performance, the tripartite model identifies somatic symptoms – not worry – as unique to anxiety.

Reconciling these apparently conflicting viewpoints, however, is not as elusive as it first appears. This reconciliation is premised on the role of worry, and also attention and concentration. It is acknowledged that researchers such as Hopko et al. (1998) argue that it is not the degree of worry per se that engenders impaired performance, but rather the ability to inhibit such worries so as to preserve the capacity of working memory that may then be devoted to task performance. However, the findings from Chapter 6 of this thesis suggest that while inhibition is one contributing factor to the anxiety-working memory relationship, it is not the only factor. Consequently, it remains possible that inhibitory deficiency pertaining to worry and some other facet of anxiety may affect performance via alternative routes, and it would therefore be premature to abandon research into these relationships.

Worry has been found to be present in both anxiety and depression (Starcevic, 1995). However, many studies evaluating the tripartite model utilise measures of anxiety and depressive symptoms that do not include items measuring worry. One study that did do this using the Mood and Symptoms Questionnaire (Watson et al., 1995b), found that the single worry item (“Worried a lot about things) loaded on the negative affect factor which Watson et al. termed general distress. Interestingly, other items that loaded on this factor included memory problems (“Trouble remembering things”; although this had a slightly higher loading on the somatic anxiety factor, .31 vs. .30), as well as concentration and attention difficulties (“Trouble concentrating”, “Trouble paying attention”).

The finding that worry and attention and concentration difficulties may not be unique to anxiety has important bearing on the PET for several reasons. First, along with Starcevic’s (1995) findings, it indicates that worry is also characteristic of depression. Second, attention and concentration difficulties – which are what the PET views worry as affecting – are also evident in both anxiety and depression (Ellis & Ashbrook, 1988; Watson et al., 1995b). Thus, neither worry nor attention and concentration, which the PET claims are integral in the impact of anxiety on performance, are unique to anxiety. It is noted that attention – specifically, selective attention – is intimately linked with inhibition, and the two constructs are difficult to disentangle (Kane et al., 1994; Passolunghi et al., 1999). Consequently, it is possible that a deficits in inhibitory processing is also common to both anxiety and
depression, although it is noted that the correlations reported between depression and inhibitory processing presented in Appendix H (part a) did not support a link between these two constructs. Third, the model proposed to account for depression-linked impairments in working memory, the RAM, is very similar to the PET in that it attributes the source of impaired performance to non task-focused thoughts consuming attentional resources (refer to Section 1.6.2). Altogether, this suggests that anxiety-linked and depression linked impairments in working memory may actually reflect the operation of common mechanisms inherent in negative affect. This suggests a move away from conceptualising anxiety and depression as having distinct influences on working memory, which is the current approach most research adopts.

Certainly, the relationship between anxiety, depression, and working memory is not as simplistic as indicated by the above discussion, and Watson et al.’s (1995b) findings of worry, and concentration and attention difficulties being common to both anxiety and depression clearly need to be replicated. What the literature does suggest is that the mechanisms by which anxiety and depression affect working memory performance may be common to both (i.e. non task-focused thoughts consume working memory capacity because of the limited efficacy of inhibitory processes). This, however, does not preclude distinctions between the effects the two mood states have on working memory. Indeed, several differences may be observed between the impact of anxiety on performance and that of depression on performance. Most notably, the non task-focused thoughts that consume attention are qualitatively different in content (cf. A.T. Beck, 1976). Recently, R. Beck, Benedict, & Winkler (2003) suggest that depression is characterised by thoughts relating to self-criticism and hopelessness, whereas anxiety is linked with panic-related thoughts\(^\text{14}\).

Another critical difference that may differentiate anxiety and depression in their impact on working memory performance is the role of motivation and effort. Eysenck and Calvo (1992) propose that anxious individuals exert more effort than

\(^{14}\) Incidentally, R. Beck et al. (2003) additionally identified worry to be linked with negative affect, while depression was linked with self-criticism and hopelessness, and anxiety with panic-related thoughts. The use of the term worry, in the context of Beck et al.’s study (where it is regarded to be distinct from depression- and anxiety-related thoughts), is misleading in considering the PET. The presence of thoughts that are not relevant to completing the task at hand is the critical factor in the PET, regardless of the content of these thoughts. In the context of R. Beck et al.’s study, therefore, the thoughts linked with negative affect, depression, and anxiety, are all non task-relevant thoughts, and therefore may be subsumed under what the PET considers to be ‘worry’.
their non-anxious counterparts in order to attain an equivalent level of performance as they are motivated to circumvent the adverse consequences of failure. In contrast, it may be that depressed individuals expend less effort than non-depressed individuals due to decreased motivation. This avenue may indeed prove a fruitful one for future research endeavouring to differentiate between the effects of anxiety and depression on working memory. Consider, for instance, the two routes via which anxiety can impact on working memory performance (refer to Figure 1.1) outlined by the PET. The first route, which has formed the focus of the present programme of research, implicates worry as a critical mechanism in the process. Worry affects working memory by consuming capacity in the system, and also by enhancing motivation to improve performance. However, if worry does not serve to discriminate between anxiety and depression (i.e. this route addresses the common, but not the distinct, influences of anxiety and depression), then this route becomes redundant for the purpose of distinguishing the effects of anxiety and depression on working memory performance.

The second route via which anxiety can impact on working memory performance (highlighted in green in Figure 1.1) also implicates motivation. Specifically, it suggests that incentive interacts with trait anxiety to affect motivation which, in turn, affects performance. A study conducted by Eysenck (1985) employing monetary incentive to enhance motivation, however, suggests that this route does not engender state anxiety – and worry – unlike the first route. By removing the factor of worry (which is common to both anxiety and depression) and focusing instead on motivation and effort, the distinct influences of each mood on working memory performance may be identified. The question therefore arises as to how the differences between anxiety and depression may be manifest if employing this route.

An important consideration in studying the impact of motivation and effort on performance must be given to the measures of performance selected. Currently, most studies adopt reaction time as a measure of efficiency, suggesting that lowered processing efficiency may result from anxious individuals taking longer to attain an equivalent level of performance due to a willingness to persist at the task. In contrast, depressed individuals – who are likely to lack motivation – may actually take longer to respond to task demands. That is, it appears that the notion of effort may be conceptualised differently, with the PET alternative relating to the willingness to persist or engage, and the depression alternative relating to the
amount of energy expended per unit time. Reaction time, as a measure, does not clearly differentiate between the two alternatives. Certainly, other measures of cognitive performance that are key in predicting different outcomes for depression and anxiety need to be developed and refined.

To summarise, this section addressing the issue of comorbid depression has demonstrated a clear need for closer alignment between research investigating the anxiety-working memory relationship and research investigating the depression-working memory relationship. An evaluation of the tripartite model of anxiety and depression, coupled with the similarities between theories outlining the impact of anxiety and depression on working memory performance, argue for a reconceptualisation of how anxiety and depression affect working memory. Specifically, those considerations suggest that future research should focus on clarifying which mechanisms are common to anxiety and depression (e.g. worry) and which are distinct (e.g. motivation).

7.6 Recommendations for future research

The preceding summary of the present programme of research makes clear recommendations for future research. First, it is recommended that the study of the anxiety-working memory relationship be expanded to incorporate a role for depression. Anxiety and depression are highly related constructs, and the literature reviewed in the preceding sections suggest that both may affect working memory performance in a similar manner. That is, it is possible that these similarities reflect the operation of common, rather than distinct mechanisms. Certainly, there are aspects of performance (e.g. motivation) that may serve to differentiate between the effects of anxiety and depression. By integrating the effects of depression into the anxiety-working memory relationship, a more comprehensive picture of how each impacts on working memory may be explicated. Specifically, as the present programme of research was focused only on anxiety, it aimed to control for the effects of depression by using statistical methods. In integrating depression into the anxiety-working memory relationship, it will be important to include depression as a variable of interest (e.g. by examining the working memory performance of individuals with differing levels of depression).
Second, the present programme of research has highlighted the need for further clarification of the state/trait anxiety distinction. Importantly, the assumption inherent in much of the anxiety-working memory literature that trait anxiety x stress interaction effects on working memory performance reflect the operation of state anxiety needs to be more closely examined. It is recommended that trait anxiety and stress be systematically examined in future research and, more critically, that measures of state anxiety be obtained. This will be critical in clarifying the effects of anxiety on working memory.

