UNIVERSITY OF SOUTHAMPTON

FACULTY OF MEDICINE, HEALTH AND LIFE SCIENCES

School of Psychology

EXPLORING THE ROLE OF WORKING MEMORY IN UNDERSTANDING EDUCATIONAL UNDERACHIEVEMENT IN ANXIETY AND DEPRESSION

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ABSTRACT

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Research has shown that high levels of emotion are associated with lowered academic performance. However, the mechanisms involved in this relationship are as yet unclear. One potentially important process is the disruption of working memory. Building on previous research such as Wine (1971) and Sarason (Sarason, 1984), Eysenck and Calvo (1992) formulated a processing efficiency theory (PET) to account for the disruptive effects of anxiety on cognitive task performance. Briefly, PET suggests that anxiety can have the effect of reducing cognitive storage and processing resources in the working memory system. One effect is a reduction in task effectiveness, or the accuracy of performance. H.C. Ellis and colleagues have proposed a similar model, the resource allocation model, with special reference to depressed mood (e.g. Ellis & Moore, 1999). Under both theoretical frameworks, the negative effects of emotion are assumed to be most clearly seen on complex cognitive tasks. In addition, the negative effects of anxiety on performance are thought to be most pronounced under stressful conditions.

This thesis explored the relationship between emotion, working memory and academic performance in an attempt to further understand the processes involved in educational underachievement in anxiety and depression. The first empirical investigation reported in Chapter Three was an initial step in testing the simple relationship between three emotions (trait anxiety, depression and test anxiety) and academic performance measures. Consistent with previous research moderate negative relationships were found between the two constructs. Chapter Four showed that working memory partially mediated the negative trait anxiety-academic performance relationship. Chapter Five replicated the mediation hypothesis also incorporating depression and test anxiety. A moderated mediation hypothesis was also tested. That is, that the negative links between emotion, working memory and academic performance were shown to be most pronounced when stress reactivity was high. Chapter Six replicated these moderated mediation results and tested an emotion x working memory interaction hypothesis that suggested that those with high emotion and low working memory were the poorest academic performers. Chapter Seven evaluated the moderated mediation and interaction hypotheses in a longitudinal study which allowed for some preliminary conclusions to be made concerning causality. It was shown that emotion was negatively associated with academic performance via verbal working memory over time when stress reactivity was high. Over time, high emotion and low working memory in combination were associated with lower academic performance. In Chapter Eight, the implications of the findings in this thesis for theory and practice were discussed.

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DESIDERATA

Go placidly amid the noise and the haste,
and remember what peace there may be in silence.
As far as possible, without surrender,
be on good terms with all persons.
Speak your truth quietly and clearly;
and listen to others,
even to the dull and the ignorant;
they too have their story.
Avoid loud and aggressive persons;
they are vexatious to the spirit.
If you compare yourself with others,
you may become vain or bitter,
for always there will be greater and lesser persons than yourself.
Enjoy your achievements as well as your plans.
Keep interested in your own career, however humble;
it is a real possession in the changing fortunes of time.
Exercise caution in your business affairs,
for the world is full of trickery.
But let this not blind you to what virtue there is;
many persons strive for high ideals,
and everywhere life is full of heroism.
Be yourself. Especially do not feign affection.
Neither be cynical about love,
for in the face of all aridity and disenchantment,
it is as perennial as the grass.
Take kindly the counsel of the years,
gracefully surrendering the things of youth.
Nurture strength of spirit to shield you in sudden misfortune.
But do not distress yourself with dark imaginings.
Many fears are born of fatigue and loneliness.
Beyond a wholesome discipline,
be gentle with yourself.
You are a child of the universe
no less than the trees and the stars;
you have a right to be here.
And whether or not it is clear to you,
no doubt the universe is unfolding as it should.
Therefore be at peace with God,
whatever you conceive Him to be.
And whatever your labours and aspirations,
in the noisy confusion of life,
keep peace in your soul.
With all its sham, drudgery, and broken dreams,
it is still a beautiful world.
Be cheerful. Strive to be happy.

'Desiderata' by Max Ehrmann (1927)

DECLARATION OF AUTHORSHIP

I, ……MATTHEW OWENS…….,

declare that the thesis entitled

………… EXPLORING THE ROLE OF WORKING MEMORY IN UNDERSTANDING EDUCATIONAL UNDERACHIEVEMENT IN ANXIETY AND DEPRESSION…………

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
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Signed: ……………………………………………………………………….

Date:………………………………………………………………………….

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ABBREVIATIONS

α = Chronbach's alpha

AIC = Aikake's information criterion

AWMA = automated working memory assessment

β = standardised regression weight

CANTAB = Cambridge neuropsychological test automated battery

CAT = Cognitive abilities test

CE = central executive

CFI = comparative fit index

CTAS = children's test anxiety scale

Δ_i = AIC difference

$\Delta\chi^2$ = chi squared difference test

GCSE = general certificate of secondary education

KS2 = Key stage 2 national curriculum tests (maths, English and science)

MHV = Mill Hill vocabulary scale

PET = processing efficiency theory

PL = phonological loop

RAM = resource allocation model

RCADS = revised child anxiety and depression scale

RMSEA = root mean square error of approximation

SAT = national curriculum standard assessment tests

SPM = Raven's standard progressive matrices

STAIC = state trait anxiety inventory for children

VSSP = visuospatial sketchpad

CHAPTER ONE: COGNITION AND EMOTION.

1.1 Introduction.

The debate concerning the relationship between cognition and emotion is not a new one. For example, Aristotle divided the mind into cognition, emotion and conation (or motivation). Descartes argued for the superiority of the rational mind over bodily emotions which were entirely separate entities and therefore could not interact with one another (Russell, 1996). Conversely, Hume argued that: “Reason is, and ought only to be the slave of the passions, and can never pretend to any other office than to serve and obey them.” (Hume, 2003). In the 1980s this debate was revived with emotion viewed as primary and independent of cognition on the one hand (Zajonc, 1980; Zajonc, 1984) and cognitive appraisal as primary and antecedent on the other (Lazarus, 1982; Lazarus, 1984). Since that time there have been calls to provide integrative accounts of cognition and emotion. Lane, Nadel, Allen and Kasniak (2000), for example, argued for a cognitive neuroscience of emotion on the basis that neural processes underlying cognition and emotion are unlikely to be fundamentally different. Integrative accounts of cognition and emotion in developmental psychology have also been encouraged (Bell & Wolfe, 2004).

Excessive emotion has similarly been known and described for some time, while classified under various terms. Berrios (1999) gives several examples. For instance, generalised anxiety disorder was described by Ribot in 1896, under the term *panophobia* as: “the state in which the patient fears everything, and where anxiety, instead of being riveted on one object, floats as in a dream” (as cited in Berrios, 1999, p.88) Another example can be found from Hartenberg who in 1901 conceived timidité as a: “combination of fear, shame, and excessive embarrassment engendered by social situations, and that the disorder could seriously impair psychosocial competence” (as cited in Berrios, 1999, p.88). In terms of low mood Berrios (1988) also showed that the contemporary phenomenon of depression has its roots in the ancient term ‘melancholia’. One of the earliest definitions of depression was given in 1885 by Régis as: “the state opposed to excitation. It consists in a reduction in general activity ranging from minor failures in concentration to total paralysis” (as cited in Berrios, 1988, p.301).

Although emotional disturbances are often characterised as negative, it should be noted that fear is a typical developmental process that is thought to be relatively transitory, stabilising at about 11 years old (Gullone, 2000). Anxiety is also argued to be useful in threatening situations, thus increasing the chances of survival (Muris & Field, 2008). For example, an animal phobia might be a useful response to potentially dangerous small animals such as spiders and snakes, social phobia could be useful to guard against a threat to reputation or status, whereas blood phobia and hypochondriasis might protect against threats to health. Generalised anxiety or worry could protect the individual from general dangers. The adaptive qualities of anxiety can be seen as analogous to those of pain. For example, individuals congenitally insensitive to pain often suffer traumatic injuries which contribute to an early death (Sternbach, 1963). From an evolutionary perspective it has also been argued that depression is equally adaptive. Nesse (1998, p.413) points out that emotional disorders are: "Darwinian algorithms, shaped by natural selection to maximize reproductive success, not our happiness". Several examples are given for the possible benefits of sadness. For instance, although searching for a lost loved one in grief may seem futile in modern society, it may have lead to recovery of the lost one in the ancestral environment. It is further argued that depression may serve as an impetus to force the individual to disengage from futile enterprises; possibly foraging where there is no longer food in ancient times, perhaps from a failing relationship or job in the modern day.

Clinical problems with emotions are usually diagnosed based on their persistence over time and whether they interfere with everyday functioning. The Diagnostic and Statistical Manual of Mental Disorders IV Text Revision (DSM IV-TR) (American Psychiatric Association, 2000) gives several types of mood disorder including major depressive disorder, bipolar disorder and dysthymic disorder. Depressive disorders are in part diagnosed by major depressive episodes which are defined by: depressed mood, anhedonia, weight change, sleep disturbance, psychomotor retardation, feelings of worthlessness, recurrent thoughts of death, a diminished ability to think or concentrate and indecisiveness.

Anxiety disorders include: panic disorder, agoraphobia, specific phobia, social phobia, obsessive-compulsive disorder, post-traumatic stress disorder, generalised anxiety disorder and separation anxiety disorder. The DSM IV-TR highlights several problem areas for anxiety disorders including fear and dread accompanied by physiological symptoms such as palpitations, sweating, nausea, chest pain and trembling or shaking. There is also a tendency to avoid fear provoking situations and form obsessions. Excessive worry is proposed to be the sine qua non of anxiety. These aspects of anxiety have been summarised into three core components of behaviour, cognition and physiological response (Weems, Zakem, Costa, Cannon, & Watts, 2005). It is clear from the DSM IV-TR classifications, for example, that cognitive elements such as worrisome thoughts and concentration problems are one major feature of the emotional disorders. Moreover, Beck has claimed that: "The primary pathology or dysfunction during a depression or an anxiety disorder is in the cognitive apparatus." (Beck, Emery, & Greenberg, 1985, p.85). This theme of cognition in emotion will prove to be key when turning to understanding the low academic performance in individuals with high levels of emotion. First, however, the epidemiology of the emotional disorders will be discussed.

Before addressing the epidemiology of emotional disorders, it should be pointed out that the categorical classification system of DSM IV-TR is not without its critics. Although useful in defining problems, DSM IV-TR can be criticised for being too inclusive to be meaningful. For example, along with the anxiety and mood disorders proper, DSM IV-TR also includes a mixed anxiety-depressive disorder, which refers to those individuals who have anxiety and depressive symptomatology yet fall below the thresholds for any existing anxiety or depression disorders. Furthermore, because of boundary disputes between disorders and between disorders and normality, Widiger and Samuel (2005) have urged for the consideration of a more dimensional approach to disorder. Indeed, in the study of emotion and cognition, many researchers take a more dimensional approach to emotion. For example, Spielberger found evidence for a distinction to be made between state and trait anxiety (Gaudry, Vagg, & Spielberger, 1975). The former refers to the evoked state of anxiety, which may include a physiological response, which results from a perception of threat or danger. The latter refers to a dimensional personality trait that leaves the individual prone to anxiety. In this thesis it is assumed that there is a close relationship between high levels of emotion traits such as anxiety and depression and emotional disorder as categorised by classification systems such as DSM. It is assumed that the symptoms will be qualitatively similar, only that the disorders represent more severe cases which sit at the extreme of a continuum. Nevertheless, much of the relevant research into epidemiology focuses on disorder per se, which will be reviewed in the following section.

1.2 Epidemiology of Emotional Disorders.

There is general agreement that the anxiety and depressive disorders are widespread in the general population (Wittchen & Jacobi, 2005). Approximately one in five people will suffer from an emotional disorder in their lifetime. The large scale National Comorbidity Survey, carried out by Ronald Kessler's group in the United States, found that anxiety disorders were the most prevalent class of psychiatric disorders, closely followed by depression. The group has reported lifetime prevalence rates of 28.9% for anxiety disorders and 20.8% for mood disorders (Kessler, Berglund, Demler, Jin, & Walters, 2005). These prevalence estimates compare well with the constantly updated rates available from the National Comorbidity Survey website, currently at 31.2% for any anxiety disorder and 21.4% for any mood disorder (National Comorbidity Survey, 2007).

A systematic review of prevalence and incidence studies from countries throughout the world supports these prevalence estimates, while also highlighting a degree of variability. Somers, Goldner, Waraich and Hsu (2006) analysed data from several countries including Iran, Mexico, Canada, Germany, the Netherlands and others found that the lifetime prevalence rates for any anxiety disorder ranged from 9.2% (South Korea) to 28.7% (Switzerland), with a best estimate given of 16.6%. The factors involved in the heterogeneity among rates were sample size, diagnostic criteria used, country, and sample size. The authors also found the now welldocumented sex difference in anxiety where prevalence rates were higher for females.

Childhood anxiety disorders are also highly prevalent. A longitudinal study that followed over 1400 children aged 9 -13 years up until age 16, has shown that by the age of 16, 15% have already suffered an emotional disorder (Costello, Mustillo, Erkanli, Keeler, & Angold, 2003). Asbahr (2004), searching Medline from 1981 to 2003, estimated a similar prevalence rate for anxiety disorders in childhood and adolescence (10%). Social phobia, which appears later in adolescence has an equivalent prevalence. In a review of 23 European epidemiology studies Fehm, Pelissolo, Furmark and Wittchen (2005) showed that social phobia, which appeared between 12 and 16 years, had a median lifetime prevalence estimate of 6.7% (range = 3.9 to 13.7%). The onset of social phobia after age 25 appears to be quite rare. This was demonstrated by Wittchen, Stein and Kessler (1999) who showed that the cumulative hazard function for social phobia in both males and females reached 100% before 24 years of age. However, an estimated prevalence rate somewhere between 7% and 13% in western countries has been made by Furmark (2002). Considerable variability was found in this study that was attributed to several methodological variables including diagnostic criteria, assessment type and number of situational probes used.

Age-of-onset for emotional disorders is usually very early in life (anxiety) or in early adulthood (mood). In this sense the emotional disorders are quite distinct from physical disorders as they have their strongest foothold in youth and yet have a lower risk for those who grow through these early high risk ages unscathed (Kessler et al., 2005). The median age-of-onset in the Kessler et al. study (2005) for any anxiety disorder was 11 years, lower than that for mood disorders (30 years). Within the anxiety disorders specific phobia and separation anxiety had the lowest median age of onset (7 years), while social phobia and obsessive compulsive disorder emerged in the teenage years (13 and 19 years, respectively). Panic disorder, agoraphobia and generalised anxiety disorder appeared later, at adulthood (24, 20 and 31 years, respectively). Age-of-onset for specific mood disorders was consistently later in life than the anxiety disorders, including major depressive disorder (32 years), dysthymia (31 years) and bipolar disorder (25 years). Although it can be seen that there are some qualitative and quantitative differences between anxiety and depression there is also considerable overlap.

1.3 The relationship between anxiety and depression.

Anxiety and depression are classified as separate disorders under the DSM-IV-TR system (American Psychiatric Association, 2000). A major depressive episode is characterised by depressed mood and a loss of interest in nearly all activities. In children and adolescents the mood may be more irritable than sad. There is also likely to be, among other symptoms, changes in appetite/weight, decreased energy, sleep problems, suicidal ideation or attempts. Generalised anxiety disorder, on the other hand, is characterised primarily by excessive worry and fear about most aspects of life (e.g. job responsibilities, health of self and family members, household chores, car repairs, being late for appointments etc.), coupled with increased physiological activity and somatic complaints. Conceptually, the two sets of phenomena are clearly separate entities and in some senses opposites. For example, in depression there seems to be a lack of motivation to engage in and a withdrawal from the surrounding world. Whereas in anxiety, the individual is most concerned with every aspect of life and is often fearful of harm or death. However, despite these striking differences, there are a number of similarities. For example, shared in DSM classification of depression and anxiety is the lack of energy in the former and the fatigue in the latter. Both also share problems with sleep disturbance. Most interesting and pertinent to this thesis is the shared problems with cognitive functioning. In depression, there is difficulty in thinking, concentrating and making decisions. In anxiety there is also difficulty in concentrating. Worrisome thoughts in anxiety and withdrawal from the world and negative rumination are likely to reduce the general amount of cognitive resources available to the anxious or depressed individual.

Anxiety and depression often co-occur. Scores on self-report measures of anxiety and depression tend to be rated similarly by individuals. This effect was shown, for example, in a large sample (N = 52265) where a strong correlation between the two subscales of the Hospital Anxiety and Depression Scale of r = .55 was found (Mykletun, Stordal, & Dahl, 2001). A similar correlation (r = .58) has been found in a sample of 968 12-18 year-olds (Muris, Merckelbach, Schmidt, Gadet, & Bogie, 2001). In terms of disorder per se, experiencing either anxiety or depression significantly increases the likelihood of experiencing the other disorder. In a birth cohort study Moffitt et al. (2007) demonstrated that generalised anxiety disorder and major depressive disorder are highly comorbid. The total comorbidity for the sample was 12%. The study also showed that 72% of lifetime anxiety cases also had depression, and 48% of lifetime depression cases also had anxiety. Furthermore, almost all of the study members who experienced either disorder at three or more assessments (indicating prolonged or recurrent disorder) experienced the other disorder.

A meta-analysis of 21 studies addressing the comorbidity of anxiety and depression showed that the strength of the association between the two was strong. Having either disorder made it eight times more likely, in terms of odds ratios (8.2, 95%CI 5.8, 12.0) that the other would be present (Angold, Costello, & Erkanli, 1999). This finding replicates exactly the findings published from the National Comorbidity Survey in the US (Kessler et al., 1996). As Chavira, Stein, Bailey and Stein (2004) have noted, the high rate of comorbidity between anxiety and depression, coupled with the primacy of the anxiety disorders, has prompted interest in anxiety as a risk factor for depression (Parker et al., 1999; Pine, Cohen, & Brook, 2001). This so-called sequential morbidity, is potentially important as it suggests that treating the first disorder provides a window of opportunity for preventing the second. However, Moffitt et al. (2007) have challenged the prevailing view that anxiety usually precedes depression. The results of this study showed that although it was true that 37% of depressed cases were preceded by anxiety, 63% were not. Furthermore, 32% of anxiety cases were preceded by depression. This suggests that the sequential comorbidity between anxiety and depression may be more balanced than was previously thought. Similarly, Kessler et al. (2008) found that generalised anxiety disorder preceded major depressive episode and vice versa. Furthermore, it was suggested that treatment of the temporarily primary disorder and its effect on onset of comorbidity would be the only way to resolve the uncertainty as to whether generalised anxiety disorder and major depressive episode are causal risk factors of each other or only markers. There is clearly a debate as to the precise nature and causal status of the comorbidity between anxiety and depression, however, that the two phenomena correlate is well-established. Reasons for this co-occurrence are complex; however, a large amount of shared variance between the two phenomena is likely to come from genetic factors.

1.4 Genetic Epidemiology.

Anxiety disorders follow a pattern of familial aggregation. That is, they occur in more members of a family than would be readily accounted for by chance. They are also heritable disorders. That is to say, there is a fraction of the variability in anxiety disorders that is explained by genetic differences. A recent meta-analysis of genetic studies concerning the anxiety disorders (Hettema, Neale, & Kendler, 2001) extrapolated data from several studies that included samples of panic disorder, generalised anxiety disorder, phobias, and obsessive compulsive disorder. On average, first-degree relatives of those with anxiety disorders were shown to be five times more likely to also be diagnosed with an anxiety disorder. The meta-analysis also suggested that the main source of liability to anxiety disorders was genetic. Across the four disorders, heritability was found to be between 20% - 40%. In panic disorder, heritability effects were found to be equivalent in two studies that had studied gender effects, suggesting that genes affect panic disorder equally in women and men. The remaining variance was attributed to non-shared environmental factors. Therefore, common family environments do not appear to play a role in the aetiology of panic disorder. Similarly, in generalised anxiety disorder, the effect of genes on liability to disorder was found to be equal across genders, however, a small common family environment effect was found for women only. The remaining variance was explained by individual-specific environment.

Although part of the results for phobias (social, specific, and agoraphobia) initially suggested that genes had little part to play in explaining the variance, and that common experience was more important, the authors suggest that this was likely due to limitations in statistical power. In obsessive compulsive disorder, the aggregate risk for first degree relatives was 8.2% compared with 2% for comparison relatives. No twin studies were reported using obsessive compulsive disorder samples. However, subsequent research that has analysed the genetic influence on obsessive compulsive disorder (Hudziak et al., 2004) showed that genetic factors account for approximately 55% of variance in obsessive compulsive disorder and unique environmental influences accounting for the remaining 45%. Shared environmental influences only appeared (16%) in a single sample in this study comprised of 12 year-olds. Samples included a US sample comprised of 8 and 9 year-olds and Dutch samples of 7, 10 and 12 year-olds.

From Hettema's work we can conclude that anxiety aggregates in families, has a moderate genetic component, and that the majority of the rest of the variance is due to individual-specific environmental factors; shared environmental factors appear to have a much smaller involvement. The familiarity of anxiety is an established finding, corroborated by other work in the field (Kendler, Davis, & Kessler, 1997; Merikangas et al., 1998), and the heritability estimate is reasonable with one qualification: Heritability estimates are usually somewhat higher in younger children. For example, Eley et al., (2003) reported heritability estimates of 50% for general distress, 39% for separation anxiety, 52% for fear, 54% for obsessive-compulsive behaviours and 64% for shyness/inhibition in 4 year-old twins. In fact, more recently, heritability estimates for young children have been reported as being higher still, as high as 73% for separation anxiety disorder, and 80% for specific phobia (Bolton et al., 2006). The point raised by Hettema et al. (2001) that after genetics most of the rest of the variance explained is due to individual-specific factors, is however, challenged by other studies. For example, Eley et al. (2003) conclude that there is: "considerable evidence of shared environmental influences in childhood anxiety" (p. 496).

A study by Sullivan, Neale and Kendler (2000) has shown that depression is also familial, where this pattern is mostly accounted for by genetics. However, it was shown that depression results from a combination of both genetic and environmental influences. There is also an interesting line of research that suggests a close genetic relationship between anxiety and depression in addition to its simple comorbidity. That is, the same genes may be responsible for both anxiety and depressive disorders. For example, a recent study found that the estimated genetic correlation between generalised anxiety disorder and major depression was r =.74 for men and at unity for women (Kendler, Gardner, Gatz, & Pedersen, 2007). Given that virtually the same genetic factors are involved in the two disorders, this suggests that vulnerability to either is in large part a result of environmental experiences. Leaving aside the causes of emotional disorders, their effects can be large and wide-ranging.

1.5 The burden of emotional disorders.

The broad effects of anxiety can be devastating, accounting for a larger proportion of the disease burden in western countries than breast cancer or HIV (Rapee, Kennedy, Ingram, Edwards, & Sweeney, 2005). Wittchen (2002) showed that generalised anxiety disorder, for example, has a negative impact on work productivity and is associated with increased health care utilisation. This disorder was estimated to have an annual cost of $42 - 47 billion in the US in 1990. Four components of psychiatric and non-psychiatric medical treatment, indirect workplace costs and, to a lesser extent pharmaceutical costs, explained the total cost. Depression also causes serious burden on society. Greenberg et al. (2003) showed that the cost of depression in the US was $83.1 billion in 2000. Costs were broken down into treatment (31%) suicide related costs (7%) and employment (62%).

1.6 Educational impact.

Emotional disorders are also consistently associated with educational underachievement. In the National Comorbidity Survey, it was found that individuals with an anxiety disorder were 1.4 times, and with a depressive disorder 1.2 times (odds ratios) more likely to fail to complete high school or college (Kessler, Foster, Saunders, & Stang, 1995). In a recent update, the negative effect of emotion on early school termination was found for high school students only (Breslau, Michael, Nancy, & Kessler, 2008). In this study, in terms of odds ratios, having any anxiety disorder made drop-out from school 1.3 times more likely and having any mood disorder made it 1.5 times more likely.

Similarly, Ameringen, Mancini, & Farvolden (2003), found that of 201 patients with an anxiety disorder who were asked to complete a retrospective ‘school questionnaire’, approximately half indicated that they had left school prematurely. Of these, 24% indicated that anxiety was the primary reason for leaving.

There is also broad agreement that test anxiety is an important factor in explaining lower academic performance (Stober & Pekrun, 2004; Zeidner, 1998). Test anxiety is a special case of anxiety that is directed to testing situations, or evaluative situations more generally. It is: “a complex state that includes cognitive, emotional, behavioural, and bodily reactions.” (Sarason, 1984, p.931). With the added statistical power of meta-analyses, using data from over 600 studies found in two prior studies (Hembree, 1988; Seipp, 1991), Schwarzer (1990) found an average correlation of $r = -.21$ between test anxiety and academic performance. This represents the ‘best guess’ as to the true size of the relationship. Lending weight to this conclusion, a similar common correlation ($r = -.27$) has been found in a meta-analysis of 26 studies that addressed the relationship between maths anxiety and maths performance (Ma, 1999). In Hembree’s study (1988) 562 studies addressing the nature, effects and treatment of test anxiety were reviewed and homogeneous negative correlations between anxiety and aptitude/achievement (-.29), and IQ testing (-.23) were found. In Seipp’s study a weighted correlation of $r = -.21$ was found between anxiety and academic performance. However, the correlation was not homogeneous. That is, the effect sizes ranged from extreme negative ($r = -.66$) to positive ($r = .37$). This heterogeneity could be due to the different samples and measures used in the various studies. Alternatively, as the author suggests, the heterogeneity could be suggestive of the presence of non-trivial moderating factors. Put another way the relationship between anxiety and academic performance could be changed by other factors. For example, as girls tend to experience higher *levels* of emotion than boys (Mackinaw-Koons & Vasey, 2000), gender could be a moderating factor. However, Seipp (1991) found no evidence for a moderating influence of gender. Cultural factors (USA, Germany and Others) were similarly not influential on the anxiety – academic performance relationship in this study.

The relationship between anxiety and academic performance is consistently small to moderate, although still meaningful. For example, Hill and Wigfield (1984) estimated that approximately 25% of American school children have suffered lower academic achievement due to test anxiety.

Alternative methods of assessing the size of the effect that anxiety has on performance have been suggested by Schwarzer (1990). If we take the lower correlation reported of $r = -.21$, and use the binomial effect size display method (Rosenthal, 1991) we can hypothesise that 61% of high anxious individuals would fail a fictitious academic test as opposed to only 39% of the low anxious. Alternatively the correlation of $r = -.21$ can be converted into a Cohen's *d* of .43.

More recently, research has continued to find evidence for a negative association between emotion and academic variables. For example, Gumora and Arsenio (2002) found that students' general affective dispositions, academic affect and emotion regulation all made a significant contribution to grade point average, over and above that made by cognitive variables. Similarly, Crozier and Hostettler (2003) found that shyness, a temperamental construct highly correlated with anxiety (Van Ameringen, Mancini, & Oakman, 1998), was negatively correlated with school administered tests of mathematics ($r = -.32$) and English ($r = -.26$). The cross-sectional and retrospective nature of these and other studies, however, leaves the question of causality uncertain. It could be that poor performance is driving the relationship with anxiety.

Hembree (1988), however, argued that test anxiety causes poor academic performance. It was shown that in 137 controlled treatments studies there was an average positive effect size (Cohen's *d*) for the treatment group on test performance (0.39) and grade point average (0.61). That is, those treated for test anxiety demonstrated higher scores on educational tests than those in either a placebo or waiting list control group. Crucially none of the studies included in the analysis included any element of study skills improvement. More recently an RCT study tested the effect of an anxiety reducing intervention (cognitive-behavioural stress management) for typically developing children. This study found improved performance on GCSE scores that was equivalent to an average letter grade higher for the intervention group (B) as compared to the control group (C) who received their education as usual (Keogh, Bond, & Flaxman, 2006). Cognitive Behavioural Therapy (CBT) has also been shown to improve parent-rated school performance with clinically anxious children (Wood, 2006).

In general, research has shown that high levels of emotion are associated with poor academic performance and reductions in anxiety are accompanied by improvements in performance. Evidence has been reviewed that is suggestive of a causal direction of effect for emotion on performance. The experimental evidence is limited however, in that prior failure in academic performance could cause anxiety which could in turn cause poorer performance. Thus, it could be said that there is a cycle of anxiety and poor performance, in which each has a reciprocal relationship with the other. An ideal way to help to resolve this problem would be to design a longitudinal study that took measurements of anxiety and performance over many time points over many years. This way, the true nature of the cause and effect relationship could be disentangled.

If elevated negative states of emotion due indeed lead to underperformance in school, then it is important to understand what mechanisms can potentially explain this relationship.

Given the cognitive elements such as worry and an inability to concentrate, highlighted previously in the DSM classifications, it is proposed that cognitive characteristics of emotion could compete for available cognitive resources and so have the potential to reduce cognitive output in terms of task performance. Given also Beck's statement introduced earlier that: "The primary pathology or dysfunction during a depression or an anxiety disorder is in the cognitive apparatus." (Beck et al., 1985, p.85), a brief review of general cognitive abnormalities in emotion is warranted. This review will illustrate, in a broader sense, why it is likely that task-relevant cognitive processes would be disrupted in those individuals with high levels of emotion.

1.7 Cognition in emotion.

The cognitive appraisal theories of emotion attest to the potential cognitive resource-draining nature of emotional cognition. In these models, the central and defining feature of disorder is proposed to be in the individuals' biased beliefs about the world. Or, as McNally (2001) summarises the approach: "change the beliefs and eliminate the disorder." (p.514). Appraisal theories have their roots in Beck's work on depression. For example, Beck has described the cognitive triad of depression that includes a negative view of the self, a biased tendency to interpret ongoing events in a negative way, and a negative view of the future as being indefinitely hopeless (Beck, 1976). A classic example of this type of model applied to the anxiety disorders is David Clark's (1986) catastrophic misinterpretation theory of panic disorder. Clark suggested that patients with panic disorder catastrophically misinterpret the bodily sensations that are associated with an increased state of arousal following the perception of a threat. Whereas bodily sensations are likely to be part of the unfolding physiological response to a perceived stressor, the panic disordered individual misappraises them as harbingers of an imminent catastrophe (e.g. a heart attack). Clearly, such catastrophic false alarms are likely to use up valuable cognitive resources needed to be drawn on in difficult tasks.

Cognitions in social phobia are also likely to be resource intensive. One cognitive model of social phobia (Rapee & Heimberg, 1997) proposes that socially phobic individuals believe that others are inherently critical and also attach great importance to being positively appraised by others. This fear of and preoccupation with negative evaluation by others, whether real or imagined, is similarly likely to use up cognitive resources which could otherwise be spent on task-relevant thinking processes. In a similar vein, Wells and Carter (1999) proposed that generalised anxiety disorder is particularly associated with meta-worry. That is, not only worry (Type I) but also by beliefs about worry itself (Type II). It is thought that individuals with generalised anxiety disorder hold rigid positive beliefs about the usefulness of worrying but also have negative appraisals of worrying, believing it to be uncontrollable and dangerous. The authors found that meta-worry was indeed associated with pathological worry and that this association was independent of

Type I worry. Clearly, worry and in addition worrying about worrying are likely to consume substantial amounts of cognitive resources.

Other researchers have viewed these aberrant cognitions collectively under the term repetitive thought, defined as: “the process of thinking attentively, repetitively or frequently about one’s self and one’s world” (Segerstrom, Stanton, Alden, & Shortridge, 2003, p.909). A recent review of different types of repetitive thought showed that many are likely to be unconstructive (Watkins, 2008). For example, anxious and depressed individuals are much more likely to engage in repetitive thought such as depressive rumination, worry and counterfactual thinking. Counterfactual thinking occurs when an individual imagines a hypothetical alternative possible outcome of a past event (counter to the factual event) and dwells on what might have been (Roese, 1997). For example, a person might dwell on what might have been if they had studied more for a test.

Ruminative thinking, often associated with depression, has been found to predict depressive episodes as well as symptoms of anxiety (Nolen-Hoeksema, 2000). Interestingly, the results of this study suggested that rumination may be particularly characteristic of individuals with mixed anxiety/depressive symptoms. Thus, it is important to measure both anxious and depressive symptoms in research assessing the impact of negative thoughts on performance. In support of this notion, Study 1 in Segerstrom (2000) showed that rumination and worry, were common concomitants of both anxiety and depression. Using structural equation models, a latent variable fitting general rumination, worry and depressive rumination was similarly correlated with depression and anxiety in undergraduate students. As well as rumination and worry emotional disorders are also characterised by altered information processing.

Specifically, it has been argued that negative emotionality or emotional disorders per se are often accompanied by selective or biased processing of emotional information (Mathews & MacLeod, 1994). More recently these biases in anxiety have been called cognitive distortions (Muris & Field, 2008). The two most common types of cognitive distortion are attentional bias and interpretive bias. In the former, attention is said to have been directed towards or captured by emotionally relevant stimuli, while in the latter, ambiguous stimuli are more often interpreted as negative or threatening. Interpretive biases relate to the way ambiguous stimuli are interpreted. That is, ambiguity is often resolved in a negative way by anxious individuals (Hadwin, Garner, & Perez-Olivas, 2006). For example, Hadwin, Frost, French and Richards (1997) presented aurally ambiguous words (homophones) to children that either had a threat or a neutral content, such as bury-berry (coffin-fruit). Children were subsequently asked to point to one of two pictures; each representing one aspect of the homophone (threat or neutral). The results showed that self-reported anxiety levels were positively related to a negative interpretation of the homophone. Similarly, Stopa and Clark (2000) found that individuals with social phobia were more likely than healthy controls to believe that ambiguous situations were negative, and that mildly negative events were in fact catastrophic.

Other studies have demonstrated an interpretive bias in depression (Mogg, Bradbury, & Bradley, 2006). One study has shown the presence of interpretive biases for anxiety and depression. Dineen and Hadwin (2004) showed that in a group of children, self-reported depressive symptoms were related to negative interpretations of ambiguous stories for self, while parent reported anxiety symptoms were predictive of a negative interpretation of the stories with others in mind. The interpretive bias findings show how it is likely that cognitive resources would be depleted more for individuals with high levels of emotion. Not only by any 'real' threatening stimuli, but also by those that are ambiguous but interpreted as threatening or might give rise to rumination and preoccupation.

Attentional bias has been measured using the modified Stroop and the visual probe paradigm. The visual probe paradigm, for example, involves the presentation of pairs of stimuli where one is neutral and the other emotional. Following the brief presentation of stimuli, a probe appears in place of one of the stimuli and participants are then required to respond to the probe. The latency of response to a probe after a stimulus has disappeared is thought to measure attention to the stimulus that has recently disappeared. Therefore shorter latencies to a probe following a relevant emotional stimulus are indicative of attention being given towards, or vigilance for, the emotional stimuli. This attentional bias has been demonstrated in children. For example, Vasey, Elhag and Daleiden (1996) found that, in a sample of 11-14 year old schoolchildren, a high test anxious group demonstrated vigilance for a probe following threat-related words. It was suggested that the anxious vigilance of the high test anxious individuals may leave them with insufficient attentional resources to make adaptive responses. For example, they might excessively attend to internal and external signals of threat during a test and so not perform as effectively as they otherwise might. It has been suggested that cognitive performance of individuals with high anxiety may be analogous to working with two tasks simultaneously. That is, the cognitive activity associated with emotion may make significant demands on available capacity, potentially reducing ability to perform well. It might be that the threat posed by evaluative situations in academic testing contributes to this ‘secondary task’ (Tobias, 1985).

1.8 Summary.

In summary, the emotional disorders have been shown to be widespread in the general population. Furthermore, anxiety and depression are highly correlated and comorbid; possibly even sharing common genetic factors. There is a general negative impact and cost to society associated with the emotional disorders which also extends to educational outcomes. Given the wealth of evidence that suggests cognitive distortions are a central feature of the emotional disorders, Mathews and MacLeod (1994) suggest that, “a persisting tendency to selectively process emotionally threatening material represents the cognitive mechanism underlying vulnerability to emotional disorders.” (p.41). It is therefore possible that one mechanism to explain the inverse relationship between emotion and academic performance will be a cognitive one.