Third, and most importantly, the present programme of research highlights a need for greater specification of the CE component of the working memory model within the PET. It is urged that future research is closely aligned with the evolving literature on the fractionation of CE processes. Regarding the relationship between anxiety and working memory (which formed the focus of this thesis) the findings of this program of research, together with Dutke and Stöber’s (2001) study, suggest that not all CE processes are affected by anxiety in the same way. For instance, inhibition appears to be affected by stress, whereas updating does not appear to be so affected. Other CE processes such as shifting and dual tasking have already been delineated, and future research investigating links between each of these CE processes (and others that will be identified with ongoing research into the fractionation of the CE) and anxiety, and with working memory performance more generally, will provide a greater understanding of the mechanisms by which anxiety affects working memory.

For each of the CE processes identified, it is also recommended that the impact of depression be investigated using the same methodologies adopted for the anxiety research. For instance, the present program of research, together with the existing literature, suggests that anxiety affects inhibition but, not likely, updating. Research suggests that a link between depression and inhibition is likely (see Chapter 6), however it is unclear as to the impact of depression on updating. One ramification of comparing and contrasting the effects of anxiety and depression on the various CE processes is that different profiles of working memory performance may be revealed for the two mood states, in a manner akin to the different profiles each has in the areas of attentional and memory biases (refer to J.M.G. Williams, Watts, C. MacLeod, & Mathews, 1997, for a review).
Fourth, and finally, the above approach in distinguishing the effects of anxiety and depression on working memory performance is a very cognitive one, and is firmly focused on one aspect of the PET – namely, which CE processes are susceptible to elevated levels of mood. At a more global level, an alternative yet complementary approach to differentiating between anxiety and depression may be to explore the role of motivation. Research adopting this approach could focus on varying incentives, with the expectation that this is likely to affect motivation and effort to a greater extent in anxious than in depressed individuals. However, it is cautioned that more refined measures need to be developed to distinguish between the effects of motivation in anxiety and depression. One potential avenue of investigation is to incorporate measures of subjective effort.

7.7 Conclusions

The present programme of research has sought to clarify and extend the existing anxiety-working memory literature by exploring the predictions of the PET, while simultaneously addressing factors that currently complicate an interpretation of the link between anxiety and working memory. The findings of this research provided limited support for the PET, predominantly verifying its prediction that the adverse impact of anxiety would be more pronounced with increasing demands made on working memory (Prediction 2). There was mixed support for the first prediction of the model that states that anxiety-linked impairments in performance are more pronounced on measures of efficiency than on measures of effectiveness. Specifically, where performance effectiveness was equated, elevated levels of anxiety did not necessarily serve to impair efficiency, at least as indexed by reaction times. Regarding the factors mediating the anxiety-working memory relationship, this thesis suggests that: (a) working memory performance was predominantly affected by situational stress, although this was not mediated by state anxiety levels; (b) cognitive, rather than somatic anxiety affected working memory performance; and (c) effects on working memory performance were attributable to anxiety rather than depression.

A clear finding from the present programme of research was a need for greater specification of the CE component of working memory within the PET. Since the development of the PET (Eysenck & Calvo, 1992), research within the working memory literature has focused on the fractionation of CE processes. The findings from Chapter 6 indicate a clear need for the PET to embrace the literature into the
fractionation of CE processes in order to wield greater explanatory power. This study highlighted that the process of inhibition plays a role in the anxiety-working memory relationship, with the observation that the experience of cognitive stress served to impair performance on the directed ignoring and reading span tasks. What was also apparent was that anxiety did not appear to affect the CE process of updating, but it may affect other processes such as shifting and dual tasking. Thus, it is suggested that anxiety does not appear to affect all CE processes uniformly, and this is perhaps the most significant finding of the present programme of research.

Although the focus of this thesis was firmly on the anxiety-working memory relationship, it makes strong recommendations for the integration of research on depression within this. Presently, research into the link between anxiety and working memory has progressed largely independently of research into the depression-working memory relationship. This has occurred in spite of marked similarities in the dominant theories proposed to account for each relationship. Support for the integration of these two strands of research is derived from this thesis, which suggested a link between reading span scores, inhibition, anxiety, and depression. Altogether, it proposes that common mechanisms may underpin the effects of anxiety and depression on working memory. However, it is additionally expected that distinctions between the effects of anxiety and depression on working memory performance will be evident, and this may be manifest in research investigating the roles of motivation and effort. Differences may also possibly be evident in the form of different ‘executive’ profiles for anxiety and depression, however such a conclusion may only be arrived at following an examination of the impact of anxiety and depression on each of the CE processes identified. In all, this thesis argues for a shift away from regarding the anxiety-working memory relationship as distinct from the depression-working memory relationship, towards conceptualising anxiety and depression as having common and distinct effects on working memory performance.

Finally, recommendations for future research were identified, including (a) a closer alignment with evolving research into the fractionation of CE processes; (b) the adoption of a systematic approach to evaluating the effect of anxiety and depression on each of the processes; (c) a more thorough approach to investigating the state/trait anxiety distinction; and (d) an exploration of the role of motivation in discriminating between the effects of anxiety and depression on working memory
performance. In integrating evolving research along the above dimensions, a more comprehensive picture of the common and distinct effects that anxiety and depression have on working memory may be obtained.
REFERENCES


**APPENDIX A: CORRELATIONS OF STATE ANXIETY AND DEPRESSION RATINGS WITH INDICES OF WORKING MEMORY PERFORMANCE (CHAPTER 4)**

Table A.1. Correlations between state anxiety ratings, state depression ratings, and indices of working memory performance.

**a. Memory span scores**

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<tr>
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<th>Spatial</th>
<th>Verbal</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Fixed</td>
<td>Running</td>
</tr>
<tr>
<td>POMS Anxiety</td>
<td>.04</td>
<td>-.05</td>
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<tr>
<td>POMS Depression</td>
<td>-.09</td>
<td>-.09</td>
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**b. Latency variables from fixed tasks**

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<td>3</td>
<td>4</td>
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<tr>
<td></td>
<td>P</td>
<td>I</td>
</tr>
<tr>
<td>POMS Anxiety</td>
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<td>.14</td>
</tr>
<tr>
<td>POMS Depression</td>
<td>.03</td>
<td>.16</td>
</tr>
</tbody>
</table>

**Note:** Anxiety and Depression ratings are averaged across the Post Mood Induction and Post Experiment Phases. P denotes preparatory intervals, I denotes inter-item intervals. 3 denotes Sequence Length 3, and 4 denotes Sequence Length 4. <sup>a</sup> denotes p < .001; <sup>c</sup> denotes p < .05
### c. Latency variables from running tasks

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<th>Verbal</th>
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<tbody>
<tr>
<td></td>
<td>2 P I</td>
<td>3 P I</td>
</tr>
<tr>
<td>POMS Anxiety</td>
<td>.01 .02 -.12 .08</td>
<td>.07 .20 .12 .09</td>
</tr>
<tr>
<td>POMS Depression</td>
<td>.08 .03 .15 .13</td>
<td>.12 .22 -.22 .08</td>
</tr>
</tbody>
</table>

Note: Anxiety and Depression ratings are averaged across the Post Mood Induction and Post Experiment Phases. P denotes preparatory intervals, I denotes inter-item intervals. 2 denotes Sequence Length 2, and 3 denotes Sequence Length 3. * denotes p < .001; ‡ denotes p < .05
APPENDIX B: CORRELATIONS OF STATE ANXIETY AND DEPRESSION RATINGS WITH INDICES OF WORKING MEMORY PERFORMANCE (CHAPTER 5)

Correlations of state anxiety and depression ratings with indices of working memory performance are presented in Table B.1. As state anxiety and depression ratings were not measured immediately post mood induction, the ratings reported below (and also in Table B.2) refer to ratings administered in the Post Experiment Phase. From Table B.1, STICSA State Cognitive Anxiety ratings were significantly correlated with memory span scores for the Fixed Spatial task, and also with preparatory intervals for Sequence Length 4 of the same task. This reflected enhanced memory span scores with increasing levels of anxiety, but also impaired performance on the preparatory intervals. It is noted that Eysenck and Calvo (1992) explicitly state that anxiety does not necessarily serve to impair performance accuracy. More generally, however, there is an absence of effect of state anxiety on working memory performance, and this is most noticeable on running tasks (tasks on which anxiety-linked impairments would be expected to be most evident).

Table B.2 presents correlations between state anxiety ratings and state depression ratings with indices of working memory performance reflecting susceptibility to increasing load. The effect on performance of Increasing load was assessed by examining (a) fixed and running versions of the same task, such as in the case of memory span scores and the parallel reaction time analyses; and (b) the effect of an increase in sequence length, as in the case of the fixed reaction time analyses and the running reaction time analyses. Fixed and running versions of the same task permit an examination of increasing load as the latter additionally invokes processing. Increasing sequence length on fixed tasks reflect increases in memory load, whereas increasing sequence length on running tasks reflect increases in both memory and processing load.

The only effect involving state anxiety ratings was a positive correlation between CIQ Task-relevant ratings and the changes as a function of sequence length in the preparatory intervals for the Running Spatial task. However, an unexpected finding is that the Running Verbal task is not correspondingly affected.
Table B.1. Correlations between state anxiety ratings, state depression ratings, and indices of working memory performance.

### a. Memory span scores

<table>
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<th>Verbal</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fixed</td>
<td>Running</td>
<td>Fixed</td>
<td>Running</td>
</tr>
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<tr>
<td>POMS Depression</td>
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### b. Latency variables for fixed tasks

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### c. Latency variables for running tasks

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Note: Anxiety and depression ratings are those obtained in the Post Experiment Phase. P denotes preparatory intervals, I denotes inter-item intervals. 2 denotes Sequence Length 2, 3 denotes Sequence Length 3, 4 denotes Sequence Length 4. <sup>c</sup> denotes p < .05
Table B.2. Correlations between state anxiety ratings, state depression ratings, and indices of increasing load on working memory performance.

### a. Transition from fixed to running tasks*

<table>
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<td>POMS Depression</td>
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<td>STICSA Cognitive</td>
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</table>

* Transition from fixed to running tasks; P denotes preparatory intervals, I denotes inter-item intervals.

### b. Transition from lower sequence length to higher sequence length**

<table>
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<tr>
<th></th>
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<th>Spatial Running P</th>
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<td>.28(^c)</td>
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</table>

** Reaction times for fixed tasks are based on the difference between Sequence Lengths 3 and 4; reaction times for the running tasks are based on the difference between Sequence Lengths 2 and 3.

\(^c\) denotes \(p < .05\)

Note: Anxiety and depression ratings are those obtained in the Post Experiment Phase.

* Reaction times are based on Sequence Length 3.
APPENDIX C: SUBSIDIARY ANALYSES (CHAPTER 5)

C.1 Introduction
The analyses reported below were motivated by the absence of mood effects resulting from the mood induction procedures reported in Chapter 5. These analyses involved composing participants into groups based on whether their scores increased or decreased on a particular mood measure from the Pre Mood Induction Phase to the Post Experiment Phase of the experiment. This reclassification constituted the Mood Change variable (Mood Change: Increased, Decreased), and the only mood measures considered here were the POMS Anxiety, STICSA State Somatic, and STICSA State Cognitive measures, for changes in ratings were not evident in the original analyses. The analyses on indices of working memory performance were then reanalysed in a manner similar to that reported in the original analyses, and the only other between-groups factor included in these analyses was Trait Anxiety Group.

C.2 Reanalysis
Memory span and preparatory and inter-item intervals for the parallel analyses were each subjected to a 2 (Trait Anxiety Group: Low, High) x 2 (Task Modality: Spatial, Verbal) x 2 (Task Status: Fixed, Running) x 2 (Mood Change: Decreased, Increased) mixed-design ANOVA. Preparatory and inter-item intervals for the fixed and running analyses were each subjected to three sets of analyses:

1. Parallel reaction time analyses comparing performance on one sequence length (Sequence Length 3) across all four working memory tasks. Here, reaction times were subjected to 2 (Trait Anxiety Group: Low, High) x 2 (Task Modality: Spatial, Verbal) x 2 (Mood Change: Decreased, Increased) mixed-design ANOVAs.
2. Fixed reaction time analyses comparing performance across two sequence lengths (3 and 4) on fixed tasks only. Here, reaction times were subjected to 2 (Trait Anxiety Group: Low, High) x 2 (Sequence Length: 3, 4) x 2 (Mood Change: Decreased, Increased) mixed-design ANOVAs.
3. Running reaction time analyses comparing performance across two sequence lengths (2 and 3) on running tasks only. The analyses were identical to that for (2), however Sequence Lengths were 2 and 3 in these analyses.
POMS Anxiety ratings. Participants were categorized into whether their POMS Anxiety ratings increased or decreased over the course of the experiment (ns of 29 and 33 respectively). Analysis of memory span scores revealed a significant Trait Anxiety Group x Mood Change x Task Modality x Task Status interaction, $F(1,58) = 6.41$, $p < .05$. When the four-way interaction was broken down by examining the Task Status x Task Modality interaction at each level of the Trait Anxiety Group x Mood Change interaction, the effect was significant only for the High Trait Anxiety Group participants who experienced a decrease in mood change over the course of the experiment. Here, memory span scores were equivalent for the Spatial and Verbal Running tasks, $t(15) = 1.59$, n.s., however higher scores were observed for the Fixed Verbal task compared to the Fixed Spatial task, $t(15) = 2.89$, $p < .05$ (see Figure C.1). No significant involving the Mood Change variable were observed for preparatory or inter-item intervals.

Figure C.1. Means (and standard errors) of memory span scores for each Task Modality x Task Status condition for High Trait Anxiety participants who experienced a decrease in POMS Anxiety ratings.
STICA State Somatic Anxiety ratings. The Increased and Decreased Mood Change groups comprised 37 and 15 participants, respectively. Only the memory span analyses yielded a significant effect involving the Mood Change variable, with a significant Trait Anxiety Group x Mood Change x Task Modality x Task Status interaction, $F(1,48) = 6.26, p < .05$. When the four-way interaction was broken down by examining the Task Status x Task Modality interaction at each level of the Trait Anxiety Group x Mood Change interaction, the effect was significant only for the Low Trait Anxiety Group participants who experienced an increase in mood change over the course of the experiment. Here, memory span scores were equivalent for the Fixed Spatial and Verbal tasks, $t(21) = 1.20$, n.s., however higher scores were observed for the Running Spatial task than the Running Verbal task, $t(21) = 2.51$, $p < .05$ (see Figure C.2). It is interesting to note that the direction of this significant result runs contrary to that of the POMS Anxiety change ratings, thereby rendering the interpretation of either interaction in terms of the PET problematic.