Mathews and Macleod (1994) have pointed out that many researchers have noted high levels of anxiety or depression are associated with a reduced ability to perform complex tasks and that capacity limited cognitive resources such as working memory are reduced by an emotional state. The following chapter will review the literature that addresses this specific cognition x emotion interaction in terms of task performance in general and academic performance testing situations in particular. In this way, it may be possible to partially explain the negative effect of emotion on academic performance.

CHAPTER TWO: EMOTION AND LEARNING.

2.1 Introduction.

Previous research has found individual differences in the level of anxiety experienced in response to testing situations. Research has focused on those at the high and low extremes of the test anxiety dimension and individual differences in anxiety are often defined by responses to self-report questionnaires. For example, the test anxiety scale (Sarason, 1978) asks for the extent of agreement to items such as :"I freeze up on things like intelligence tests and final exams" and :"During a course examination, I frequently get so nervous I forget the facts I know". Another example is the reactions to tests questionnaire (Sarason, 1984) which measures four test anxiety components of tension ("I feel jittery before tests"), worry ("Before taking tests I worry about failure"), test-irrelevant thinking ("Irrelevant bits of information pop into my head during a test") and bodily symptoms ("My heart beats faster when the test begins"). Throughout this literature review 'high and low anxiety' will refer to the individuals scoring at the extreme ends of this continuum, unless otherwise specified.

Individuals with high levels of anxiety are of particular interest with respect to learning and test performance. The high anxious individual has been characterised as spending: "a part of his task time doing things which are not task oriented. He worries about his performance, worries about how well others might do, ruminates over choices open to him, and is often repetitive in his attempts to solve the task" (Marlett & Watson, 1968, p.203). Research has shown that this task-irrelevant nature of cognition in the emotional individual is central to understanding lowered academic performance.

The first systematic investigation into the effects of anxiety on learning was carried out by Mandler and Sarason (1952), although research related to test anxiety theory can be traced to work carried out at the time of the Great War (c.f. Stober & Pekrun, 2004). Mandler and Sarason's seminal paper investigated the effect of anxiety drives on intelligence tests and reported that low anxious individuals outperformed those with high anxiety. The authors made a distinction between functional task-relevant drives that aid in the completion of the task thus reducing anxiety and detrimental anxious task-irrelevant drives. Task-irrelevant drives were defined as: “feelings of inadequacy, helplessness, heightened somatic reaction, anticipations of punishment or loss of status and esteem, and implicit attempts at leaving the test situation. It might be said that these responses are self rather than task centered” (Mandler & Sarason, 1952, p.166).

Several key findings were reported in this study. Individuals in the high anxious group were slower to complete the block design test and scored fewer points on the digit symbol test. However, over six trials the high anxious group tended to improve performance scores to almost equal the low anxious group. In addition, an intervening success or failure report improved performance for the low anxious group, but lowered scores for the high anxious group. These results suggest that there is a negative effect of anxiety on test performance and that the effect may be transient in nature. The results also highlight that feedback can have differential effects on performance depending on the emotional disposition of the individual.

In a review of the literature, Wine (1971) provided a similar although subtly different theoretical analysis to that of previous accounts of test anxiety, focussing on attention. Here, the test anxious individual is characterised as being concerned with self-relevant variables (e.g. rumination, self-evaluation, perception of own autonomic responses) and is unable to direct attention towards the task for completion. An attentional interpretation: “states simply that the reason “worry” debilitates task performance is that it is attentionally demanding and distracts attention from the task” (p. 100). Wine proposes three implications that can be drawn from the research reviewed in her study. First, the attentional approach is explicitly concerned with the cognitive activity of the test anxious individual and more precisely what they are attending to. Second, the analysis implies that test anxious individuals may benefit from attention training. Third, the approach is only concerned with autonomic arousal insofar as it becomes attentionally demanding. The physiological symptoms associated with anxiety have been described in DSM IV-TR (American Psychiatric Association, 2000) and the influence of the awareness of such arousal in the testing situation has also been extensively researched.

2.2 Worry and emotionality.

Liebert and Morris (1967) made the important distinction between emotionality and worry in relation to expectancy of success or failure in an exam. The authors drew items from Mandler and Sarason's test anxiety questionnaire to form two scales that reflected the worry and the emotional aspects of test anxiety. Worry was defined as: "cognitive concern about one's own performance" whereas emotionality referred to: "autonomic reactions that tend to occur under examination stress" (p.975). In this study students were asked about their expectations of success in an imminent exam. Based on their probability rating for a successful outcome, students were categorized into low, medium and high expectancy groups. In addition, prior to the exam the test anxiety questionnaire was administered to all participants. The results showed that worry, but not emotionality, was related to low expectation of exam success.

Similarly, Morris and Liebert (1970) found that emotionality was less predictive of grade scores for psychology undergraduates than worry. In their second study the authors found that the overall correlation between anxiety and performance was $r = -.33$. However, with worry partialled out, the correlation dropped to $r = -.08$. Conversely with emotionality partialled out the correlation was less attenuated ($r = -.23$). Along with the results of a previous study (Morris & Liebert, 1969) this suggests that the cognitive component is the most important variable in explaining the poor performance of anxious students. Indeed, reviews of the literature have reached the same conclusion (Morris, Davis, & Hutchings, 1981; Wine, 1971). However, Wine argues that this does not mean that autonomic arousal is not demanding of attention, only that it is less likely unless there are high levels which could become distracting and annoying. An important point to bear in mind that stems from the emotionality research is that emotionality as measured by questionnaire is arguably the perception of bodily symptoms and not necessarily physiological arousal per se. Relatedly, the situational factors involved in a testing situation are important to the extent that they give rise to perceived stress in the anxious individual.

2.3 Stress-inducing situational factors.

From Mandler and Sarason's work it is clear that these factors pertaining to test conditions are important in understanding the emotion-performance relationship. It has been noted by other researchers, for example, that the poor performance typically found for high trait- and/or test-anxious individuals is especially pronounced under stressful conditions (Eysenck & Calvo, 1992). An early experiment by Sarason, Mandler and Craighill (1952) demonstrated the differential effect of stress induction on tests measuring IQ. In the second experiment of this study, high and low anxious university students were either told that they were going to take an intelligence test that would be compared to their entrance test scores, or told that their performance was only of general importance in helping to standardise a test. The results showed that high anxious students under stressful conditions were slower to complete a stylus maze test and made more errors. A study using a similar procedure (Kaye, Kirschner, & Mandler, 1953) found poorer memory spans in a stressful condition for group testing. Similarly a failure report ("try to do as well as you can as your record was really poor last time", p.116) and other stressful elements of the testing situation such as using dummy 'microphones' produced lower digit span scores on a follow up test than participants in a control condition (Moldawsky & Moldawsky, 1952).

More complex investigations have shown that the poorer performance of individuals with high anxiety in stressful conditions is likely to be specifically due to the perceived interference of emotional thoughts. For example, Deffenbacher (1978) assumed that performance of highly test anxious individuals varies with evaluative stress and that evaluative stress elicits behaviours that interfere with performance. In this study participants were asked to solve *high-difficulty* anagrams under high and low stress conditions. In the high stress condition, the intelligence-testing nature of the task was emphasised as well as the 'ease' with which the anagrams could be solved. The time limit involved and the importance of solving as many anagrams as possible to compare well with others were also stressed. The results showed an anxiety x stress interaction on the anagram solving task such that the high anxious group solved fewer anagrams, but only in the high stress condition. It was also found that the high anxious group in the high stress condition reported the most interference from anxiety, worry and emotionality. Emotionality in this study was defined as attention to physiological cues such as upset stomach, perspiring and a racing heart.

Studies focusing on worry, the component argued to be most predictive of poor test performance in anxious individuals, have shown that reducing the stress in a testing situation attenuates the typically elicited interference for high anxiety individuals. For instance, Sarason (1984) investigated the effect of worry on performance. In this study, low, medium and high worriers were asked to complete difficult anagrams under different conditions. Participants were either in a control condition (no communication), a reassurance condition ("you will do just fine") or an attention-directing condition where participants were directed to stay focussed and concentrated on the task. First, the results showed that the high worriers reported more cognitive interference than middle and low worriers. Second, in the control condition the high worriers performed worse on the anagrams than the middle and low worriers. Third, there was a worry x condition interaction such that the high worriers only performed worse than the middle and low worriers in the control condition. In both the reassurance and attention-directing conditions the performance of the high worriers was equivalent to the other groups.

This body of research suggests that stressful situations are typically required for the negative effects of emotion on performance to emerge. Thus far, this review has focused on anxiety. This is largely a reflection of a bias towards anxiety found in the literature. However, a parallel cognitive interference model with special reference to depressed mood has been proposed, that views poor task performance in terms of task-irrelevant thoughts.

2.4 Depressed mood.

The resource allocation model (RAM) is a cognitive interference model proposed by Ellis et al. (Ellis, 1985; Ellis, 1990; Ellis, 1991; Ellis & Ashbrook, 1988; Ellis & Moore, 1999). RAM assumes that the induction of a sad mood, or any emotional state, will reduce the ability of the individual to allocate attentional resources to a cognitive task. This process is argued to occur because there is a competition for resources between irrelevant thoughts and the cognitive task at hand. The task-irrelevant thoughts are suggested to pre-empt cognitive resources in two ways. First, depressed people allocate more attentional resources to processing irrelevant features of the task. Second, depressed individuals think more about their low mood. Specifically, these authors propose that it is the consequences of the mood state that produces negative effects on memory tasks via distracting thoughts and lack of attention devoted to task-relevant features (Ellis & Moore, 1999).

RAM predicts that irrelevant thoughts will be negatively correlated with cognitive performance and that emotional states in general will cause irrelevant thoughts. Over two experiments Seibert and Ellis (1991) tested these predictions. The authors used a mood induction procedure that involved participants reading aloud self-referent statements for happy ("Life's a blast, I can't remember when I've felt so good"), sad ("I feel I am being suffocated by the weight of my past mistakes") and neutral moods ("there are 60 seconds in one minute"). The cognitive task involved the presentation of trigrams that gave the opportunity for participants to process the letters as presented (e.g. R ITW EL) or could be reorganised to enhance memory recall (e.g. RIT WEL). This task was used as the effects of mood on memory tasks are proposed to be greatest on difficult tasks (Ellis, 1985). Intrusive thoughts were measured by listing thoughts or thinking aloud into a tape recorder. The results of two experiments showed that the proportion of negative thoughts was greater in the sad and happy compared with the neutral mood conditions, where correlations of $r = -.72$ and $r = -.67$ were found between irrelevant thoughts and recall. This result confirmed the hypothesis that not only negative mood but indeed any emotional state causes irrelevant thoughts.

Further evidence in support of the model was provided by this group (Ellis, Thomas, & Rodriguez, 1984) who found that depressed mood induction predicted poor recall performance of simple and elaborated sentences. After a mood induction procedure similar to the one outlined above, participants were shown either base ("the hungry child opens the door") or elaborative sentences ("the hungry child opens the door of the refrigerator"). Recall of the target word was then tested (e.g.

hungry). The authors point out that under normal or mood neutral conditions, people tend to recall more information, in terms of target words, when it is embedded in a rich relevant sentence context. In the elaborated example above, the target word hungry is elaborated on by the context of the door belonging to a refrigerator. In contrast the base example does not specify the target word in any particular way. With a depressed mood, however, it is proposed that recall will be impaired in a number of ways. First, it is possible that recall will be generally impaired in the depressed mood condition due to reduced allocation of task-relevant resources. Second, the facilitation of recall in the elaborated condition would be larger in the neutral condition than in the depressed mood condition because the negative effects of depressed mood are assumed to be greater when the encoding demands are more complex or require more activity. The results of three experiments showed that task-relevant processing was reduced in the depressed mood induction group. Participants had poorer recall than in the neutral mood induction and were therefore said to be allocating fewer cognitive resources to the task at hand. Furthermore, in Experiment 1 there was a mood x sentence type interaction such that the facilitative effects of elaborative sentences were only reliably seen in the neutral mood induction condition. In Experiment 3, difficulty was manipulated by making the target word (e.g. dream) almost self-evident in the easy condition ("the girl awakened from her frightening ___") and less obvious in the hard condition ("the man was alarmed by the frightening ___"). There was a significant mood x difficulty interaction showing that the neutral condition recalled 46% of the difficult items and the depressed condition recalled only 23%.

Recently brain imaging and event related potential (ERP) research has lent support to the RAM. Meinhardt and Pekrun (2003) evaluated RAM using the P3 ERP component as a measure of cognitive resources. In two experiments, participants were either asked to read previously written emotional scripts of their own personal life or shown affective pictures (positive, negative and neutral) whilst simultaneously being presented with an odd ball task. The odd ball task is an auditory attention task where the participant must attend to and make an internal count of a high or low target tone (target tone is arbitrarily chosen) that occurs 20% of the time. The results of both experiments showed a decreased P3 component in positive and negative conditions compared with neutral, suggesting that emotional states can reduce available cognitive resources. An important question that has arisen in the research relating to emotion and performance is precisely which aspects of cognition are affected. This is a question that is addressed to some extent in the processing efficiency theory (PET) (section 2.7) by incorporating the concept of working memory. Before discussing PET, the next section will outline the working memory concept and will consider its broader association with academic performance.

2.5 Working memory.

In his monumental work *An essay concerning human understanding* John Locke proposed that the retention of ideas was achieved in two ways. First, through the immediate workspace of memory: “keeping the idea…for some time actually in view” and secondly through a long-term memory store: “the store-house of ideas” (Locke, 1877, p.262-263). This division of the mind was echoed by William James who used the term primary memory to refer to the specious present whereas secondary memory: “is the knowledge of a former state of mind after it has already once dropped from consciousness”(cited in Andrade, 2001). The terms primary and secondary memory were revived in a paper by Waugh & Norman (1965) who found that unrehearsed verbal items were forgotten due to interference from other items (and not trace decay). Rehearsal transfers items from the limited capacity primary store to a much larger secondary store and recently perceived items can be kept in both stores at the same time. This was to become the modal model, described in several places by Atkinson and Shiffrin et al. (e.g. Shiffrin & Atkinson, 1969).

More recently, a dynamic concept of working memory has been introduced (Baddeley, 2000; Baddeley, 1986). Working memory has been defined as: “those mechanisms or processes that are involved in the control, regulation, and active maintenance of task-relevant information in the service of complex cognition” (Miyake & Shah, 1999, p. 450). This concept was borne from weaknesses in the modal model revealed by several sources of evidence. For example, brain damaged patients were observed with a digit span of only two or three items and yet normal ability to learn word lists and remembering stories (Baddeley, 1986). This dissociation runs counter to the modal model; an impaired short-term store should lead to impoverished recall and general learning.

Although several models of working memory have been proposed (Miyake & Shah, 1999), the multi-component model has been the most productive in terms of stimulating research. Wager and Smith (2003) go further to suggest that: “most broad architectures of human cognition incorporate some version of this framework” (p. 255). At its fundamental level, Baddeley’s multi-component model is a tripartite system comprised of a modality free master module (central executive) and two slave subsystems (phonological loop and visuospatial sketchpad). The phonological loop (PL) holds and manipulates speech based information, while the visuospatial sketchpad (VSSP) performs a similar function for visual and spatial information. The central executive (CE) is a modality-free component, assumed to have no storage of its own, that coordinates information from the two slave systems. Importantly, the CE facilitates the storage *and* processing elements that together form the core feature of complex working memory.

The PL is the most understood component of the tripartite working memory model and is thought to be comprised of a phonological store that can hold memory traces for a short period before fading, and a rehearsal process that is analogous to sub vocal speech. Baddeley (1986) outlined several lines of evidence supporting the phonological loop, including the phonological similarity effect and articulatory suppression. The phonological similarity effect refers to the poor recall of items that share a similarity, as compared to those that do not. For example, Baddeley cites a study where words such as *man, mad, cad, mat, cap* were only recalled 9.6 % of the time, but dissimilar words such as *pit, day, cow, sup, and bar* were correctly recalled 82.1% of the time. This finding suggests that a phonological rehearsal loop is important in memory. The specificity of the effect relating to phonology is supported by other findings that have found that similarity of meaning has much less of an effect on recall. Articulatory suppression refers to the prevention of phonological rehearsal by uttering an irrelevant sound such as “the” throughout the task. This form of suppression has shown to reduce the performance on digit span, and also removes the phonological similarity effect (Baddeley, 1986).

Evidence from neuroimaging studies also supports the existence of the PL. In a review of 256 PET and fMRI studies, Cabeza and Nyberg (2001) found that, along with prefrontal activation, verbal/numeric tasks tended to show left-sided parietal activation. Furthermore, the authors suggested that the left-sided parietal region may constitute a phonological store, whereas the left-hemisphere prefrontal activations in Broca's area may reflect the phonological rehearsal process.

The VSSP is responsible for the storage and manipulation of visual and spatial information. This component is less understood than the PL, where for example the principle of rehearsal is well-described (Baddeley, 1996b). A study by Bruyer and Scailquin (1998) made several elaborations regarding the VSSP. Over three experiments the authors showed that on visuospatial tasks there was little or no interference from an articulatory suppression task (i.e. repeating "la"). Conversely, there was a significant amount of interference from a visuospatial secondary task (locating the position of an auditory tone). This evidence supports the notion of separate working memory components (PL and VSSP). Moreover, the results of this study showed that on tasks requiring the generation or rotation of mental images, the strongest interference came from a secondary random letter generation task tapping the CE. This effect was not seen on a simple image maintenance task. This result suggests that there is a passive visuospatial store and a more active device for manipulating visuospatial information. The results also show that CE processes drawn on in the secondary task can affect CE demanding VSSP primary tasks.

Supporting evidence in favour of a separate visuospatial component is also found in brain imaging studies that show the correlates of the visuospatial sketchpad are reflected broadly in the right hemisphere and not in the left. For example, a clear-cut double dissociation between hemispheric activity was found when Smith, Jonides and Koeppe (1996) asked participants to either remember the names of four letters or the spatial position of three dots.

It is also thought that the VSSP can be further fractionated into separate visual and spatial components. Della Sala, Gray, Baddeley, Allamono and Wilson

(1999) used a visual patterns test as a relatively pure measure of visual memory and the Corsi blocks test to tap spatial memory. A visual interference task was used that involved the presentation of colourful abstract paintings by avant-garde artists such as Pollock and Kandinsky. The spatial interference task involved participants being asked to follow a series of wooden pegs in a board by touch alone (i.e. without seeing it). The results showed a highly significant span type x interference type interaction. On the visual task, accuracy was at 66% with visual interference but much greater (84%) with spatial interference. The pattern was reversed on the spatial task. Accuracy was at 66% with spatial interference but, again, greater at 82% with visual interference.