Figure C.2. Means (and standard errors) of memory span scores for each Task Modality x Task Status condition for Low Trait Anxiety participants who experienced an increase in STICSA State Somatic Anxiety ratings.
**STICSA State Cognitive Anxiety ratings.** The Increased and Decreased Mood Change Groups for this set of analyses comprised 30 and 16 participants, respectively. Memory span analyses indicated a significant Trait Anxiety Group x Mood Change x Task Status interaction, $F(1,43) = 4.18$, $p < .01$. The Trait Anxiety Group x Task Status interaction, when analysed at each level of the Mood Change variable, was significant only when mood change decreased over the course of the experiment. Here, Running task span scores did not differ between Low and High Trait Anxiety Groups, $t(15) = .61$, n.s., while there was a trend towards higher span scores for the High Trait Anxiety Group on Fixed Task Status tasks, $t(15) = 2.1$, $p = .054$ (see Figure C.3). The PET does not make explicit predictions regarding the effects of anxiety on measures of accuracy (which could be regarded as a measure of effectiveness), however it is interesting to note that it was the performance of those participants whose mood decreased, rather than increased, over the course of the experiment that was the source of difference.

![Figure C.3](image_url)

**Figure C.3.** Means (and standard errors) of memory span scores for each Trait Anxiety Group x Task Status condition restricted to the Decreased Mood Change group defined with reference to STICSA State Cognitive Anxiety ratings.
Analyses of preparatory interval reaction times for the Fixed tasks revealed a significant Mood Change x Sequence Length interaction, $F(1,42) = 5.42, p < .05$. Participants in the Decreased Mood Change Group exhibited equivalent reaction times across both the lower and higher sequence lengths, $t(15) = 1.06$, n.s. However, participants in the Increased Mood Change Group were faster at the higher sequence length than at the lower one, $t(29) = 2.20, p < .05$ (see Figure C.4). That is, an increase in sequence length had the effect of speeding up reaction times for participants who experienced an increase in cognitive anxiety over the course of the experiment. This finding runs contrary to the PET, which predicts that the effects of anxiety become more pronounced with an increasing load.

Figure C.4. Means (and standard errors) of memory span scores for each Mood Change x Sequence Length condition, where Mood Change is defined with reference to STICSA State Cognitive Anxiety ratings for the fixed reaction time analyses.
Four sets of words were desired for the directed ignoring task – Related, Unrelated, Somatic Threat, and Cognitive Threat. The words comprising each set were selected based on ratings of an initial pool of 212 words. The initial pool of words were constructed as follows. First, the 16 stories utilised in this task were constructed. Based on this, words that were either semantically or thematically related to the story were generated to form Related words. Words that were neither semantically nor thematically related to the story were generated to form Unrelated words. Threat words were selected from past research (Dalgleish, 1995; C. MacLeod & E.M. Rutherford, 1992; Mathews, May, Mogg, & Eysenck, 1989) as well as a thesaurus (Kirkpatrick, 1987), and were neither semantically nor thematically related to the story.

Ten adults, comprising six females, aged between 21 and 35 (M = 26.7; SD = 5.03), rated the 212 words along two seven-point scales. The first asked, "How threatening is this word?". The endpoints of the scale were labelled "not at all threatening" (1) and "extremely threatening" (7). The second scale asked "Is this word more related to the somatic domain or to the cognitive domain?". The endpoints of this scale were labelled "somatic" (-3) and "cognitive" (3), with the midpoint labelled "equally cognitive and somatic" (0). Raters were informed that the cognitive domain was related more to being examined and evaluated, while the somatic domain was related more to feelings of anxiety-relaxation.

Sixty-four Related words, 16 Unrelated words, and 16 Threat words (comprising 8 Cognitive and Somatic Threat words each) were chosen from the ratings. Several characteristics were desired of these sets of words that were to form the Distractor Word categories pertaining to word frequency, word length, threat ratings, and domain ratings. Means (and standard deviations) for each of the distractor words along these dimensions are presented in Table D.1.
Table D.1. Mean (and standard deviation in parentheses) word frequency ratings, word length, threat and domain ratings for the Directed Ignoring task.

<table>
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<tr>
<th>Distractor Word Type</th>
<th>Frequency</th>
<th>Length</th>
<th>Threat</th>
<th>Domain</th>
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<td>Related</td>
<td>29.75 (31.82)</td>
<td>6.52 (2.08)</td>
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<td>-.13 (.49)</td>
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<tr>
<td>Unrelated</td>
<td>28.06 (27.54)</td>
<td>6.31 (1.45)</td>
<td>1.63 (.22)</td>
<td>.22 (.39)</td>
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<tr>
<td>Somatic threat</td>
<td>39.00 (44.58)</td>
<td>5.88 (1.55)</td>
<td>5.11 (.78)</td>
<td>-1.95 (.34)</td>
</tr>
<tr>
<td>Cognitive threat</td>
<td>24.38 (29.87)</td>
<td>7.75 (2.43)</td>
<td>4.79 (.42)</td>
<td>2.14 (.30)</td>
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</table>

First, it was desired that the four distractor word groups did not differ in word frequency ratings, nor in word length. To this end, word frequency norms (Kučera & Francis, 1967) and word lengths were subjected to two one-way ANOVAs. Distractor Word was the independent variable. These indicated that word frequency norms were equivalent across all Distractor Words, $F(3,92) = .31$, n.s., as were word lengths, $F(3,92) = 1.36$, n.s.

Second, it was desired that Related and Unrelated distractors were rated as less threatening than the Threat (Cognitive and Somatic) distractors. It was also desired that within the Threat distractors, the Cognitive Threat and Somatic Threat distractors were rated as equally threatening. To evaluate these premises, threat ratings were subjected to a one-way ANOVA with Distractor Word as the independent variable. Distractor Word was partitioned into two orthogonal comparisons to evaluate these two premises: 1) Related and Unrelated Distractor Word vs. Threat Distractor Word; and 2) Cognitive vs. Somatic Threat Distractor Word. The first of these comparisons yielded a significant main effect of Distractor Word, $F(1,92) = 1171.35$, $p<.001$, indicating Threat distractors were rated to be more threatening, $M = 4.95$, $SD = .63$, than the non-threat (Related and Unrelated) distractors, $M = 1.49$, $SD = .28$. The comparison contrasting Cognitive with Somatic Threat Distractor Words indicated they were rated to be equally threatening, $F(1,92) = 3.34$, n.s.

Third, it was desired that the Related and Unrelated distractors were rated to be less cognitive than the Cognitive Distractor Words and less somatic than the Somatic Distractor Words. It was also desired that Related distractors did not differ from Unrelated distractors in domain ratings. To assesses these, domain ratings were subjected to a one-way ANOVA with Distractor Word as the independent variable.
Distractor Word was partitioned into two orthogonal comparisons: 1) Related and Unrelated Distractor Words vs. Cognitive Distractor Word; and 2) Related and Unrelated Distractor Words vs. Somatic Distractor Word. These revealed that 1) Related and Unrelated Distractor Words were rated to be less cognitive, $M = -.06$, $SD = .49$, than Cognitive Threat Distractor Words, $M = 2.14$, $SD = .30$, $F(1,92) = 146.56$, $p < .001$; and 2) Related and Unrelated Distractor Words were rated as less somatic (mean and standard deviation as above) than Somatic Threat Distractor Word, $M = -1.95$, $SD = .34$, $F(1,92) = 133.29$, $p < .001$.

Finally, it was also desired that the Cognitive and Somatic Threat Distractor Words did not differ in terms of relevance to their respective domains; this was verified when absolute domain ratings were subjected to an independent samples $t$-test, $t(14) = 1.19$, n.s.

In summary, the distractor words possessed the following properties: (a) word frequency norms and word lengths were equivalent across all distractor words; (b) threat distractors were rated as more threatening than non-threat (i.e. related and unrelated) distractors, with cognitive and somatic threat distractors rated equivalently threatening; and (c) non-threat words were rated to be less somatic than somatic distractors and less cognitive than cognitive distractors, with the cognitive and somatic distractors equivalent in terms of relevance to their respective domains.
The Zoo

There are many animals to mammals gorilla see at the zoo ostrich leopard. In the African Savannah exhibit, mammals ostrich leopard you can see giraffes running mammals gorilla alongside wild geese. There gorilla leopard mammals are also rhinoceros and zebras ostrich gorilla in this section. Tigers, mammals leopard lions, and cheetahs form gorilla leopard the Great Cats exhibition. They ostrich gorilla leopard are very graceful animals. There leopard mammals is also a bird gorilla ostrich enclosure. Here, there are flamingos, mammals ostrich pelicans, and even penguins. Children gorilla leopard mammals like to watch the elephants leopard gorilla painting and laugh at mammals ostrich the funny expressions that leopard ostrich the extremely playful orang utans mammals gorilla ostrich make. Feeding time for the gorilla ostrich otters is also a great attraction at the zoo, as ostrich mammals the otters stand up ostrich leopard on their hind legs gorilla mammals patiently awaiting their food. Sometimes, mammals leopard the zoo is open at ostrich gorilla mammals night, at which time leopard ostrich it is best to ostrich gorilla see the nocturnal animals at mammals leopard play.

Note: This passage is taken from the practice trial of the directed ignoring task
APPENDIX F: DIRECTED IGNORING TASK - STORIES, DISTRACTORS, AND COMPREHENSION QUESTIONS (CHAPTER 6)

Story

Gardening at home

Today was the start of autumn, and for Nora, that meant that it was time to do some gardening in preparation for spring. Nora used to study horticulture, and had a passion for gardening. She loved autumn as the foliage on the trees would soon turn brown. Her first plan was to clear her lawn of the weeds that had grown over summer. Nora's next plan was to plant some rosemary, mint, and basil for an edible garden. At the nursery, Nora selected the plants she wanted, but there were so many other plants to admire. She decided to also plant some daffodils and tulips, and settled on a pink and yellow colour scheme for her garden. Satisfied with her purchases, Nora then went home.

Distractor types

<table>
<thead>
<tr>
<th>Related</th>
<th>Unrelated</th>
<th>Threat - cognitive</th>
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<td>inept</td>
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<tr>
<td>herb</td>
<td>youngest</td>
<td>examination</td>
<td>tense</td>
<td>xxxxxxx</td>
</tr>
</tbody>
</table>

Questions

1. Nora used to study…
   a. Zoology
   b. Horticulture
   c. Engineering
   d. Psychology

2. Nora loved autumn because…
   a. The foliage on the trees would soon turn brown
   b. The weather would soon turn cold
   c. Animals were preparing to hibernate
   d. It would snow soon

3. What colour scheme did she decide on for her garden?
   a. White and blue
   b. Blue and purple
   c. White and red
   d. Pink and yellow

4. Nora went to the nursery to buy rosemary, mint and basil, but also bought…
   a. Sunflowers and roses
   b. Lilies and orchids
   c. Daffodils and tulips
   d. Carnations and chrysanthemums
Story

Going bushwalking

Jeremy lived near a eucalyptus forest. One crisp morning, he decided to take a walk in the forest. It would be a nice short trip for that day. He packed a small bag with his lunch and his thermos that was filled with black coffee, and set off. He loved the local flora and fauna, and would often spend hours admiring them. As he walked through the forest, the smell of the eucalyptus trees filled the air, and he could hear the birds in the distance. After a few hours, Jeremy stopped to have lunch. As he rested on the ground, he poured coffee from his thermos. Jeremy felt instantly refreshed after sipping his coffee. Following lunch, he continued on his tour of the forest.

Distractor types

<table>
<thead>
<tr>
<th>Related</th>
<th>Unrelated</th>
<th>Threat - cognitive</th>
<th>Threat - somatic</th>
<th>Control</th>
</tr>
</thead>
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<td>cancer</td>
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<td>brass</td>
<td>incompetent</td>
<td>pain</td>
<td>xxxxxx</td>
</tr>
<tr>
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<td>dame</td>
<td>inferior</td>
<td>poisonous</td>
<td>xxxxxxx</td>
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<tr>
<td>tea</td>
<td>nickname</td>
<td>stupid</td>
<td>tense</td>
<td>xxxxxx</td>
</tr>
</tbody>
</table>

Questions

1. Where did Jeremy decide to walk?
   a. In a swamp
   b. In a jungle
   c. In the city
   d. In the eucalyptus forest

2. Jeremy filled his thermos with...
   a. Coffee
   b. Milk
   c. Soup
   d. Hot chocolate

3. What could he hear in the distance?
   a. Frogs
   b. Crickets
   c. Birds
   d. Lions

4. Where did he have lunch?
   a. Under a pine tree
   b. On the ground
   c. By a lake
   d. Next to the birds
Gone Fishing

Ralph Dalton was alone except for his year old dog Fletch. Fletch, a golden retriever, was a present to him from his wife Elaine for their first anniversary. This was the first time he had taken the dog on a fishing trip on the Murray River. The fish were biting that day, and Ralph caught six of the biggest silver bream he had ever seen in just two hours. His wife would cook some of the bream for dinner, and there would still be enough left to give to the neighbours. Fletch began barking at a dog on the opposite shore, rocking the boat and knocking the fish overboard. Ralph gave Fletch an annoyed look but Fletch just looked back, wagging his tail and tongue.

Distractor types

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Questions

1. On his anniversary, Ralph got a…
   a. Fishing rod  c. Dog called Fletch
   b. Hat  d. Boat

2. Ralph caught…
   a. Bream  c. Tuna
   b. A cold  d. Squid

3. Fletch barked at the…
   a. Horse  c. Cow
   b. Stranger  d. Dog

4. Who would cook the fish?
   a. Ralph's neighbour  c. Nobody
   b. Ralph's wife  d. Ralph
Story

The Art Gallery

Bertha McKee brushed off the droplets of water that had fallen on her as she walked through the sprinklers to get to the art gallery. She worked there as a volunteer at the information booth. She took her seat at the information booth and waited for the day's art viewers to arrive. Bertha loved art, and this job allowed her to see all of the different types of art. She picked up a box of pamphlets that told of upcoming displays. When she looked through one of the pamphlets, she became very excited. The Mona Lisa was soon to arrive, and ‘Sunflowers’, by Vincent Van Gogh, was also arriving in a few months. Bertha could not wait for the exhibits to show at the gallery.

Distractor types

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Questions

1. Bertha McKee...
   a. Wasn't able to work  c. Was looking for work
   b. Worked at the library d. Worked at the art gallery

2. Bertha had just walked through...
   a. Sprinklers c. Mud
   b. A construction site d. Haze

3. When it came to art, Bertha...
   a. Was dumb c. Preferred Rembrandt
   b. Loved different types of art d. Liked Monet

4. What did Bertha pick up?
   a. A newspaper c. A pamphlet
   b. An infection d. A display
The Bank

Derek went to the bank early in the morning to avoid a queue. He wanted to open a new account to save money. Even though it was early in the morning, there were already several other people there waiting in line. Derek waited for twenty minutes before being served. He wanted to open a savings account, and had to fill out several forms before queuing in another line. The pen leaked, and Derek ended up with ink all over his hands. By this time, it was shortly after noon. Derek spent another half an hour waiting in line before being served again. When he finally opened the account, it was already early in the afternoon. Derek decided to take the rest of the day off.

Questions

1. Derek went to the bank to...
   a. Apply for a loan
   b. Open a savings account
   c. Obtain a cheque book
   d. Change his personal details

2. When Derek got to the bank...
   a. Other people were already waiting in line
   b. He was the first one there
   c. He ran into his friend
   d. He was all hot and bothered

3. After the bank, Derek decided to...
   a. Go back to work
   b. Go back to university
   c. Eat breakfast
   d. Take the rest of the day off

4. When did Derek go to the bank?
   a. In the afternoon
   b. On Tuesday
   c. Early in the morning
   d. On Friday
Story

The Basketball Match

Glen Taylor won two tickets to the basketball match. He took along his cousin Andrew, who was a big fan of basketball. It was the first time that Glen had been to a match, and he wondered how different it would be to watching it on television. When Glen and Andrew arrived at the stadium, they found their seats. They were near the front, and close enough to get a good look at the players on the team. The atmosphere in the stadium was electric, as everyone cheered loudly for the team. Glen and Andrew joined in the cheering when their team made the shot. It was even more fantastic than Glen had imagined, and it was far better than watching the match on television.