The CE is perhaps the least understood component in the model but is thought to be: " the most important component in terms of its general impact on cognition" (Baddeley, 1996a, p.5). Certainly the tripartite model of working memory has been very influential in stimulating a great deal of research, which is arguably one of the most important features of a theory. The CE is thought to act as a cognitive resource allocator, much as the *supervisory attentional system* (SAS) does in the model of Norman & Shallice (1986). The SAS was thought to be responsible for the inappropriate perseveration in some patients with frontal lobe damage and the excessive distractibility in others (Baddeley, 2003).

Other neuropsychological evidence supports the concept of a CE. For example, Baddeley, Della Sala, Papagno and Spinnler (1997) grouped patients with frontal lobe lesions into those with and without dysexecutive syndrome and asked them to perform dual tasks of digit span and a spatial tracking task. The results showed that only for the dysexecutive group did the dual task produce lower scores on an individual task whilst simultaneously performing the other. This supports the idea of a CE at least in explaining frontal lobe lesion patients and suggests it may be located in the frontal lobes.

In terms of brain imaging studies, however, it is less clear as to the anatomical location of the CE. In dual-tasking studies, it is expected that the regional brain activity identified when two tasks are performed simultaneously is extra to that seen when the same tasks are performed individually. It is assumed that the extra activity, after subtraction, is the correlate of the CE. D'Esposito et al. (1995) found in a simultaneous task condition that there was increased activation in the mid-dorsal prefrontal cortex that was not seen when the two tasks were performed separately. However, this study is one of only a few to show this clear pattern. As Andres puts it: "Except for the first study published (D'Esposito et al. 1995), the neuroimaging findings provide no evidence for a neural locus for a specific function of dual task coordination of the central executive in the prefrontal cortex but are consistent with the hypothesis that it involves interactions between different brain regions." (Andres, 2003, p.886). Baddeley also argues that the CE may involve the activation of a number of brain regions (Baddeley, 1998). Indeed, in a review of the CE brain imaging by literature Collette and Van der Linden (2002) found exactly that; although CE tasks were associated with prefrontal brain activation, a number of other regions were also recruited.

Although Baddeley's model is tripartite in essence, a fourth component more recently proposed is the episodic buffer (Baddeley, 2000). This component is much less studied than the components of the original tripartite model. The episodic buffer is assumed to be a limited multi-modal store that is accessed by the CE. It is proposed to be capable of housing the representations of information from long term memory and the other slave systems. As with the CE, Baddeley does not expect the episodic buffer to have a single unitary anatomical location.

Although the multi-component model of working memory is the dominant one within the psychological literature, it should be noted here that, often with regard to the CE, it has not been without its critics (e.g. Parkin, 1998). The CE has been difficult to pin down leading to sharp criticism from some quarters: "The 'central executive' is a hypothetical entity that sits atop the mountain of working memory and attention like some gigantic Buddha, an inscrutable, immaterial, omnipresent homunculus, at whose busy desk the buck stops every time memory and attention theorists run out of alternatives." (Donald, 1991, p.327).

A contrasting model of working memory is the embedded processes model (Cowan, 1999). This is a unitary model of working memory that encompasses memory in the focus of attention, memory out of the focus of attention but nevertheless activated, and inactive elements of memory. The model is embedded in the sense that active memory is a subset of long term memory and the focus of attention is a subset of active memory. It is a more unitary model than Baddeley's in that it is based on any modality and representation. It also differs in that working memory is viewed as simply those portions of long-term memory that are presently activated. The tripartite model in contrast argues that working memory is a separate system.

2.6 Working memory and academic performance.

Working memory has been shown to be important in a wide range of cognitive activities including academic learning. For example, Gathercole and Pickering (2000a) used several working memory tasks to tap the PL, VSSP and CE components in six to seven year old schoolchildren and measured their academic progress over time. The results showed that PL measures explained variance in future vocabulary scores (16 months later) whereas CE measures contributed to vocabulary, literacy and arithmetic tests. This suggests the higher importance of CE processes over the PL and VSSP in academic performance.

Gathercole and Pickering (2000b) found that CE measures (all tasks involved storage and processing of verbal information) strongly discriminated between a low achievement in English and/or maths group (N = 24) and a group without any low achievements (N = 60). Three CE measures showed effect sizes of .81 to .89 where an effect size of 1 would indicate that the low achievement group scored 1 standard deviation lower than the normal group. Two VSSP measures discriminated between the two groups with effect sizes of .87 and .89. PL measures also discriminated between the two groups but to a much lesser extent. Non-significant effect sizes ranged from .20 to .53 with only one measure providing a significant effect size (.65). In summary, CE measures were most important in characterising low academic achievers, followed by VSSP and PL measures.

A more recent study showed that working memory measures were highly related to achievement in both seven and 14 year olds (Gathercole, Pickering, Knight, & Stegmann, 2004). More specifically, there was a clear relationship between both

PL and CE measures and differences in achievement in maths and English for the younger group. In the older group, PL and CE measures were both related to maths and science but not reliably to English. In addition CE tasks best discriminated between the maths achievement groups (low, average and high), whereas CE and PL tasks characterised differences between the science groups (low, medium and high).

Overall the results of these educational studies show that a range of working memory measures is related to academic performance measures in children. The data do suggest, however, that working memory may be particularly related to maths and science. In the case of maths, CE tasks may be especially relevant. In the context of the influential tripartite model of working memory, PET will now be introduced as a framework with which to understand the interactive effects of emotion and cognition on academic performance.

2.7 Processing efficiency theory.

In their processing efficiency theory (PET), Eysenck and Calvo (1992) reviewed the extant literature starting with the assumption that anxiety affects cognitive performance primarily when stress is high and particularly on difficult tasks. However, two main difficulties in the literature were identified. First, the authors noted that although the effects of anxiety on performance are often found to be negative, there are sometimes null and even positive effects. To account for these findings the authors proposed that anxiety has not only a negative influence via the distracting thoughts described by others (Morris et al., 1981; Tobias, 1985; e.g. Wine, 1971) but can also serve as a motivation for successful task completion. In other words, an anxious individual is driven to avoid the aversive consequences of performing poorly (e.g. loss of self-esteem, negative evaluation by others) and increases the amount of resources devoted to the task. For this reason a distinction is made between performance effectiveness and efficiency. Effectiveness refers to the accuracy of a task in absolute terms and is synonymous with performance. Efficiency refers to the relationship between performance and the amount of resources expended. That is, efficiency refers to the ratio between performance and effort. Therefore anxious individuals will report increased effort in performing tasks and take longer to finish them. In so doing, the task performance per se may be equivalent to that of low anxious individuals. That is, the increased motivation to do well on a task and subsequent increased effort may attenuate the negative effects on anxiety. In this sense, the theory adds a dynamic element to the anxiety-performance relationship, seeing the anxious individual as more than passively being affected by intrusive thoughts. This motivational aspect of the theory in particular is one of the important differences between PET and RAM (discussed in section 2.4), where there are no claims made concerning motivation in depressed mood.

The second issue in relation to previous research is that task difficulty has not been well defined. It is therefore difficult to identify precisely where in the cognitive system anxiety may have its effects. The inclusion of Baddeley's working memory model allowed for a more accurate description. Stemming from the finding in the literature that worry is the primary ingredient in anxiety, effects on performance in PET are proposed to be seen most often on the PL and the CE components of working memory. It is suggested that on average, tasks that make demands on both storage and processing (CE tasks) should be susceptible to the greatest effects of anxiety because they are using the most cognitive capacity. Negative effects of anxiety will also be seen on tasks tapping the phonological loop as there is a shared sub vocal element between worry and the PL. In addition, and because the VSSP does not involve phonological resources that could be consumed by worry, it is proposed that negative effects are less likely to be seen on the VSSP, unless the task also makes substantial demands of the CE. Furthermore, PET suggests that anxiety is likely to often produce effects of lowered processing efficiency but also lowered effectiveness. In the latter case, this is most likely when the task is making heavy demands of the CE.

There is empirical support for the predictions made by PET. Darke (1988), for example, investigated the differences between high and low anxiety groups on the digit span from the Wechsler intelligence test and a modified sentence span task. The former makes some limited demand on the central executive while the latter makes heavy demands, utilising both storage and processing. In the sentence span task, participants must decide if presented sentences are true or false. Subsequently, the last word in the sentence must be recalled. Significant group differences were found on both tasks showing that the high anxiety group performed worse in both cases. In fact, a post-hoc effect size calculation shows that the high anxiety group performed considerably worse on the sentence span test (Cohen's *d* = 0.9) relative to the digit span test (Cohen's *d* = 0.4); therefore providing supporting evidence for PET. Like many studies in this area, this study used a form of stress induction. Here, it involved the emphasis on digit span being part of intelligence tests and participants were told that their performance would be compared with that of others.

Further support for the theory was demonstrated by MacLeod & Donnellan (1993), who showed that high anxious individuals showed much slower decision times than low anxious individuals on a grammatical reasoning task; disproportionately so under a simultaneous memory load condition. This finding was later replicated by Derakshan & Eysenck (1998) who found that verbal reasoning was slower with a concurrent high load memory task. This effect was significantly greater for high anxious and defensive high anxious groups, as opposed to low anxious and repressor groups. There was also a greater slowing of response latency in a memory task for the high anxious and defensive high anxious groups. These two studies support the notion of inefficient processing in high levels of anxiety. Evaluative stress was also a component in the latter study, operationalised via instructions that stressed good task performance was indicative of intellectual ability and the tasks were also strictly timed.

Also supporting the inefficiency prediction of PET, Elliman, Green, Rogers and Finch (1997) used a measure of sustained attention as an indicator of task performance. They found that although there were no differences between high and low anxious groups on the number of correct hits in the task, the high anxious group had significantly slower reaction times over the course of the task. This finding supports PET in that effectiveness seems to have been upheld through increased effort, as evidenced by the significantly slower reaction times in the high anxious group. This performance efficiency effect was found to be independent of psychomotor performance, as there were no significant differences between the two groups on a finger tapping task or a simple reaction time measure. Unlike many studies, in this study participants were explicitly told that they were in a non-evaluative condition.

The interference of anxiety on working memory with special reference to the phonological loop was investigated in reading performance by Calvo and Eysenck (1996). According to PET, high anxious individuals should be able to comprehend as much text as low anxious individuals under normal conditions but comprehend less under increasingly complex conditions that drain CE resources and preclude the use of compensatory strategies. In this study, high and low test anxious individuals were asked to read sentences for later comprehension in either a word-by-word or sentence-by-sentence presentation. There were three conditions of no interference, interference from meaningful speech and articulatory suppression (repeating "OLA"). No group differences were found in the sentence-by-sentence condition. It was proposed that the high anxiety group did use auxiliary reading strategies (i.e. regressions, reduced reading speed and articulatory rehearsal) to combat the cognitive resource-draining effects of anxiety. In the word-by-word presentation (reading regressions were not possible) the high anxiety group performed significantly worse on the comprehension task in the meaningful speech and articulatory suppression conditions (articulatory rehearsal is inhibited) but not in the no interference condition.

The prediction by PET that test anxiety would have a detrimental effect on the efficiency of verbal and not spatial working memory tasks was tested by Ikeda, Iwanaga and Seiwa (1996). The authors found that the high anxiety group had equivalent levels of worry in the verbal and spatial working memory conditions although the high anxiety group took longer to complete the verbal task. Thus, consistent with PET, the high anxiety group was less efficient on the verbal task, compared with the low anxiety group. It can be argued that any potential performance deficits (i.e. effectiveness) on the verbal task could have been attenuated by increased effort as indexed by increased reaction time. It should be noted that the tasks in this study may not have been sufficiently demanding of the CE to produce any signs of lowered effectiveness as they were essentially memory and recognition tasks. This study used a stress induction procedure that involved telling the participants that the tasks were intelligence tests and that they were under observation by monitor camera.

Although PET predicts that negative effects on task performance will be seen more often on the PL than VSSP, an important study has shown that trait anxiety can adversely affect scores on a nonverbal task (Eysenck, Payne, & Derakshan, 2005). Participants in this study were asked to follow a spatial tapping task (Corsi blocks) whilst carrying out a secondary task. The secondary tasks involved either simple finger tapping in time with a metronome (control), constantly repeating the letters A,B,C,D (PL), tapping out a Z formation (VSSP) or counting backwards from a two-digit number in ones (CE). The procedure involved an element of evaluative stress in the form of telling participants that they were being monitored and giving them false negative feedback. The results showed that the high trait anxiety group performed more poorly than the low group only when the secondary task was tapping the CE. Therefore the effect of anxiety was shown to be on the modality free CE and not the VSSP per se. This study demonstrates the importance of complex tasks that make use of the CE in understanding effects of emotion on academic performance.

In general, studies have used state anxiety (Tohill & Holyoak, 2000), trait anxiety (Derakshan & Eysenck, 1998), test anxiety (Darke, 1988; Ikeda, Iwanaga, & Seiwa, 1996) or a combination of these measures (Calvo & Eysenck, 1996) in assessing the effect of anxiety on performance. In terms of the relationship between anxiety and academic performance, Seipp (1991) found that this relationship was identical for state and trait anxiety (r = -.21). A further analysis in this study showed that the relationship between anxiety and academic performance was slightly stronger for test anxiety when compared with ‘general anxiety’. At first sight, this suggests that state, trait and test anxiety are all important factors in explaining negative effects of anxiety on performance. In fact, it is proposed in PET that the effects of trait anxiety on performance are mediated by state anxiety. However, Eysenck et al., (2005) found no effects of self-report state anxiety on performance or any interaction between trait and state anxiety. As an explanation for the null result for state anxiety, it was hypothesised that actually any amount of state anxiety could be sufficient to impair performance in high trait anxious individuals. Importantly, this suggests that the level of state anxiety is actually less important than the personality based reaction to stress.

There is also evidence to show that depression has a similar negative impact on working memory. Christopher & MacDonald (2005) assessed both clinically anxious and clinically depressed patients and found impaired performance on a range of visuospatial and phonological working memory tasks relative to controls. However, the clearest results were on three of the four CE measures that showed the anxiety and depression groups had comparable levels of impairment relative to controls. For example, a backwards letter span task was used (comparable to a backwards digit span) where letter strings increased from two to seven per list. In addition, participants performed the task concurrently with interference tasks of repeating 'the' and counting backwards from 99 in ones. Participants were then required to recall the list in reverse order. The results showed that the control group was significantly better than the anxiety (mean difference = 1.82) and depression (mean difference = 2.11) groups. This provides evidence that CE impairment may be present in both anxiety and depression. Indeed, the authors proposed a common source of disruption in working memory (intrusive thoughts) for both anxious and depressed patients.

While most research in the literature looks at levels of emotion in general or in relation to tests, some researchers have focused on maths and maths anxiety. Maths anxiety researchers have described the disruptive 'online effects' of anxiety on maths performance (Ashcraft & Krause, 2007). Ashcraft and Krause showed that high maths anxiety differences on a maths test only became apparent when the complexity of the maths and therefore the demands on the CE are considered. For example, the authors demonstrated that there were no apparent differences between low, medium and high maths anxiety groups on the early part of a maths test involving whole number arithmetic ("even high anxious individuals can answer whole number answers correctly", p.245). However, at later more complex stages, the high anxious group began to show performance deficits relative to the other groups. This evidence is consistent with PET in that anxiety effects on performance are seen only when demands on the CE are being made.

Similarly, Ashcraft and Kirk (2001) found that high maths anxiety individuals had small working memory spans, increased reaction times when performing addition with a memory load task (making demands of the CE) and made more errors. This effect on working memory was not specific to maths but also generalised to affect a letter transformation task. This illustrates the modality-free nature of the CE and again shows that anxiety is likely to be particularly involved with CE processes.

Hopko, Ashcraft, Gute, Ruggiero and Lewis (1998) investigated the effect of anxiety on working memory in the context of maths. It is argued that although PET goes far to explain deficits in efficiency and effectiveness on cognitive tasks in terms of resource-draining due to worry and intrusive thoughts, perhaps more pertinent is the failure of the inhibition system to limit the amount of task irrelevant information (including worry) being attended to. The results of this study showed that high and medium maths anxious individuals took longer to read paragraphs with maths distractors embedded in the text, than low anxious individuals. They also made more foil errors. Foil errors refer to using a distractor as an answer to comprehension questions in related paragraph conditions (i.e. paragraphs about maths that also contain maths distractors). The conclusion was that high anxious individuals are attending more to the distractors, or failing to inhibit more, than the low anxious individuals.

In line with this attentional perspective, a recent conceptualisation of the anxiety-performance relationship is provided in the attentional control theory (ACT; Eysenck, Derakshan, Santos, & Calvo, 2007). This thesis is not testing the predictions made by ACT; however for completeness it will be briefly outlined here. The ACT aims to subsume PET. It shares commonalities with it and is also an extension of it. One commonality between PET and ACT is that the effects of anxiety are proposed to impact most clearly on CE processes. Indeed one aim of ACT is to be more precise about which components of the CE are likely to be most affected by anxiety. ACT fractionates the CE into component parts of shifting, inhibition and updating. It is predicted that effects of anxiety on performance will be demonstrated more often on tasks that tap the inhibition and switching functions than on the updating function.

2.8 Child studies of the negative effect of emotion on cognitive performance.

The majority of studies in this area have been concerned with adults and there has been a dearth of research addressing the relationship between emotion and working memory in children (Visu-Petra, Ciairano, & Miclea, 2006). Emotional problems can emerge at any age as DSM IV-TR makes clear. For example, many patients with generalised anxiety disorder report that they have been anxious and nervous all their lives and over half of those presenting for treatment report onset as being in childhood or adolescence (American Psychiatric Association, 2000). It is therefore likely that there will be similar findings in both child and adult samples. Several relevant child studies are outlined below.

Hadwin, Brogan and Stevenson (2005) assessed the predictions of PET in a sample of 30 children (9-to-10-year-olds) and found that a high state anxiety group was less efficient on working memory tasks, in terms of increased mental effort and increased time taken to complete tasks. The authors measured the children on their forwards and backwards digit span and gave them a spatial working memory task. In addition to measuring the performance of children on the working memory tasks, the authors also measured time taken and mental effort involved in performing each task (“how hard did you have to try?”). The results showed no main effects of state anxiety on performance effectiveness. They did, however, find a relationship between anxiety and efficiency: the high state anxiety group invested more effort into the forward digit span task and took longer to complete the backwards digit span task.