Distractor types

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Questions

1. Glen took along his...
   a. Friend
   b. Cousin
   c. Uncle
   d. Sister

2. Where were Glen’s seats?
   a. Behind a post
   b. At the very back row
   c. Near the front
   d. Near the changerooms

3. The atmosphere in the stadium was...
   a. Boring
   b. Quiet
   c. Sombre
   d. Electric

4. When the team made a basket, Glen and Andrew joined in the...
   a. Cheering
   b. Jeering
   c. Fighting
   d. Playing
The Birthday Celebration

Rebecca was soon turning nineteen, but she had not yet decided how to celebrate it. All she wanted was a place for everyone to have a good time and enjoy good food. She did not know which of her friends she was going to invite. She was unsure about this as her work friends did not get along with her friends she plays netball with. She thought it best to have several small gatherings with these different groups of friends. She would have one gathering with her friends from work at her favourite coffee shop near work. As for the other gathering, Rebecca’s friend from netball suggested that she have a small gathering down at the pub. Rebecca liked the sound of both those options.

1. How old was Rebecca turning?
   a. Nineteen
   b. Seventeen
   c. Thirty
   d. Eighteen

2. Rebecca’s friends...
   a. Were all best friends with one another
   b. Played golf regularly
   c. Were all very busy
   d. Did not get along with one another

3. In the end, she decided to...
   a. Throw one big gathering
   b. Not hold a gathering at all
   c. Hold two separate gatherings
   d. Stay at home

4. Rebecca’s celebration with her work friends was at...
   a. Her house
   b. A coffee shop near work
   c. A nightclub
   d. A lunch bar
Story

The Family Picnic

The Smiths were preparing for a picnic at Cook National Park. There was always plenty of delicious food at the picnic, including sandwiches, pizza, cinnamon buns, salad, and even a barbecue. Aunt May, Uncle Jim, and their cousins were going to meet them at the National Park. Packing their things into their blue car, the Smiths set off. While in the car, Sally Smith and her brothers decided to count the types of vehicles that passed along the way. There were several station wagons and lorries, not to mention motorbikes, scooters, and even a golf cart! Soon, the Smiths arrived at the park. Sally and her brothers went off to play with their cousins, while their uncle and aunt helped unpack the large picnic basket.

Questions

1. The Smiths were going for a picnic at...
   a. Cook National Park
   b. Yellow Stone Park
   c. Kings Park
   d. Burswood Park

2. While in the car, Sally and her brothers...
   a. Played cards
   b. Admired the flora and fauna
   c. Counted the types of vehicles passing by
   d. Read a book

3. At these picnics, there was always plenty of...
   a. Wildlife
   b. Flies
   c. Annoying mosquitoes
   d. Delicious food

4. The food was carried in a...
   a. Paper bag
   b. Picnic basket
   c. Plastic bag
   d. Cardboard box
The House Project

Phillip and Gloria purchased a house and planned to make improvements to the entire house. Most of it was in fairly good condition, but some parts required more work. They would need to get a carpenter to build shelves in the kitchen and an electrician to do some work in the study. The bathroom also required some work, and they decided that buying a new bath and installing new taps for the basin would improve its appearance. The rest of the house only needed a nice coat of paint. Phillip wanted the interior of the house to be painted red, but Gloria preferred yellow. In the end, they compromised and decided to paint half the walls in the house red, and the other half, yellow.

Questions

1. Where did Phillip and Gloria plan to make improvements?
   a. The garden
   b. The entire house
   c. The sidewalk
   d. The garage

2. What did they want done in the kitchen?
   a. To get a dishwasher
   b. To put pot plants in
   c. To have shelves built
   d. To re-tile the floor

3. What colours did they end up painting the house?
   a. Red and yellow
   b. Blue and yellow
   c. Silver and red
   d. Red and green

4. What were they buying for the bathroom?
   a. A bath and taps
   b. Towels
   c. Toilet seat
   d. Shower curtain
The library visit

Susan was taking her very active twins, Tommy and John, to the library for the first time. They wanted to wear their favourite clothes. Tommy pulled out his fluffy blue pants, and John found a bright red cape in the chest of play clothes. On the way to the library, Susan told the toddlers about all the things they would see there. Both kids loved the big storybooks. Tommy asked if there would be books on trains, while John wanted books on witches. Susan was also glad to go to the library as she could browse through some magazines and look for books on South American cooking. At the library, the twins were amazed at all the books there were. They enjoyed themselves very much.

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1. Susan had…
   a. Twins
   b. Triplets
   c. Problems
   d. A toothache

2. Who was going on the outing?
   a. Her nieces
   b. The neighbour’s children
   c. Ted and Tonia
   d. Tommy and John

3. Susan was hoping to get books on...
   a. African cooking
   b. South American cooking
   c. Carpentry
   d. Thai cooking

4. What did the children want to wear on the outing?
   a. Gum boots
   b. A raincoat
   c. Their favourite clothes
   d. A gold chain
Story

The Market

Every Sunday morning, Angela Cameron went to the markets and this Sunday was no exception. Angela enjoyed going to the markets, as there were many things to see there. Her first stop was to shop for groceries and she liked that there were several fruit and vegetable stalls where she could pick up some supplies for the coming week. She bought some peaches, and bananas, as well as carrots and tomatoes. Angela then looked for a housewarming present for her friend. She could not decide between a nice set of fluffy towels and big comfortable cushions for her friend’s couch. In the end, she bought the cushions for her friend, and towels for her own place. She then went home to have a leisurely lunch.

Distractor types

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Questions

1. Angela went to the market every…
   a. Saturday evening  
   b. Friday morning  
   c. Sunday morning  
   d. Monday evening

2. Her first stop was to shop for…
   a. Groceries  
   b. Bait for fishing  
   c. A housewarming present  
   d. Flowers for the house

3. What did Angela end up buying her friend?
   a. Teapot and cups  
   b. Fish  
   c. Flowers  
   d. Cushions

4. What did Angela go home for?
   a. Dinner  
   b. Lunch  
   c. Breakfast  
   d. Supper
Story

The music fan

Jason always wanted to be a rock star. He is a big fan of heavy metal music, and has many heavy metal albums. He has been collecting albums since he was thirteen, when he bought an ACDC album. At this age, he would lie in bed with the radio turned up loud, and play air guitar to all the songs on the album. He dreamt of being famous and playing guitar on stage in front of thousands of adoring fans. Jason’s taste in music has since matured, but he still wonders what it would be like to be a famous rock star. Sometimes, when he thinks no one is looking, he puts ACDC on and plays air guitar like he did when he was thirteen.

Distractor types

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Questions

1. Jason is a big fan of...
   a. Jazz
   b. Folk music
   c. Pop music
   d. Heavy metal music

2. His first album was by...
   a. Metallica
   b. Alien Ant Farm
   c. ACDC
   d. Def Leppard

3. When he was younger, Jason wanted to be a...
   a. Rock star
   b. Drummer
   c. Songwriter
   d. Jazz musician

4. When he thinks no one is looking, he...
   a. Plays keyboards
   b. Play air guitar
   c. Dances around in the room
   d. Plays the drums
Story

The new baby

Fred Wilson and his friend Ivan Southmore walked quickly down the white corridors of the hospital. Fred was excited to be there that day. His enthusiasm was understandable since this was the birth of his first child and he wanted to show his new daughter off to his friend. As they arrived at the nursery window Fred gave his friend a nudge and pointed to a small bundle right near the window. Fred pressed his face right up against the glass and began to fog it up. “Isn’t she absolutely beautiful?” Fred said to his pal, “She’s got her Daddy’s brown eyes.” Ivan agreed and after about half an hour of staring they decided to go and see the newborn’s mother and share her joy.