A similar finding was reported in a study by Emerson, Mollet and Harrison (2005), although the authors were not explicitly using the PET framework. In this study, a group of high anxious/depressed boys (aged nine to 11 years old) differed in their cognitive abilities. On a trail making test, there were no differences between groups in terms of time taken to complete a simple consecutive trial where participants are asked to connect numbered circles in consecutive order. However, the anxious/depressed group took longer to finish the more demanding sequential trial where participants must alternate between numbered and lettered circles. This result provides further evidence supporting an effect of processing efficiency. In addition, the anxious/depressed group made more perseverative errors in both trials and were less accurate on a concept formation task than controls. These data additionally suggest an effect of processing effectiveness.

Again, outside the framework of PET, Toren et al. (2000) studied 19 clinically anxious children and 14 controls (age range = 6 - 18) on measures of verbal learning, executive functions and non-verbal functioning. Verbal learning was measured using the California verbal learning test. This test involves learning a list of words over several trials and, after an interference list, being tested for immediate and delayed recall and later recognition of the original word list. Executive functioning was measured using the Wisconsin card sorting test (WCST) which involves sorting stimuli cards into sets according to a rule unknown to the participant. On each turn of the card the participant is told only whether they are right or wrong. Nonverbal processing was measured by the Rey-Osterrieth complex figure test. This test requires participants to copy a complex figure and reproduce it without prior warning. The authors found that the anxiety group had poorer verbal learning and executive functioning. In contrast there was no difference between the groups in nonverbal ability. These results are supportive of the assumptions of previous research in that negative effects of anxiety were seen on a verbal learning test (tapping the PL), the WCST (CE) but not on the nonverbal test (VSSP) which was unlikely to be tapping into substantial CE resources.

The authors of this study point out that there were also no group differences on IQ and so differences could not be attributed to working memory or general cognitive ability. However, the anxiety group was substantially lower in their IQ score (115 vs 122; Cohen's d = .85). It should be noted that in this study the standard deviations for IQ were smaller than would be expected in the general population. Nevertheless, this raises an important point that has wide implications for this area of research. Low IQ scores for an anxiety group does not necessarily mean that the anxiety deficit on other tasks is attributable to IQ, as a wealth of research has highlighted the influence of anxiety on IQ tests. These tests are administered in a testing setting and so are equally prone to the disruption that is seen on a range of other cognitive tests (McDonald, 2001). For this reason it has been argued that: "It is questionable whether intelligence test scores adequately describe the underlying abilities of individuals who have high anxiety drive in the testing situation" (Mandler & Sarason, 1952, p.172).

Gunther, Holtkamp, Jolles Herpertz-Dahlmann and Konrad (2004) tested clinically anxious and depressed and control children (aged between eight and 17 years) on range of cognitive tasks that included the Rey auditory-verbal learning test (RAVLT), a simple reaction time task, a go/nogo test measuring inhibition, a sustained attention task, and a divided attention task. They found a significant impairment on several indices of the RAVLT that was specific to depression.

The RAVLT consists of five learning trials of a word list, a presentation of a distractor list, recall after the distractor list, 30-minutes delayed recall, and a subsequent recognition trial. In this study, trial one was considered a measure of working memory, trials one to three were used as a measure of free recall and the difference between trials three and one was used as a rate of learning acquisition. The recall after a distractor list is an index of interference by the distractor list. The negative effects of depression were seen on interference, delayed recall and recognition. One weakness of this study is that the working memory measure was a very simple short term memory one-trial recall test. More generally, the RAVLT is a test of memory and not more complex cognition. As has been discussed, negative effects of emotion on cognition are likely to emerge on complex tasks involving CE processes. Lower divided attention absolute scores (effectiveness) or increased reaction time (efficiency) in the anxiety group would have been expected from the perspective of PET, yet no such differences were found. Compensatory strategies could have been employed by the anxiety group to improve performance (reaction time was slightly slower for the anxiety group compared to controls). In addition, the influence of stress is undocumented in this study. It was neither induced nor measured. It is possible that given a more complex set of tasks to perform and either measuring or inducing stress, the anxiety and depression groups would score lower than controls.

The results as presented in this study are also somewhat slightly problematic in that the mean scores on all tests are adjusted for IQ. As has been noted previously, IQ measures are also influenced by emotional factors. Nevertheless, the authors found that the depressed group was impaired in the number of words recalled after learning trials. The authors proposed that the memory deficit could be due to high levels of the physiological stress hormone cortisol. Indeed, depression has been characterised by an aberrant cortisol profile (Foreman & Goodyer, 1988). Cortisol is also a more general marker of stress and has a connection with cognition. This issue will be explored further in the following section.

2.9 Cortisol: a biological marker of stress reactivity.

As has been highlighted, stress reactivity is clearly an important variable in the emotion-performance relationship. Given the known problems with an over-reliance on self-report (see Nisbett & Wilson, 1977) it might be prudent in research to use a physiological measure of stress reactivity to a testing situation. However as Eysenck and Calvo (1992, p. 413) point out, " it has been extremely difficult to find any psychophysiological differences between groups high and low in trait anxiety or in the closely related personality dimension of neuroticism." One physiological measure that may be able to indicate stress reactivity however is cortisol. In addition, there is evidence to suggest that this variable could be important in cognitive functioning. Although this thesis is not explicitly concerned with the biological mechanisms underlying a stress response, it will be helpful to outline the action of cortisol and highlight why it may be an appropriate measure to use as a marker of stress in testing situations.

Cortisol, the glucocorticoid (GC) released in humans (corticosterone in rats), is the end product of the hypothalamic-pituitary-adrenal axis (HPA) response to such perceived physical or psychological threats. Specifically, the hypothalamus releases corticotropin-releasing factor (CRF) which is in turn transported to the anterior lobe of the pituitary gland. In the pituitary gland, CRF stimulates the release of stored adrenocorticotropic hormone (ACTH), which is then transported via the blood to the adrenal glands, which sit at the upper pole of each kidney. Here, in the middle layer of the adrenal cortex (zona fasciculata) ACTH stimulates the rapid biosynthesis of cortisol from cholesterol. Cortisol is then released into the bloodstream, and has the general catabolic effect of breaking down proteins into amino acids. These released amino acids are then utilised by the liver in the synthesis of numerous enzymes that are involved in the production of glucose (gluconeogenesis). The effect of cortisol is also antagonistic to insulin which also increases the production of glucose in the liver. Cortisol is known to influence many tissues in the body, and is able to cross the blood/brain barrier (Het, Ramlow, & Wolf, 2005).

It is also beginning to emerge that a sustained stress response, or pathophysiological condition such as an affective disorder, can adversely affect cognition (Roozendaal, 2000). As Lupien et al. (2005, p.238) conclude: “human cognitive processing from childhood to old age is very sensitive to acute and chronic increases of GCs”. Research shows that both acute and chronic effects of cortisol can have a deleterious impact on working memory functioning (Lupien, Lecours, Lussier, & Schwartz, 1994; McEwen & Sapolsky, 1995), and that there may be a special role for working memory in the acute effects of cortisol, more so than in other functions such as declarative memory (Lupien, Gillin, & Hauger, 1999). This relatively recent attention on the effect of cortisol on working memory has been encouraged by the realisation that cortisol-relevant cell receptors are less concentrated in the hippocampus than was previously thought (due to a reliance on evidence from animal models), and more concentrated than was thought in the frontal cortex (Lupien et al., 2005). This discovery explains the association between cortisol and working memory (primarily associated with the frontal lobes), as well as learning and other memory functions that have been shown to be associated with the hippocampus. For example, Squire (1992) provided a review of the literature relating to the memory and the hippocampus and showed that rats with lesions in this area showed impairments in learning and memory.

Patients with Cushing’s syndrome (CS), who experience chronic elevations of endogenous cortisol months or even years before diagnosis, act as convenient human models to illustrate the effect of chronic over-secretion of cortisol. The symptom profile of such patients includes difficulties with concentration and memory. Impairments on tests measuring particular domains of cognitive function such as visual spatial, and verbal learning have also been found (Starkman, Giordani, Berent, Schork, & Schteingart, 2001). One aspect of research has focused on the relationship between cortisol and the hippocampus, as it has been shown for example, that hippocampal volume correlates negatively with cortisol plasma levels and positively with verbal memory scores in CS patients (Squire, 1992). Further evidence of the cortisol-hippocampus connection has been demonstrated in healthy adults, where those with increasing/high levels of cortisol over a five to six year period showed hippocampal volume decreases of 14% when compared to those with moderate/decreasing levels of cortisol (Lupien et al., 1998). Starkman, Giordani, Gerbarski and Schteingart (2003) showed that CS patients who received corrective surgery showed a decrease in urinary free cortisol levels and increases in hippocampal formation volume along with an associated improvement in verbal learning.

Specific processes through which cortisol is thought to cause hippocampal atrophy have been outlined by Sapolsky (2000). For example, prolonged stress or exposure to stress or exogenous GC**s** can have the effect of producing atrophy in the dendrites of the CA3 region of the hippocampus, which are essential for creating neural networks. Contrary to a long-standing dogma that adult neurons once lost cannot be replaced, neurogenesis does in fact occur, and is particularly pronounced in the hippocampal area. High levels of GCs can inhibit this neurogenesis. Cameron and McKay (1999), for example, showed that, in aged rats, proliferation of granule cells in the dentate gyrus is inhibited. It was found, by labelling dividing cells in the dentate gyrus of the hippocampal region, that adrenalectomised aged rats, had cell proliferation rates three times higher than sham operation young rats. That is, the adrenalectomised aged rats had cell division rates that surpassed those found in young rats. This shows both that GCs can inhibit neurogenesis, and interestingly, that the negative effect of elevated GC levels is reversible. In extreme prolonged stress, hippocampal neurons can be annihilated by GCs. This may not occur directly through

GCs themselves but through the GC effect of worsening the regulation of calcium and glutamate, which causes aptosis (programmed cell death). Although glucocorticoid receptors are restricted to specific areas of the brain in lower animals they are widely distributed throughout the cortex in primates (Erickson, Drevets, & Schulkin, 2003; Lupien et al., 2005) and so any effects of cortisol are likely to also be seen in the prefrontal areas associated with working memory.

Research has shown that elevated levels of the stress hormone cortisol, negatively affect working memory. Al'absi, Hugdahl, & Lovallo (2002) measured plasma levels of cortisol and divided participants into high and low cortisol responder groups based on their response to two stressor tasks. They found that on a mental arithmetic task, designed to tap into the working memory function, the 'high cortisol responders' made more errors and completed fewer items than low responders. Domes, Rothfischer, Reichwald and Hautzinger (2005) found that after treatment of 25mg of synthetic cortisol (hydrocortisone), low cortisol responders (those whose plasma levels measured <68.25 nmol/l after the administration of synthetic cortisol) scored significantly higher on a verbal memory task than high cortisol responders (> 68.25 nmol/l) or placebo controls. Lupien et al. (1999) found that working memory was more sensitive to high doses of hydrocortisone than declarative memory. Both Lupien et al. (1999) and Domes et al. (2005) report inverted U shaped relationships between cortisol and working memory in their data, suggesting that moderate amounts or increases in cortisol response may be beneficial for cognition and that only relatively high levels of cortisol have negative effects. In support of this conclusion, Blair, Granger and Razza (2005) found that, in a group of children on the Head Start programme, moderate amounts of cortisol reactivity were positively associated with executive functions.

These associations are probably explained by the fact that GCs in the blood, bind with two types of receptors: mineralcorticoid (MR) and glucocorticoid (GR). Cortisol binds to the former with an affinity 6-10 times higher than with the latter. During a normal circadian trough around 90% of MRs are occupied, while around 10% of GRs are occupied. However, in times of stress, the MRs are saturated and around 67% of GRs are occupied (Lupien et al., 2005). It is thought that GRs are specifically involved in the consolidation of learning and memory, whereas MRs are important in behavioural reactivity in response to novelty situations (de Kloet, Oitzl, & Joels, 1999).

Triggering the stress response has traditionally thought to be caused by 'perceived stressors'. That is, stress is caused by whatever the individual considers to be stressful; what is stressful to one person might not be stressful to another. However, in the case of cortisol release, there appears to be some specific triggers. In a review of over 200 papers, Dickerson and Kemeny (2004) found that the tasks containing one or more elements of uncontrollability or social evaluation were associated with the largest cortisol and adrenocorticotropin hormone changes. These tasks also had the longest recovery times.

2.10 Interference and deficit models.

Many studies have shown that anxiety causes poor performance (e.g. Hembree, 1988). Nevertheless two competing hypotheses of defective skills versus interference have been proposed to account for the poor test performance of high anxious students (Tobias, 1985). The interference hypothesis has been described earlier and Tobias summarises it well: "students high in anxiety are hypothesised to divide their attention between task demands and personal concerns principally composed of negative self-preoccupations; those lower in anxiety, on the other hand are presumed to devote a greater proportion of their attention to task demands" (p. 137). Conversely, a deficits approach assumes that inadequate preparation prior to assessment and poor test-taking skills accounts for the poorer performance of test anxious individuals and that elevated anxiety levels are reflective of awareness of poor preparation.

Two important studies have tested the deficit and interference models in their relative strength to predict academic performance in undergraduate students. Smith, Arnkoff and Wright (1990) showed that while ability made a significant contribution to explaining variance to introductory psychology course grades (11%), negative thoughts and underlying concerns accounted for a further 19% of the variance. Musch and Bröder (1999) found that study habits did not predict performance on a statistics exam, but that maths skills accounted for 9% of the variance in the exam scores. Anxiety made a smaller unique contribution (5%) that was short of being statistically significant (p =.06).

Tobias (1985) suggested a reformulation of the deficit and interference hypotheses by emphasising cognitive capacity. With a finite cognitive capacity, task demands and the capacity absorbed by anxiety exceed available cognitive processing capacity, interference in learning can result. It is suggested that the evaluative nature of some tasks act for the high anxious student in an analogous way to a demanding secondary task. It might be that effective study skills and test-taking strategies that reduce the load on cognitive capacity during a test may require more effort and lead to increased anxiety.

It is argued that optimal performance on academic tests comes from students with good study or test-taking skills and low test anxiety. Such students have the greatest proportion of cognitive capacity available for these task demands. Conversely, students with a combination of high test anxiety study skills make maximum demands on their cognitive capacity, "possibly exceeding available capacity for dealing with the task" (Tobias, 1985, p.139). By extension, it can be argued that those with high anxiety and low working memory capacity are likely to be the worst performers on academic tests. Rather than a competing hypothesis this would translate into an emotion x cognition interaction hypothesis.

2.11 Transient and chronic effects of anxiety on performance.

The effects of anxiety are assumed to be transitory (Eysenck & Calvo, 1992) and there is much evidence in keeping with this idea. For example, anxious individuals can improve their performance over subsequent trials (Mandler & Sarason, 1952) and under reassurance conditions (Sarason, 1984). However, the effects could be more chronic. For example, Eysenck and Calvo suggested that there may be a reciprocal relationship between working memory and anxiety. That is, poor working memory may lead to worry which would in turn reduce available resources. One way to test whether any type of adverse effects of emotion on performance are acute or chronic is to use a longitudinal study design. Indeed other researchers have called for such studies (Hopko, Crittendon, Grant, & Wilson, 2005; Musch & Bröder, 1999; Schwarzer, 1990). Specifically, a longitudinal design will allow for a test of acute effects at any given cross-sectional time point and a test for chronic effects over time.

2.12 Summary and aims of the thesis.

Previous research has suggested that task-irrelevant thoughts characterise the anxious or depressed student. This conceptualisation has been formed in terms of anxiety drives (Mandler & Sarason, 1952), attention (Wine, 1971), cognitive capacity (Tobias, 1985), resource allocation (Ellis & Moore, 1999) processing efficiency (Eysenck & Calvo, 1992), and attentional control (Eysenck et al., 2007). Perhaps the most important theoretical advance was the PET model that synthesised existing work with the working memory concept. Thus allowing for a detailed study of where, more precisely, the effects of anxiety might lie and couching the emotion x task difficulty in terms of CE processes. The common denominator to these perspectives is that task-irrelevant rather than task-relevant cognitions have a central role in the relationship between emotion and performance.

Many studies have shown that anxious cognitions are triggered by situational stress (Deffenbacher, 1978; Wine, 1971). Although physiological measures of stress have not been shown to be linearly related to performance, it is possible that they will act as moderators of the link between emotion and performance. That is, if an individual is stressed, emotion will interfere with working memory/task performance. Given the close association between cortisol and cognition, it could be an appropriate marker of stress reactivity to a testing situation and was used as such in this thesis.

PET has shown that the effects of anxiety on performance per se are likely to be strongest when the tasks involved make heavy demands on CE processes. Similarly, in academic performance, a range of working memory tasks are thought to be beneficial, however, CE tasks are perhaps the most important. This is especially true for tasks likely to make heavy demands on the CE such as IQ tests or maths tests.

Anxiety has been the focus of much of the research although depressed mood is also associated with poor cognitive performance. There may be a common source of disruption that can be called task-irrelevant thoughts. Eysenck and Calvo (1992) note the similarity between PET and RAM and it is suggested that more work should be done to incorporate depressed mood.

The two competing models of interference by anxiety and deficit through poor study skills in academic performance have been reframed in terms of cognitive capacity. Work from Tobias (1985) suggests that individuals with high emotion and low cognitive capacity will perform the worst of all combination groups on academic performance tests. This is an emotion x cognition interaction hypothesis.

Recently, the idea that strong emotions are negatively associated with both working memory and academic performance has been demonstrated by Aronen, Vuontela, Steenari, Salmi and Carlson (2005). The authors of the study measured 66 children, 6 to 13 year-olds, on psychiatric symptoms, auditory and visual working memory parameters and academic performance. Although the authors did not specifically test for it, the pattern in the data suggests the presence of a mediating role for working memory between psychiatric symptom and academic performance. For example, anxious/depressive symptoms were correlated to some working memory measures and some working memory measures were correlated with teacher reported academic performance. The authors do suggest, however: “it is possible that anxiety/depressive symptoms affect working memory function, as well as the ability to concentrate, leading to a lower level of academic performance at school”. This is a mediation hypothesis where working memory mediates the relationship between emotion and academic performance. This possibility would also be consistent with PET and would be an extension of its application to academic testing in children.