Distractor types

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Questions

1. Fred arrived at the hospital with…
   a. The ambulance
   b. His friend
   c. His family
   d. His cousin

2. Fred walked down the hospital…
   a. Halls
   b. Sadly
   c. Corridors
   d. Passages

3. When they arrived at the nursery window, Fred…
   a. Pointed to a small bundle
   b. Felt embarrassed
   c. Smiled at the baby
   d. Saw a pink bundle

4. The baby had her…
   a. Daddy’s eyes
   b. Daddy’s hands
   c. Father’s ears
   d. Father’s nose
Story

The outdoor cinema

Space Out, a movie about aliens from Jupiter, was showing at the outdoor cinema. Karen Dunlop arranged to meet her cousin outside the cinema before the movie. They bought popcorn and found their seats. The aliens were new to Earth, although they had previously been to Saturn, Mercury, and even Pluto. They had travelled much of the solar system and wanted to learn about life on earth. The aliens came to earth on a mission to understand how human beings function. When the movie finished, Karen and her cousin looked around in the foyer of the cinema. There were displays on the solar system, which were very fascinating for Karen. After admiring the displays, Karen and her cousin left the cinema to get some dinner.

Distractor types

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Questions

1. Karen and her cousin were going to watch…
   a. Lost in Space       c. Alien City
   b. Star Wars           d. Space Out

2. The aliens were from…
   a. Venus               c. Jupiter
   b. Uranus              d. Neptune

3. The aliens were on a mission to…
   a. Understand human beings c. Conquer Earth
   b. Eliminate human beings   d. Capture human beings

4. In the foyer of the cinema, there were displays on…
   a. The pyramids of Egypt       c. The world's oceans
   b. The solar system           d. The Australian states
Story

The trip

It was Charlie’s first trip to Europe. He had been looking forward to it for a year, and had spent the last few months planning where he would visit. Most of all, Charlie looked forward to visiting France, and hoped to see the Eiffel Tower in Paris. He had spent the last ten months learning to speak French, and took along his English-French dictionary with him. When he arrived in Paris, his good friend Marc met him at the airport. Marc was French and would show Charlie around the sights of Paris. Charlie had arrived in spring, but the weather was unexpectedly chilly for that time of the year. It was a good thing he wore his scarf and gloves to keep him warm.

Distractor types

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Questions

1. Where was Charlie most looking forward to travelling to?
   a. Norway                      c. Germany
   b. Italy                      d. France

2. What did Charlie take on the plane with him?
   a. French thesaurus             c. English-French dictionary
   b. Travellers cheques           d. Travel guide

3. Which season was it?
   a. Summer                      c. Autumn
   b. Spring                      d. Winter

4. Charlie wanted to see...
   a. The Eiffel Tower             c. Arc deTriumph
   b. Notre Dame                  d. Napoleon’s Tomb
Story

Working in information technology

Tim Smith works with computers in a small local information technology company. He performs a variety of roles, but his main role is providing assistance to those who require technical knowledge. Areas in which people often require assistance include graphic design and web design, internet and email services, and database development. Tim also assists with technical mapping, spreadsheets, and programming when the need arises. Sometimes, when business is quiet, Tim will also work in customer liaison. He enjoys the interaction that these roles allow him, as it is a nice change from working with computers. He also enjoys the diversity of his job as it allows him to develop skills in several areas. In doing so, he is able to build on his computer training.

Distractor types


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Questions

1. Where does Tim Smith work?
   a. A fish and chip shop  
   b. A large corporation  
   c. A small local company  
   d. The local petrol station

2. Tim’s main role is to...
   a. Assist those who require technical knowledge  
   b. Run computer training courses  
   c. Manage the company  
   d. Keep the computers clean

3. When business is quiet, Tim works in...
   a. The workshop  
   b. The garage  
   c. Maintenance  
   d. Customer liaison

4. Which of the following is not part of Tim’s tasks at work?
   a. Graphic design  
   b. Making coffee  
   c. Web design  
   d. Database development
## APPENDIX G: READING SPAN TASK STIMULI (CHAPTER 6)

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<td>For once, Jennifer’s dad did not have an answer to her question. By the time they finished painting the room, it was already midnight. What had they been painting? a) a picture b) the house c) the room d) the ceiling.</td>
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<td></td>
<td>2</td>
<td>The Royal Family is cherished and well-loved by many in Britain. Britney was touched when she saw Gary had sent her beautiful flowers. How did Britney feel? a) petrified b) horrified c) touched d) warm.</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>The students all agreed that the lecture was on an interesting subject. The heavy rain and winds indicated it was the start of winter. Who thought it was an interesting subject? a) the students b) the pupils c) Jenny d) Mark.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Ben asked the waiter for the bill after the very different dinner. The class had already begun when Wayne finally got the urgent message. What did Ben ask the waiter for? a) an entree b) a napkin c) the bill d) a glass of wine.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Graham and Lucy liked their holiday home down South by the river. Tom arrived at the engagement party and was given a warm welcome. Where did Tom arrive at? a) the funeral b) the wedding c) the housewarming party d) the engagement party.</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Although the farm was located in Scotland, it was near the border. Phar Lap will always be remembered as a famous racehorse champion. The ringing bell was a signal that the Spanish lesson had finished. The farm was in... a) Australia b) England c) Scotland d) Sweden.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>The Swedish diver calmly stood high above the crowd on the platform. Joan was running a little late for her early morning violin lesson. Amanda wished for a cool winter after the long and hot summer. What was Joan learning? a) the piano b) the violin c) the flute d) the cello.</td>
</tr>
<tr>
<td>Set Size</td>
<td>Trial</td>
<td>Sentences</td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
<td>-----------</td>
</tr>
</tbody>
</table>
| 3        | 3     | Coast Accounts were very disappointed they lost the much sought-after contract.  
Sewing is not at all difficult if you just follow the pattern.  
When Susan purchased a plot of land, she decided on a builder.  
What had Susan purchased?  
a) some land  
b) a new dress  
c) a car  
d) a house |
| 1        | 1     | When Paul went shopping, he was determined to stick to his budget.  
Aunt May became very hard of hearing as she got gradually older.  
Colin had been planning this trip with Alison so he could propose.  
After hours of loud music, the neighbours finally turned down the volume.  
Paul went...  
a) shopping  
b) fishing  
c) to the pub  
d) to the football |
| 2        | 2     | The children were ecstatic when they found chocolate hidden in the kitchen.  
The novel was so old that its pages had already turned yellow.  
Since she purchased some shares, Natasha began to watch the stock exchange.  
After many years of campaigning, Mick was finally made a club member.  
What was old?  
a) the house  
b) the novel  
c) the club  
d) the computer |
| 3        | 3     | The accounting firm was pleased with the progress of the new partner.  
Colleen refused to vacuum the house, but she did not mind washing.  
Judging by the deafening applause, the children’s play was a huge success.  
Jimmy wanted to watch the cricket game so the children moved aside.  
Colleen would not...  
a) clean the house  
b) do the laundry  
c) make the coffee  
d) vacuum the house |
| 1        | 1     | John James will be representing Brazil in the Olympic Games in swimming.  
Some teenagers take time off between high school and uni to travel.  
Charmaine decided to have some friends over for a barbecue that Friday.  
All the leaves turn a beautiful golden shade of brown in autumn.  
With his lottery winnings, Lee bought a business that made recycled paper.  
What do some teenagers do prior to university?  
a) play  
b) work  
c) travel  
d) study |
<table>
<thead>
<tr>
<th>Set Size</th>
<th>Trial</th>
<th>Sentences</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td>The player wanted to be in the competition but was kept waiting. It was cold outside so Miranda took along her warm red jacket. The gymnast’s new and complex routine drew gasps from the stunned audience. Jenny felt honoured to be seated next to the captain during breakfast. As the bridesmaid spoke at the reception, she was overcome with laughter. Where did the bridesmaid speak? a) at the wedding b) in the car c) at a church d) at the reception.</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>It is not uncommon to see wildlife when travelling in the forest. Many of the students found drama to be a very interesting topic. Once they had signed the contract, Kristy and Edward were extremely happy. Now that Peg’s book was finally published, she was officially an author. It is important to prepare the surface of the walls when painting. What subject did the students find interesting? a) drama b) psychology c) history d) politics.</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>The fashion critics were stunned and also delighted by the daring design. The principal urged the teacher to consider future plans for his career. They had been looking forward to hearing the speaker talk about finance. The tourists felt deceived by the brochure when they saw the hotel. It was stunning to see the glowing sun setting over the ocean. The socialite was frantic when she realised her precious dogs were missing. The fashion critics were… a) enthusiastic b) critical c) stunned d) amazed.</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>The Christmas tree was covered entirely in tinsel and looked very pretty. The mixture that the herbalist prescribed Dawn was effective on her illness. Dale sent Penny to get vegetables from the shop on the corner. Lately, Jay has been quite obsessed with following current trends in fashion. The student teacher was frustrated that the rowdy class would not listen. In science, it is vital that all the chemicals are correctly measured. How did the teacher feel about the class? a) annoyed b) frustrated c) angry d) pleased.</td>
</tr>
<tr>
<td>Set Size</td>
<td>Trial</td>
<td>Sentences</td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
<td>-----------</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>Famous for his plays, Dylan Thomas was seen as a literary genius. The crowd gathered around to watch their team playing in the football match. Doug loved maths and found the problem-solving task easy to complete. Kevin made a grand entrance at the magician’s ball dressed in silver. Although the guest of honour was late, the surprise party was lovely. Karl decided he would serve his dinner guests duck braised in orange. Doug found the task…</td>
</tr>
<tr>
<td></td>
<td></td>
<td>a) simple</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) boring</td>
</tr>
</tbody>
</table>
APPENDIX H: CORRELATIONS OF STATE ANXIETY, INHIBITION, AND INDICES OF WORKING MEMORY PERFORMANCE

(CHAPTER 6)

Table H.1. Correlations of state anxiety ratings, state depression ratings, inhibition, and indices of working memory performance

a. State anxiety and directed ignoring task performance

<table>
<thead>
<tr>
<th>Distractor Type</th>
<th>Control</th>
<th>Related</th>
<th>Unrelated</th>
<th>Threat</th>
<th>Cognitive</th>
<th>Somatic</th>
<th>Overall</th>
<th>Word</th>
<th>Unrelated/Threat</th>
<th>Degree of Slowing</th>
</tr>
</thead>
<tbody>
<tr>
<td>POMS Anxiety</td>
<td>-.05</td>
<td>-.13</td>
<td>-.02</td>
<td>-.09</td>
<td>-.16</td>
<td>-.11</td>
<td>-.09</td>
<td>-.06</td>
<td>-.09</td>
<td>-.09</td>
</tr>
<tr>
<td>POMS Depression</td>
<td>.19</td>
<td>.12</td>
<td>.11</td>
<td>.11</td>
<td>.06</td>
<td>.11</td>
<td>.12</td>
<td>.11</td>
<td>.11</td>
<td>.04</td>
</tr>
<tr>
<td>STICSA Somatic</td>
<td>-.14</td>
<td>-.18</td>
<td>-.08</td>
<td>-.14</td>
<td>-.22</td>
<td>-.16</td>
<td>-.15</td>
<td>-.12</td>
<td>-.12</td>
<td>-.08</td>
</tr>
<tr>
<td>STICSA Cognitive</td>
<td>.14</td>
<td>.02</td>
<td>.08</td>
<td>.06</td>
<td>.08</td>
<td>.08</td>
<td>.05</td>
<td>.09</td>
<td>.09</td>
<td>-.06</td>
</tr>
<tr>
<td>CIQ task-relevant</td>
<td>.19</td>
<td>.01</td>
<td>.22</td>
<td>.17</td>
<td>.22</td>
<td>.19</td>
<td>.14</td>
<td>.21</td>
<td>.04</td>
<td></td>
</tr>
</tbody>
</table>

b. State anxiety and running verbal task performance

<table>
<thead>
<tr>
<th>Memory span</th>
<th>Reaction time</th>
<th>Increasing load (P)</th>
<th>Increasing load (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>I</td>
<td>P</td>
</tr>
<tr>
<td>POMS Anxiety</td>
<td>.09</td>
<td>-.08</td>
<td>.00</td>
</tr>
<tr>
<td>POMS Depression</td>
<td>-.10</td>
<td>.17</td>
<td>.19</td>
</tr>
<tr>
<td>STICSA Somatic</td>
<td>.12</td>
<td>-.05</td>
<td>.10</td>
</tr>
<tr>
<td>STICSA Cognitive</td>
<td>-.04</td>
<td>.03</td>
<td>.18</td>
</tr>
<tr>
<td>CIQ task-relevant</td>
<td>-.07</td>
<td>-.06</td>
<td>-.09</td>
</tr>
</tbody>
</table>
c. State anxiety and grammatical reasoning task performance

<table>
<thead>
<tr>
<th></th>
<th>Memory subtask</th>
<th></th>
<th>Reasoning subtask</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proportion of errors</td>
<td>Reaction times</td>
<td>Proportion of errors</td>
<td>Reaction times</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Increasing Load</td>
<td>Low</td>
</tr>
<tr>
<td>POMS Anxiety</td>
<td>-.10</td>
<td>-.18</td>
<td>-.14</td>
<td>-.14</td>
</tr>
<tr>
<td>POMS Depression</td>
<td>-.18</td>
<td>-.04</td>
<td>.02</td>
<td>-.09</td>
</tr>
<tr>
<td>STICSA Somatic</td>
<td>.04</td>
<td>-.12</td>
<td>-.13</td>
<td>-.17</td>
</tr>
<tr>
<td>STICSA Cognitive</td>
<td>-.06</td>
<td>-.15</td>
<td>-.12</td>
<td>-.24</td>
</tr>
<tr>
<td>CIQ task-relevant</td>
<td>-.02</td>
<td>.01</td>
<td>.02</td>
<td>-.18</td>
</tr>
</tbody>
</table>

d. State anxiety and reading span task performance

<table>
<thead>
<tr>
<th></th>
<th>Reading span score</th>
<th>Comprehension errors</th>
<th>Reaction time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>POMS Anxiety</td>
<td>.08</td>
<td>-.05</td>
<td>-.20</td>
</tr>
<tr>
<td>POMS Depression</td>
<td>-.04</td>
<td>.06</td>
<td>-.06</td>
</tr>
<tr>
<td>STICSA Somatic</td>
<td>.18</td>
<td>.04</td>
<td>-.31</td>
</tr>
<tr>
<td>STICSA Cognitive</td>
<td>-.01</td>
<td>.01</td>
<td>-.24</td>
</tr>
<tr>
<td>CIQ task-relevant</td>
<td>-.10</td>
<td>.09</td>
<td>-.02</td>
</tr>
</tbody>
</table>

Note: Anxiety and Depression ratings are averaged across the Post Mood Induction and Post Experiment Phases. P denotes preparatory intervals, I denotes inter-item intervals. 2 denotes Sequence Length 2, and 3 denotes Sequence Length 3. \( ^a \) denotes \( p < .001 \); \( ^b \) denotes \( p < .01 \); \( ^c \) denotes \( p < .05 \)