The negative effects of emotion on performance are assumed to be transient but may also be chronic. There is a lack of longitudinal studies in this area which would be useful in helping to address this question (Hopko et al., 2005; Musch & Bröder, 1999).

The aim of this thesis is to understand more about the relationship between emotion and academic performance. It is generally agreed that the relationship between anxiety and academic performance is negative (Hembree, 1988; Stober & Pekrun, 2004; Zeidner, 1998). The size of the relationship is also well described and thought to be approximately (r = -.21) (Schwarzer, 1990; Seipp, 1991). However, the precise mechanisms through which this relationship operates are not fully understood. In addition, although lowered test performance has been studied in the case of depressed mood (Ellis & Moore, 1999) this work has not been as extensive as for anxiety. This thesis tested the simple relationship between emotion and academic performance and whether working memory is a potential mechanism underlying this relationship. Stress in the testing situation has been shown to be associated with lower performance, possibly acting as a trigger for the intrusive thoughts of emotion. This hypothesis was explored with regard to cortisol as the marker of stress reactivity, rather than via a stress induction procedure.

The specific cognitive aspects affected by anxiety have been suggested to be in the PL and the CE (Eysenck & Calvo, 1992). This thesis followed the framework of PET and did not make a formal comparison between the different types of executive functions (e.g. inhibition and switching) outlined in ACT by Eysenck et al. (2007) to be most susceptible to the negative effects of anxiety. Within the PET framework, the interest in this thesis was with performance effectiveness (academic performance) rather than efficiency.

The first empirical chapter of this thesis (Chapter Three) assessed the overall relationship between emotion (including anxiety and depression) and academic performance. It was expected to be a negative relationship. Chapter Four then assessed the hypothesis implicit in most studies and stated in Aronen et al. (2005) that working memory will mediate the relationship between emotion and academic performance. In this study, trait anxiety was measured along with a verbal working memory task that taps the PL and CE and a spatial working memory task that uses the VSSP yet requires little use of the CE. Consistent with PET, it was expected that trait anxiety would be negatively associated with academic performance via the task tapping the PL and CE but not through the VSSP measure. Although Baddeley's model of working memory has evolved to include a new component (the episodic buffer; Baddeley, 2000), this component is still relatively underdeveloped and so this thesis focused on the PL, VSSP and CE.

Chapter Five extended the mediation hypothesis work in Chapter Four by including a range of working memory measures and including depression. It was in this chapter that the stress reactivity hypothesis will be tested using cortisol as a measure of stress reactivity. The mediation pathways, from emotion to academic performance via working memory, were expected to be clearest when stress reactivity was high.

The first aim of Chapter Six was to retest the previous hypotheses in a larger sample. Second, in this chapter the interaction hypothesis implicit in the literature, but made explicit by Tobias (1985), that those with low working memory capacity and high levels of emotion will perform worst of all possible combinations, was also tested.

Chapter Seven tested whether the mediation and interactive hypotheses were best characterised as transient or chronic effects. That is, the mediation of the emotion – academic performance relationship via working memory could be present at cross-sectional time points or may also exist over time. Similarly, the emotion x working memory interaction could be associated with lower academic performance cross-sectionally or predict academic scores over time. This chapter, therefore, includes a longitudinal element where children were tested and retested once again, approximately nine months later. Both mediation and interaction effects were tested.

Chapter Eight discussed key findings along with limitations of the thesis and possible future directions for research.

CHAPTER THREE: THE RELATIONSHIP BETWEEN ANXIETY AND DEPRESSION IN ACADEMIC PERFORMANCE.

3.1 Introduction.

In a review of previous research, Chapter One highlighted findings that have shown that lowered academic performance is associated with both anxiety (Crozier & Hostettler, 2003; Hembree, 1988) and depression (Fröjd et al., 2008). For example, in assessing the educational consequences of having psychiatric disorders in the National Comorbidity Survey in the US, Kessler et al. (1995) and Breslau et al. (2008) showed that having an anxiety or depressive disorder was associated with an increase in the likelihood of educational failure. The aim of this study was to test these relationships in a moderately sized sample. A first step in the empirical assessment of the interplay between emotion and cognition in relation to academic performance is to identify whether there is an association, and to determine the direction and size of effect.

Following previous research, it was expected that both anxiety and depression would be negatively associated with academic performance and that these relationships would be of a similar magnitude. Evidence of such relationships would be consistent with the notion that both anxiety and depression may share a common negative influence on cognition (Aronen, Vuontela, Steenari, Salmi, & Carlson, 2005; Christopher & MacDonald, 2005). Aronen et al. (2005) suggested that anxiety and depression could both affect working memory functioning that in turn leads to lower academic performance. Christopher and MacDonald (2005) also proposed a common source of disruption in working memory (intrusive thoughts) for both anxious and depressed patients. The study reported in the current chapter tested whether the relationship between emotion and academic performance was specific to anxiety (trait anxiety and test anxiety) or linked to negative affect more broadly, including depression. In order to do this, self-report measures of trait anxiety, test anxiety and depression were administered to school children, and their academic test results were gathered from the school. The data were used to test structural equation models that included all three emotion variables as indicators of a latent variable and academic performance test results to form two further latent variables (attainment or cognitive ability). To determine the direction and size of effect between emotion and academic performance, the path between the two types of latent variables was of key importance.

Previous research into the associations between emotion and individual academic tests has been unclear due to a reliance on a unitary measure of academic performance such as grade point average (Keogh et al., 2006) or self-reported grade point average (Fröjd et al., 2008). Other research has focussed on maths tests in particular (Ashcraft & Krause, 2007). However, it was expected that there would be a non-specific effect of emotion on performance regardless of the individual test examined. This expectation is supported by a study by Crozier and Hostettler (2003) that showed significant negative correlations between teacher reported shyness and vocabulary, mental arithmetic, progress in English and maths. It has also been shown that tests of cognitive ability or IQ are equally susceptible to the negative influence of negative affect (Darke, 1988; Hembree, 1988; Hopko et al., 2005; Mandler & Sarason, 1952). In addition to these empirical studies, the Raven's IQ test manual also notes the influence of emotion on testing, suggesting that: "when the test is administered individually by a tester, it appears to introduce emotional factors which interfere with effective thought" (Raven, 2000). To test the assumption that there would be negative associations between emotion and both attainment and cognitive abilities, both types of test were used in a single sample in this study. It was expected that the negative effects of emotion would be equivalent on both types of test.

As it has been reported in the literature that girls tend to experience higher *levels* of emotion than boys (Mackinaw-Koons & Vasey, 2000), the moderating effects of gender were also considered. Age was controlled as a potential confounding variable.

3.2 Method.

3.2.1 Participants.

Eighty four (33 boys, 51 girls) were recruited from a single secondary school in Hampshire, UK. The age of the children ranged between 12 and 13 years (mean =

12.1 years, SD = 0.3). Parental consent was obtained via information letters/consent slips which were sent to all pupils in a Year group. Parents only needed to return the form if they did not want their child to participate in the study (see Appendix B1). In addition participants were presented with an information sheet and asked to sign a consent form before participating (see Appendix B2). Ethical approval for the study was obtained from the School of Psychology Ethics Committee, University of Southampton.

3.2.2 Measures.

The state-trait anxiety inventory for children (STAIC). The STAIC (Spielberger, Edwards, Lushene, Montuori, & Platzek, 1973) was used to measure trait anxiety. This measure uses a 3-point (1=almost never, 2=sometimes, or 3=often) Likert-type scale, where higher scores indicate higher levels of anxiety. It is assumed to be unidimensional and as such a single global score can be found by summing the scores on all items (maximum score = 60). The trait subscale was used in the present chapter. Internal consistency for the trait subscale was good in this sample with a Cronbach's alpha (α) of .91.

The revised child anxiety and depression scale (RCADS). The RCADS (Chorpita, Yim, Moffitt, Umemoto, & Francis, 2000) is a 47-item self-report measure designed to tap into several dimensions including separation anxiety disorder, social phobia, generalized anxiety disorder, panic disorder, obsessive compulsive disorder and major depressive disorder (MDD). A Likert scale (0=never, 1=sometimes, 2=often, 3=always) asks respondents to rate to what extent each item applies to them. The major depressive disorder (MDD) subscale of the RCADS was used in this study which correlates well (r = .71) with the most widely used measure of depression in children, the CDI (Kovacs, 1992) and has shown good psychometric properties in both non referred (Chorpita et al., 2000) and clinical populations (Chorpita, Moffitt, & Gray, 2005). Here the item 37 "I think about death" was removed as it was decided to be too sensitive for the target population. Internal consistency was good in this sample (α = .88).

The children's test anxiety scale (CTAS). The CTAS (Wren & Benson, 2004) 30-item scale designed to tap into several aspects of test anxiety including worrisome thoughts, autonomic reactions and off-task behaviours. A total score is calculated by summing the 30 items. The questionnaire uses a 4-point Likert scale (1 = Almost never, 2 = Some of the time, 3 = Most of the time, 4 = Almost always), and asks children to respond to statements that are preceded with the phrase, "While I am taking tests…" Internal consistency for the CTAS was good in the present study (α = .93).

The Cognitive Abilities Test (CAT). The CAT (Lohman, Hagen, & Thorndike, 2003) is the most widely used school assessment of reasoning ability in the UK (Strand, 2002). CAT scores are indicators of performance, predicting future national curriculum test scores. For example, the CAT mean score has been shown to predict later key stage 2 (KS2) and key stage 3 (KS3) Standard Assessment Tests (SATs), with correlations of r = .80 (NFER Nelson, 2005a) and r = .86 (NFER Nelson, 2005b) respectively. In an evaluation study measuring over 100,000 Year 7 children on the CAT in 1998 and following them through to their GCSE completion year, a significant correlation of a similar magnitude (r = .70) between standardised mean CAT scores and a General Certificate of Secondary Education (GCSE) total points score was found (NFER Nelson, 2004). The three sections of the CAT (measuring verbal, quantitative, and nonverbal reasoning) take 45 minutes each to complete and are administered by schools. Scores are standardised with a mean of 100 and a standard deviation of 15.

National curriculum Standard Assessment Tests (SATs). The national curriculum tests are indicators of academic competence that are taken in all schools in England. The tests use methods and materials developed and validated by the qualifications and curriculum authority. At the end of KS2 (from 7 to 11 years) pupils take standardised tests in maths, English, and science. Although each subject area is comprised of several different tests, the overall mark for each area has a range of 0-100, with higher scores indicating better performance. The present study used raw scores for maths, English and science.

3.2.3 Procedure.

Participants were asked by their tutor group teachers to complete the self-report emotion questionnaires (STAIC- T, RCADS and the CTAS) in the registration period at the beginning of the school day. Academic performance as measured using school administered KS2 SATs tests, and data from the CAT were also requested from the school.

3.3 Data analysis.

Structural equation modelling is a technique that can be thought of as a combination of factor analysis and linear regression. Among several strengths, the main advantage in using this method is that multiple indicators can be used to tap into assumed unmeasured or latent constructs. Thus the unreliability or error of measurement can be explicitly taken into consideration in any given model. This results in accurate estimates of regression paths between latent variables. Structural equation modelling also enables the researcher to decompose associations into direct, indirect and total effects, where the indirect effect is synonymous with a mediation pathway and the total effect is the sum of direct and indirect effects. The testing of indirect effects is addressed from Chapter Four onwards and a detailed description of the calculation of indirect effects with the aid of bootstrapping techniques is also given in Chapter Four. Structural equation modelling also allows for the calculation of overall goodness-of-fit indexes (how well the model specified fits the data actually collected) for the entire model as well as inspection of individual path estimates, factor loadings, error terms etc. It is therefore a more comprehensive description of the data than, for example, a simple regression model. Structural equation modelling is best used to test theory and hypotheses and is rarely used purely as an exploratory tool. However, after an initial model is specified there is usually some model adjustment driven by model evidence with reference to theory. In this respect there are many approaches available including inspection of individual estimates and model modification indices. More generally, structural equation modelling allows for complex hypotheses to be tested such as multi-group analyses of indirect effects. In testing hypotheses structural equation modelling can assess the change in model fit when hypothesising that certain paths in any given model are equivalent (1) or one or more paths is redundant (0). The method has good scope and flexibility for testing a range of hypotheses.

In the present study, structural equation models were estimated in AMOS 16.0 using maximum likelihood estimation. Model fit was assessed using several goodness-of-fit indices including χ^2 and associated *p* - value, χ^2/df, the Comparative Fit Index (CFI) and the Root Mean Square Error Approximation (RMSEA). Goodness-of-fit was judged with a non-significant χ^2 value. As χ^2 is affected by sample size the χ^2 ratio is also reported (χ^2/df) which will be <2 if good model fit is obtained (Tabachnick & Fidell, 2007). The CFI index will be > .95 for a well fitting model (Hu & Bentler, 1999). Bollen and Curran (2006) outline guidelines suggesting that RMSEA values <.05 indicate a very good fit, while values >.10 represent poor fit. Values in between suggest a moderate fit.

Models of emotion (trait anxiety, test anxiety and depression) predicting attainment (maths, English and science) tests (this hypothetical model is illustrated in figure 3.1) and cognitive abilities (verbal, quantitative and nonverbal reasoning) tests (shown in figure 3.2) were specified. T To assess the influence of gender, a multi-group analysis was carried out using gender as the group variable. The path of interest (the structural path between the emotion latent variable and either the attainment or cognitive abilities latent variable) was constrained to be equal across the gender groups and a chi square difference test ($\Delta\chi^2$) compared the constrained and global models. This comparison hypothesises that the regression coefficient in the structural path is invariant across groups and compares this with the unconstrained global model where the path is free to vary. If the $\Delta\chi^2$ is not significant then this suggests there is no meaningful difference between the two gender groups in the structural path. Gender differences were explored further by analysing the differences in latent variable means between genders. A procedure outlined in the AMOS software user guide (Arbuckle, 2006) involves constraining parameters to be equal across groups with the exception of the latent means.

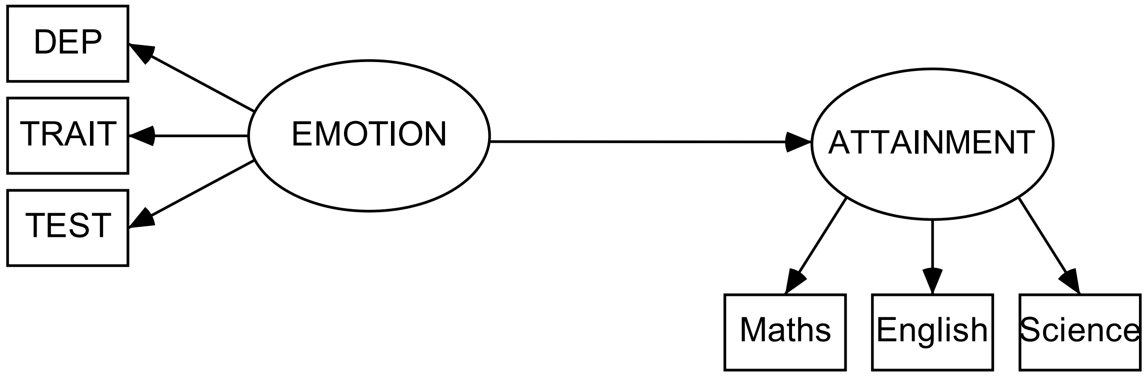


FIGURE 3.1. An illustration of structural equation model diagram showing the relationship between emotion and attainment. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Maths, English and Science measures SAT KS2 results.

The latent mean is constrained to be equal to zero for one group (arbitrarily chosen) and left free to be estimated in the second group. Thus a mean difference (and direction) can be calculated along with a standard error, critical ratio and associated *p*-value. The significance test refers to the differences between the estimated mean and the constrained mean (i.e. zero).

The global models were also tested with age controlled for. Age in months was entered into the model by allowing it to independently predict either the attainment or cognitive abilities latent variable. The structural paths were re-estimated and a nested model comparison was performed constraining the age in months path to be equal to zero. A non significant chi squared difference test here would indicate that the path was not significantly adding to the model.

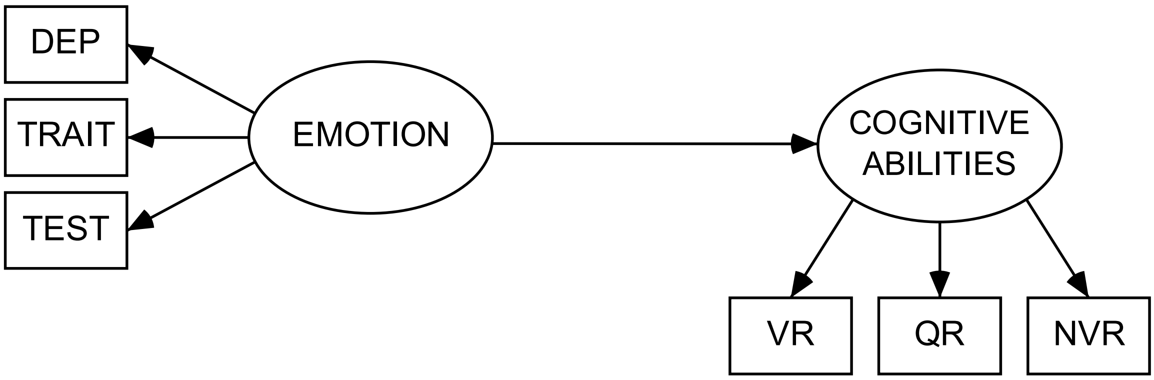


FIGURE 3.2. An illustration of a structural equation model diagram showing the relationship between emotion and cognitive abilities. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. VR = verbal reasoning, QR = quantitative reasoning and NVR = nonverbal reasoning all measured using the CAT.

3.4 Results.

The correlations between the emotional and the academic measures are given in Table 3.1. As expected, the correlations between trait anxiety and academic performance were all negative and of a similar magnitude to that found in previous studies. The median correlation between trait anxiety and the six academic tests was r = -.24.

Table 3.1. *Means, Standard Deviations, and Zero-order Correlations Between Study Variables.*

Variable	*M (SD)*	1	2	3	4	5	6	7	8	9
1. Maths	71.82 (19.42)	—								
2. English	64.48 (13.52)	.64**	—							
3. Science	63.77 (10.21)	.78**	.60**	—						
4. Quantitative reasoning	102.24 (13.96)	.73**	.53**	.60**	—					
5. Verbal reasoning	103.12 (13.20)	.62**	.55**	.68**	.64**	—				
6. Nonverbal reasoning	105.71 (15.45)	.63**	.40**	.58**	.68**	.64**	—			
7. Trait anxiety	30.86 (6.79)	-.25*	-.26*	-.26*	-.14	-.20	- .23*	—		
8. Depression	5.56 (3.90)	-.23*	-.29**	-.32**	-.15	-.29**	-.30**	.69**	—	
9. Test anxiety	63.86 (16.37)	-.23*	-.19	-.32**	-.26*	-.08	-.20	.63**	.58**	—

Note. *p < .05; **p < .01. N = 84.

The correlations were significant between trait anxiety and maths, English, science and nonverbal reasoning, but not with quantitative reasoning or verbal reasoning. Depression was similarly related to academic performance with a median correlation of r = -.29. The correlations between depression and all the academic tests were significant with the exception of quantitative reasoning. The test anxiety measure produced a median correlation of r = -.22 with the academic tests. The correlations between test anxiety and maths, science and quantitative reasoning were significant, but not between test anxiety and English, verbal and nonverbal reasoning. The academic performance measures were grouped into two categories of tests; attainment tests and cognitive abilities measures. There were positive and significant correlations within the attainment tests (median r = .64) and cognitive abilities tests (median r = .64) and between the two categories of tests (median r = .60) between both categories of academic performance. The three emotions of trait anxiety, test anxiety and depression correlated positively and significantly with one another (median r = .63).

The emotion – attainment tests structural equation model (Figure 3.3) provided an excellent fit to the data (χ^2 = 6.91, df = 8, χ^2/df = .86, p = .55, CFI =1.00, RMSEA = .00). As expected, there was a significant negative pathway between emotion and academic performance (β = -.37, p < .01), showing higher levels of emotion predicted lower attainment scores.

Age was entered into the global model and allowed to independently predict the attainment latent variable. This model was a good fit to the data (χ^2 = 11.58, df = 13, χ^2/df = .89, p = .56, CFI =1.00, RMSEA = .00), and the negative path between emotion and attainment remained negative and significant (β = -.37, p < .01). The path from age to attainment was negative but not significant (β = -.14, p = .20).

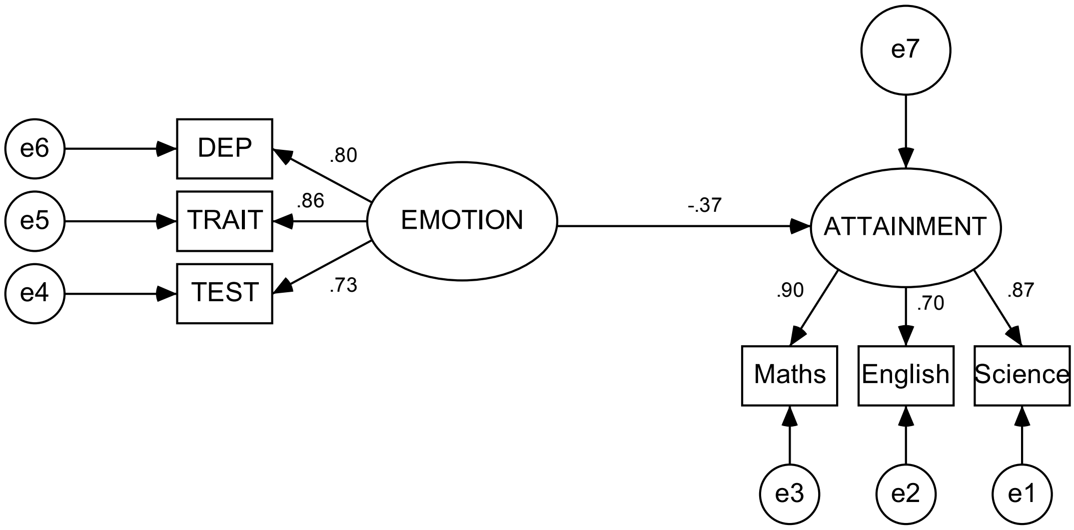


FIGURE 3.3. A structural equation model diagram showing the relationship between emotion and attainment. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Maths, English and Science measures SAT KS2 results.

A multi-group analysis using gender was carried out constraining the structural path between emotion and attainment to be equal across gender groups. The constrained model was not significantly different from the unconstrained model ($\Delta\chi^2$ = .17, Δdf = 1, p = .68) suggesting that there is no meaningful difference between boys and girls in the relationship between emotion and academic attainment. This conclusion was bolstered by a comparison of structural means between the groups of boys and girls. Girls reported 2.77 mean points lower on the emotion latent variable which was not a significant difference from the boys score (mean diff = -2.77, SE = 2.93, CR = -.95, p = .35). Similarly, boys, although scoring slightly higher than girls, were not significantly different in their attainment latent variable mean scores (mean diff = 1.29, SE = 1.92, CR = -.67, p = .50).

The emotion – cognitive abilities tests model (Figure 3.4) was also an excellent fit to the data (χ^2 = 6.03, df = 8, χ^2/df = .75, p = .64, CFI =1.00, RMSEA = .00). Again, there was a significant negative path between emotion and the academic tests (β = -.31, p < .05).

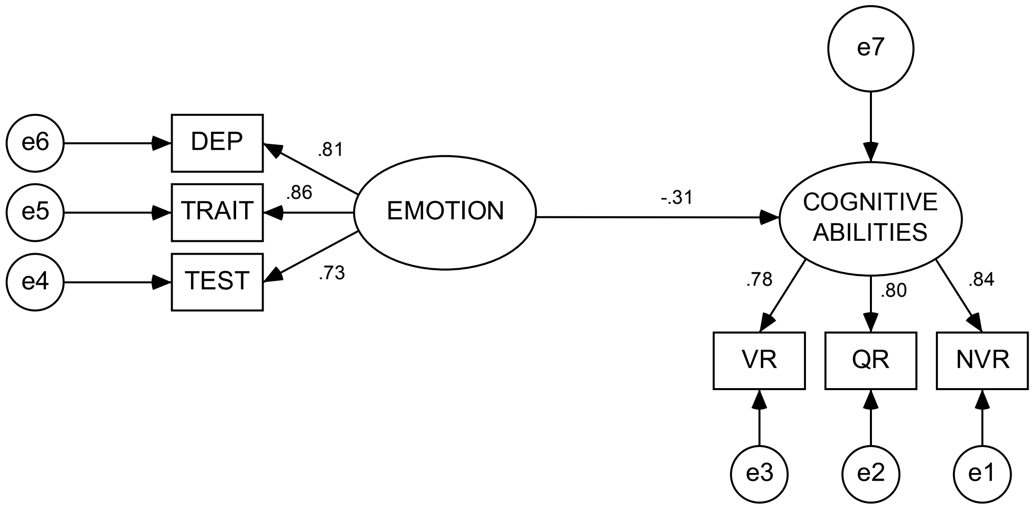


FIGURE 3.4. A structural equation model diagram showing the relationship between emotion and cognitive abilities. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. VR = verbal reasoning, QR = quantitative reasoning and NVR = nonverbal reasoning all measured using the CAT.

A multi-group analysis was performed using gender as the group variable and constraining the structural weight between emotion and attainment to be equal across gender groups. The constrained model, hypothesising equal path regression coefficients across genders, was not significantly different to the full, unconstrained model which allows the paths to vary across gender groups ($\Delta\chi^2$ = .08, Δdf = 1, p = .77). From the previous attainment analysis it is already known that boys and girls did not significantly differ in their emotion latent variable mean scores. In addition girls scored marginally higher on the cognitive abilities tests, as evidenced by a positive mean difference on the cognitive abilities latent variable mean scores, but this difference was not significant (mean diff = .71, SE = 2.82, CR = .25, p = .80). This suggests, in the same way as in the attainment tests analysis above, that there is no difference between boys and girls in the relationship between emotion and cognitive abilities tests.

The global model was tested once more with age in months independently predicting the cognitive abilities latent variable. The negative effect of emotion on cognitive abilities remained (χ^2 = 8.52, df = 13, χ^2/df = .66, p = .81, CFI =1.00, RMSEA = .00). Indeed a nested model constraining the path from age in months to the cognitive abilities latent variable to equal zero was compared against the total model and found not to be a significantly poorer fit to the data ($\Delta\chi^2$ = 2.13, Δdf = 1, p = .14).

3.5 Chapter summary.

There were significant negative associations between the emotion latent variable and both the attainment and cognitive abilities latent variables, suggesting that higher levels of emotion are associated with lower academic performance. The size of the relationships are moderate and in line with findings from previous research (Crozier & Hostettler, 2003; Seipp, 1991).

The negative relationships between emotion and the attainment tests and between emotion and the cognitive abilities tests were similar. In other words, emotion had a negative impact on academic performance regardless of whether the tests taken were attainment based (maths, English and science) or were measuring cognitive abilities (verbal, quantitative and nonverbal reasoning). The full structural equation models explored both provided close fits to the data. A comparison of the path estimates from emotion to either academic performance latent variable showed a very similar relationship regardless of which type of academic performance test under scrutiny; cognitive ability or attainment.

Age did not add significantly to the models and did not alter the relationship between emotion and academic performance. It is still possible that age differences may appear in future studies given a larger age range.

The relationship between emotion and both attainment and cognitive abilities did not change significantly, depending on whether boys or girls were being measured. A multi-group analysis revealed no significant differences in the relationship between the emotions of boys and girls and academic performance. A further analysis addressed the nature of the differences between boys and girls in both their self-reported emotional levels and academic performance. There were small mean differences in the emotion latent variable between boys and girls that indicated that, contrary to previous research, girls reported slightly lower levels of emotion. Boys were found to have slightly higher attainment scores whereas girls were found to have slightly higher cognitive abilities scores. However, it is important to point out that in all cases the difference tests between genders were non significant (*p*s > .3). There were, therefore, no meaningful differences between boys and girls in terms of their mean emotion levels, mean attainment scores, or mean cognitive abilities scores.

CHAPTER FOUR: DOES WORKING MEMORY MEDIATE THE ANXIETY - ACADEMIC PERFORMANCE RELATIONSHIP?

4.1 Introduction.

In a review of previous research Chapter One showed that high levels of anxiety, including anxiety disorders, are detrimental to academic performance (Aronen et al., 2005; Kessler et al., 1995). The results of Chapter Three are also consistent with this conclusion. It was also shown in Chapter Two that in contrast, good working memory skills are beneficial to academic performance (Gathercole & Pickering, 2000b; Gathercole et al., 2004). Based on Eysenck and Calvo's (1992) processing efficiency theory (PET) and the attentional control theory (ACT) of Eysenck et al.(2007), where anxiety is proposed to interfere with working memory functioning, the present study investigated the possibility that the associations between anxiety and academic performance were mediated via working memory performance. Previous research has found disruptive effects of anxiety on both verbal (Calvo & Eysenck, 1996) and spatial (Eysenck et al., 2005) domains, therefore, the mediation hypothesis was tested using both verbal (backwards digit span) and spatial (Corsi blocks) tasks. The backwards digit span task, more precisely, is tapping into the PL as well as the CE as the task requires storage and retrieval of information and also some manipulation of the data presented. That is, the digits are presented vocally to the participant who must then reverse the order of the digits before responding. The automated Corsi blocks task on the CANTAB is tapping into the VSSP and making few if any demands on the CE. The blocks are visually presented and follow a spatial sequence. The participant must recall the order of the sequence without further operation on the stimuli and by using a mouse pointer to indicate the sequence. In order to test whether any indirect effects of anxiety on academic performance were specific to working memory, or were more generally associated with cognition a continuous performance task, primarily measuring sustained attention with a smaller working memory component, was used as a comparison. A measure of sustained attention was used as it is likely that sustaining attention in the school classroom for long periods would be advantage for a pupil in terms of learning and test taking. If anxiety were to affect other aspects of cognition then attention would be relevant in terms of school tests. However, due to the emphasis on the disruption of CE processes by anxiety in PET, it was expected that attention would not act as a mediator between anxiety and academic performance, as working memory would. One assumption of PET is that any effects of trait anxiety will be mediated by state anxiety (Eysenck et al., 2005), therefore, the meditational role of state anxiety was tested. Potential confounding variables of age and gender were also tested.

4.2 Method.

4.2.1 Participants.

Fifty pupils (26 boys, 24 girls) were recruited from two different secondary schools in Hampshire, UK. The sample was drawn from Year 7 children who were either 11 or 12 years old (M = 11.3, SD = 0.4). Head teachers were approached regarding the study and information letters (Appendix B3) were subsequently sent to parents/guardians asking for their written consent for their child to participate in the study. Pupils also gave their informed consent to participate by signing a consent form on the day of testing (Appendix B4). Ethical approval was obtained from the University Ethics Committee.

4.2.2 Anxiety Measure.

The State-Trait Anxiety Inventory for Children (STAIC). The STAIC (Spielberger et al., 1973) consists of two 20-item scales, one measuring the current level of anxiety (state) and the other measuring the typical level of anxiety (trait). The latter scale uses a 3-point (1 = almost never, 2 = sometimes, or 3 = often) Likert-type scale, where higher scores indicate higher levels of anxiety. It is assumed to be unidimensional and as such a single global score can be found by summing the scores on all items (maximum score = 60). Internal consistency for the STAIC has been shown to be good, with Cronbach's alpha of .91 reported (Muris, Merckelbach, Ollendick, King, & Bogie, 2002), and .85 in the current sample.

4.2.3 Working memory tasks.

The Automated Working Memory Assessment (AWMA). The AWMA (Alloway, 2007) battery is comprised of 12 tests and is designed to tap the three components of working memory: the central executive, the phonological loop, and the visuospatial sketchpad (Baddeley & Hitch, (1974). It has been found by Alloway, Gathercole & Pickering (2006) to have acceptable test-retest reliability (four weeks apart) with correlations ranging from r = .64 (non-word recall) to r = .84 (digit recall). The backwards digit recall test was used from this battery to tap verbal working memory. Here children are verbally presented with sequences of digits, and are asked to repeat them in reverse order. The first block of trials contains two digits, and one digit is added over successive trials. The test stops after the sixth block, or until the child makes three errors on a given level which invokes the stop rule and the test automatically finishes. The number of lists correctly recalled is scored with the untested lists also adding to the score (minimum 0, maximum 36).

The Cambridge Neuropsychological Test Automated Battery (CANTAB). The CANTAB (2004) uses non-verbal tasks to measure a range of executive functions. Scoring on the tasks is automated by the software. The neural correlates of the CANTAB tasks have been studied and validated in neuroimaging studies with adults (Baker et al., 1996; Sahakian & Owen, 1992). More recently, the validation of the CANTAB for use with children has been established (Luciana, 2003). The spatial span task from the CANTAB was used to measure spatial working memory. This task is a computerised version of the Corsi blocks tapping test. Children are asked to follow sequences of squares that light up on the screen (minimum 2, maximum 9) and then copy the sequence after the computer has finished. The test stops after 3 incorrect attempts at a given sequence level.

4.2.4 Attention task.

The Cambridge Neuropsychological Test Automated Battery (CANTAB). The rapid visual information processing test from the CANTAB attention battery was used to assess attention. The RVIP is a continuous performance task testing sustained attention. It has also been shown that this task also requires a small amount of working memory for its successful execution (Coull, Frith, Frackowiak, & Grasby, 1996). Digits are presented in a pseudo-random order at the rate of 100 per minute. The 357 mode for 7-14 year olds was used in the present study. Participants are required to detect a sequence of digits (3-5-7) and to indicate their response by pressing a response button. Initially, the computer prompts the subject when a sequence appears by highlighting the numbers in colour and underlines them. The computer gives feedback when the pad is pressed. As the practice trial progresses, these cues are gradually phased out, and in the assessment proper, no cues or feedback are given. This task gives a number of dependent measures including hits, misses, false alarms, correct rejections, probability of hits and false alarms and mean latency. The total hits measure was used in this study which refers to the number of times the target sequence is correctly responded to.

4.2.5 Academic Performance.

The Cognitive Abilities Test (CAT). The CAT (Lohman et al., 2003) is the most widely used school assessment of reasoning ability in the UK (Strand, 2002). CAT scores are indicators of performance, predicting future national curriculum test scores. This assessment is the same as used in Chapter Three.

National curriculum Standard Assessment Tests (SATs). The national curriculum tests are indicators of academic competence that are taken in all schools in England. The tests use methods and materials developed and validated by the qualifications and curriculum authority. At the end of key stage 2 (from 7 to 11 years) pupils take standardised tests in maths, English, and science. This assessment was the same as used in Chapter Three.

4.3 Procedure.

Participants were tested individually in a quiet room at the school. The study was briefly explained to the participants and they were asked to complete the consent form. The trait form of the STAIC was completed first and then the working memory and attention tasks, which were presented on a laptop computer. The order of the tasks was counterbalanced. The state form of the STAIC was completed after the computerised tasks. Results of the CAT and SATs tests that had already been administered were collected from each school.

4.4 Data Analysis.

This study tested the hypothesis that the association between trait anxiety and academic performance was mediated by verbal working memory (see Figure 4.1). The main focus of interest was in the difference between the coefficient for the predictor on the outcome before and after controlling for the mediator (i.e. c - c' in Figure 4.1). If the relationship between predictor and criterion reduces to zero after controlling for the mediator, then perfect mediation is said to have occurred. Evidence for partial mediation is demonstrated when the relationship is significantly reduced, but not to zero. Recent research has shown that the classical method of testing mediation (Baron & Kenny, 1986; Judd & Kenny, 1981) is limited because it does not provide a direct hypothesis test for mediation and it has low statistical power (Dearing & Hamilton, 2006). MacKinnon, Lockwood, Hoffman, West and Sheets (2002) showed that the Baron and Kenny approach can have power as low as 10% to detect small effects, even with samples as large as N = 1000.
A similar argument has been made relating to the requirement of testing paths a and b in Figure 4.1 (Preacher & Hayes, 2004).

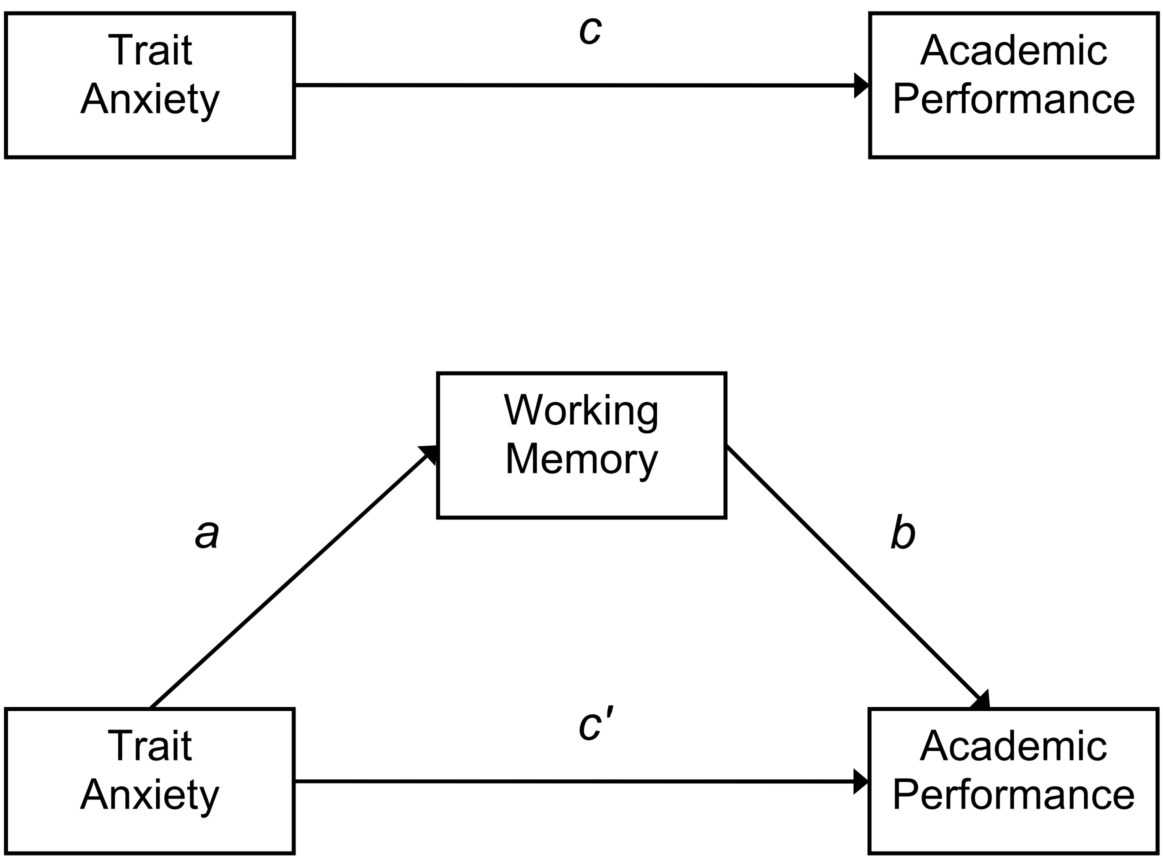


Figure 4.1 The hypothesised mediation model, where the association between trait anxiety and academic performance is mediated by working memory. c represents the association between predictor and outcome before controlling for the mediator. c′ represents the association between predictor and outcome after controlling for the mediator. c-c′ represents the size of the mediation effect. ab is equivalent to c-c′ (Mackinnon et al., 1995).

Alternative methods (Mackinnon et al., 2002) involve finding the product of coefficients (*a* and *b* in Figure 4.1). This process has been shown to be equivalent to the difference between the coefficient for the predictor on the outcome before and after controlling for the mediator (*c* - *c′* in Figure 4.1) (MacKinnon, Warsi, & Dwyer, 1995). That is, *ab* is an estimation of the size of the mediation effect. Estimating whether this effect is non-zero (i.e. there is significant mediation) has traditionally been tested using the method outlined by Sobel (1982; 1986) which involves calculating confidence intervals based on a normal distribution. The Sobel test is recommended by Baron and Kenny as a final step in testing mediation. However, given that with small sample sizes (i.e. < 400) the product of two variables is often highly skewed (Mackinnon et al., 2002; Shrout & Bolger, 2002), using the Sobel test is likely to result in failure to detect mediation when it actually exists. The use of bootstrapping techniques to empirically estimate the distribution of *ab* and a bias-corrected confidence interval to account for the departure from normality in the product variable, has recently been recommended as a method for testing mediation (Dearing & Hamilton, 2006; Shrout & Bolger, 2002). Mackinnon, Lockwood, and Williams (2004) showed that bias-corrected confidence intervals give the most accurate estimates when assessing mediation in small sample sizes. Bootstrapping involves the generation of parameter estimates derived from new samples of the data, or resamples, by randomly sampling from the original data set multiple times. The distribution and the mean of the estimates are then calculated. Confidence intervals can also be applied to the estimates. A bias-corrected confidence interval can take into account the non-normal distribution inherent in data that result from the product of variables (and other data).

In the present study, a path analysis using the AMOS 16.0 programme was first used to calculate standard regression coefficients and bootstrapped estimates of the indirect effect, along with bias-corrected 95% confidence intervals. One thousand bootstrapped re-samples were requested to estimate the indirect effect. The resulting path analysis models were all just-identified models. These types of models exist where the number of free parameters exactly equals the number of known values, resulting in zero degrees of freedom and therefore no model fit statistics. Nevertheless, indirect effects with bias-correct 95% confidence intervals are calculable. To assess whether the mediation effects in the just-identified verbal and spatial working memory models were different from one another, indirect effects were converted into percentages and then re-analysed for significant differences. This process was achieved by estimating a standard error of the difference between percentages (Swinscow, 1997) using the formula displayed in Equation 4.1, where $P1$ and $P2$ are the verbal and spatial percentages, respectively.

$$SE\ P1 - P2 = \sqrt{\frac{P1\ (100-P1)}{N} + \frac{P2\ (100-P2)}{N}} \qquad \text{(Equation 4.1)}$$

The 95% confidence intervals were then calculated by multiplying the standard error by 1.96 and adding the product to the difference for the upper bound and subtracting the product for the lower bound.

After a detailed analysis of the individual academic performance measures, the data were reduced and summarised using two structural equation models, each with a single latent variable representing the different academic performance tests. The first model (Figure 4.2) summarised the attainment tests (maths, English and science) and the second (Figure 4.3) summarised the cognitive abilities tests (verbal, quantitative and nonverbal reasoning). These models are over-identified models, in that there are more knowns in them than free parameters. Therefore the degrees of freedom (sample moments – free parameters) are positive and model fit indices can be computed.

Model fit in the structural equation models was assessed in the same way as in Chapter Three. Several goodness of fit indices were used including χ^2 and associated *p* - value, χ^2/df, the Comparative Fit Index (CFI) and the Root Mean Square Error Approximation (RMSEA). Goodness of fit was judged with a non-significant χ^2 value. As χ^2 is affected by sample size the χ^2 ratio is also reported (χ^2/df) which will be <2 if good model fit is obtained (Tabachnick & Fidell, 2007). The CFI index will be > .95 and RMSEA <.06 for a well-fitting model (Hu & Bentler, 1999). Other authors have provided more detailed guidleines concerning the use of RMSEA. Bollen and Curran (2006) reiterated these guidelines that suggest that an RMSEA value of <.05 indicates a very good fit while those greater than .10 represent a poor fit. Values in between these two parameters suggest a moderate fit. Indirect effects were calculated in the same way as in the path analysis models using 1000 bootstrapped re-samples and bias-corrected confidence intervals with associated *p*-values.

To assess the influence of gender, a multi-group analysis was carried out using gender as the group variable. The paths of interest (the structural paths between the trait anxiety, working memory and either the attainment or cognitive abilities latent variable) were constrained to be equal across the gender groups and a chi squared difference test ($\Delta\chi^2$) test compared the constrained and global models. This comparison hypothesises that the regression coefficients in the paths are invariant across groups and compares this with the unconstrained global model, where the path is free to vary. If the $\Delta\chi^2$ is not significant then this suggests no meaningful difference between the two gender groups in the structural paths.

Nested models, where one model is a subset of the total model, were compared against the global model to test whether the mediation paths (from trait anxiety to working memory, and from working memory to the academic performance measures) were adding significantly to the global model. The paths under scrutiny were constrained to be zero and a model comparison with the global model was made using a chi square difference test ($\Delta\chi^2$). A significant $\Delta\chi^2$ value means that the model has become a poorer fit to the data without the parameter of interest (i.e. the parameter should be retained). That is, the model is a poorer fit to the data when not specifying an indirect, meditation pathway.

The global models were also tested with age controlled. Age in months was entered into the model by allowing it to independently predict either the attainment or cognitive abilities latent variable. The structural paths were re-estimated and a nested model comparison was performed constraining the age path to be equal to zero. A non-significant $\Delta\chi^2$ indicates that the model will not suffer from deleting the path. That is, age is not significantly adding to the model.

State anxiety was hypothesised to mediate any significant effects of trait anxiety in the structural equation models. Models were therefore specified with the following chain: Trait anxiety, state anxiety, working memory, academic performance (either attainment or cognitive abilities tests). Evidence of mediation would be shown by a significant indirect effect.

4.5 Results.

4.5.1 Path analysis.

Table 4.1 shows the means, standard deviations, and zero-order correlations between the study variables. This matrix shows that the attainment and cognitive abilities tests all correlated well with each other. Verbal working memory correlated positively with all the attainment and cognitive abilities tests. Attention was significantly associated with maths, English, science, quantitative reasoning, but the associations between attention and both verbal or non-verbal reasoning were not significant. The verbal and spatial working memory measures were significantly but only weakly correlated with each other. Trait anxiety was negatively associated with the academic performance tests, although this only reached significance for quantitative reasoning and maths. Trait anxiety was also negatively correlated with attention, spatial and verbal working memory; however, the association only approached significance with verbal working memory.

Table 4.1. *Means, Standard Deviations, and Zero-order Correlations Between Study Variables.*

Variable	*M (SD)*	1	2	3	4	5	6	7	8	9	10	11	12
1. Maths	63.44 (19.88)	—											
2. English	54.43 (16.03)	.75**	—										
3. Science	60.44 (11.78)	.85**	.74**	—									
4. Quantitative reasoning	101.12 (14.40)	.84**	.63**	.71**	—								
5. Verbal reasoning	102.58 (14.39)	.65**	.65**	.66**	.65**	—							
6. Nonverbal reasoning	103.24 (16.07)	.77**	.77**	.75**	.78**	.64**	—						
7. State anxiety	29.71 (3.06)	.14	.17	.05	.08	.07	.02	—					
8. Trait anxiety	34.27 (6.03)	-.28*	-.25	-.18	-.30*	-.16	- .25	.08	—				
9. Verbal working memory	12.84 (4.39)	.49**	.53**	.42**	.44**	.44**	.48**	-.01	-.27	—			
10. Spatial working memory	6.14 (1.37)	.23	.10	.13	.26	-.00	.27	.18	-.16	.29*	—		
11. Attention	21.42 (1.31)	.42**	.34*	.30*	.31*	.22	.25	.08	-.13	.22	.10	—	
12. Age in months	141.16 (3.57)	.15	.11	.13	.10	-.01	.21	-.03	-.09	.12	.20	.24	—

Note. **p* < .05; ***p* < .01. *N* = 50

Regression coefficients were calculated to assess the strength of the associations in each of the paths illustrated in Figure 4.1. The coefficients and associated *p*-values are given in Table 4.2. Trait anxiety was negatively associated with math and quantitative reasoning. Trait anxiety was also negatively associated

Table 4.2. *Regression Coefficients and Associated p-values for the Paths in the Mediation Models.*

Trait anxiety and academic performance (path c in Figure 4.1)	β	*p*-value		
Maths	-.28	.04		
English	-.25	.08		
Science	-.18	.21		
Quantitative reasoning	-.30	.04		
Verbal reasoning	-.16	.25		
Nonverbal reasoning	-.25	.07		
	verbal working memory		spatial working memory	
Working memory and academic performance (path b in Figure 4.1)	β	*p*-value	β	*p*-value
Maths	.49	<.01	.23	.09
English	.53	<.01	.10	.48
Science	.42	<.01	.13	.37
Quantitative reasoning	.44	<.01	.26	.06
Verbal reasoning	.44	<.01	-.001	.99
Nonverbal reasoning	.48	<.01	.27	.05
Trait anxiety and working memory (path a in Figure 4.1)	β	*p*-value		
Verbal working memory	-.27	.05		
Spatial working memory	-.16	.27		

with English, science, verbal reasoning, and nonverbal reasoning. These associations were, however, non-significant.

Verbal working memory was positively associated with all six academic performance measures. Conversely, spatial working memory was not related to maths English, science, verbal reasoning and quantitative reasoning, but was marginally associafted with nonverbal reasoning. Trait anxiety was marginally associated with verbal working memory, but not with spatial working memory.

Estimates of the indirect effect (ab in Figure 4.1) were tested for all academic tests, whether the association between predictor and outcome (*a* in Figure 4.1) was statistically significant or not to avoid committing a type II error (see Shrout & Bolger, 2002 for the rationale behind testing mediation in the absence of a main effect). The hypothesised mediation model (see Figure 4.1) is a just identified model and results in 0 degrees of freedom. Therefore no goodness of fit indices, such as chi square, or RMSEA were calculated. Significant indirect effects via verbal working memory were found between trait anxiety and math, quantitative reasoning and nonverbal reasoning. Standardised coefficients and bias-corrected confidence intervals are shown for the indirect effects on the six academic tests in Table 4.3.

Table 4.3 *Estimation of the Mediated (ab) Association Between Trait Anxiety and Academic Performance, Via Verbal Working Memory.*

Measure	Standardised indirect effect (β)	*SE* of β	Bias-corrected 95% confidence interval	*p*-value
Maths	-.12	.08	(-.34, -.00)	.05
English	-.13	.08	(-.31, .02)	.08
Science	-.11	.08	(-.33, .00)	.05
Quantitative reasoning	-.10	.07	(-.33, -.01)	.03
Verbal reasoning	-.11	.07	(-.29, .00)	.05
Nonverbal reasoning	-.12	.09	(-.37, -.00)	.04

Note. The standardised indirect effect represents the amount of the association between trait anxiety and each of the six academic performance measures that is accounted for by working memory. That is, it is a measure of mediation. $N = 50$.

Inspection of the confidence intervals in Table 4.3 highlighted that for maths, quantitative reasoning and nonverbal reasoning, the standardised indirect paths were significant. For the remaining academic performance measures, zero was barely contained within each confidence interval, and a large part of the estimate was in the negative region. The size of the mediated effect was similar for all academic tests giving an average standardised coefficient of β = -.12. The average standardised coefficient for the unmediated path between trait anxiety and academic performance (*a* in Figure 4.1) across the six tests was β = -.24. These data suggest that verbal working memory partially mediates the relationship between trait anxiety and academic performance and this mediator explains approximately 50% of the relationship. Even though spatial working memory was weakly associated with the other measures, indirect effects were nevertheless explored to guard against type II error and to compare the results with verbal working memory. No indirect effects for spatial working memory were found (see Table 4.4).

Table 4.4. *Estimation of the Mediated (ab) Association Between Trait Anxiety and Academic Performance, Via Spatial Working Memory.*

Measure	Standardised indirect effect (β)	*SE* of β	Bias-corrected 95% confidence interval	*p*-value
Maths	-.03	.04	(-.17, .01)	.15
English	-.01	.03	(-.12, .02)	.39
Science	-.02	.04	(-.15, .03)	.36
Quantitative reasoning	-.03	.04	(-.15, .01)	.13
Verbal reasoning	.00	.03	(-.04, .10)	.64
Nonverbal reasoning	-.04	.04	(-.19, .01)	.16

Note. The standardised indirect effect represents the amount of the association between trait anxiety and each of the six academic performance measures that is accounted for by working memory. That is, it is a measure of mediation. *N* = 50.

To assess the differences between the indirect effects for verbal and spatial working memory, indirect effects were converted into percentages to indicate the extent to which each mediator explains the initial relationship between trait anxiety and academic performance. In addition, standard errors and 95% confidence intervals were calculated to assess whether the difference between the verbal and spatial indirect effects was significant. Table 4.5 shows that verbal working memory explained an average of 51% of the initial relationship between trait anxiety and academic performance, whereas spatial working memory accounted for an average of 8.6%. The differences between the percentages for verbal and spatial working memory were significant for all six academic performance measures, indicating that verbal working memory was a significantly stronger mediator than spatial working memory.

Table 4.5. *Differences Between the Amount of the Initial Relationship Between Trait Anxiety and the Academic Performance Measures Accounted for by Verbal and Spatial Working Memory.*

Measure	Indirect effect of verbal working memory (%)	Indirect effect of spatial working memory (%)	Difference	*SE* of Difference	95% Confidence interval
Maths	42.86	10.71	32.15	8.25	(15.98, 48.32)
English	52.00	4.00	48.00	8.31	(31.71, 64.29)
Science	61.11	11.11	50.00	8.20	(33.93, 66.07)
Quantitative reasoning	33.33	10.00	23.33	7.90	(7.85, 31.23)
Verbal reasoning	68.75	0.00	68.75	6.56	(55.89, 81.61)
Nonverbal reasoning	48.00	16.00	32.00	8.71	(14.93, 49.07)

Note. The 95% confidence intervals do not contain zero and so the differences between the verbal and spatial working memory indirect effects are significant for all measures. N = 50.

4.5.2 Verbal structural equation models.

The attainment model (Figure 4.2) provided an excellent fit to the data (χ^2 = 4.95, df = 4, χ^2/df = 1.24, p = .29, CFI =.99, RMSEA = .07). Consistent with the hypothesis, there was a significant indirect effect of trait anxiety on attainment through verbal working memory (β = -.13, p < .05). Confirming the importance of the meditational paths, a nested model was specified which constrained the indirect paths (from trait anxiety to verbal working memory and from verbal working memory to attainment) to equal zero. This constrained model was directly compared with the global, unconstrained model. The constrained model was a significantly poorer fit to the data ($\Delta\chi^2$ = 15.84, Δdf = 2, p < .001) which suggests that the mediation paths were adding significantly to the model, over and above the contribution made by the direct effect of trait anxiety on attainment.

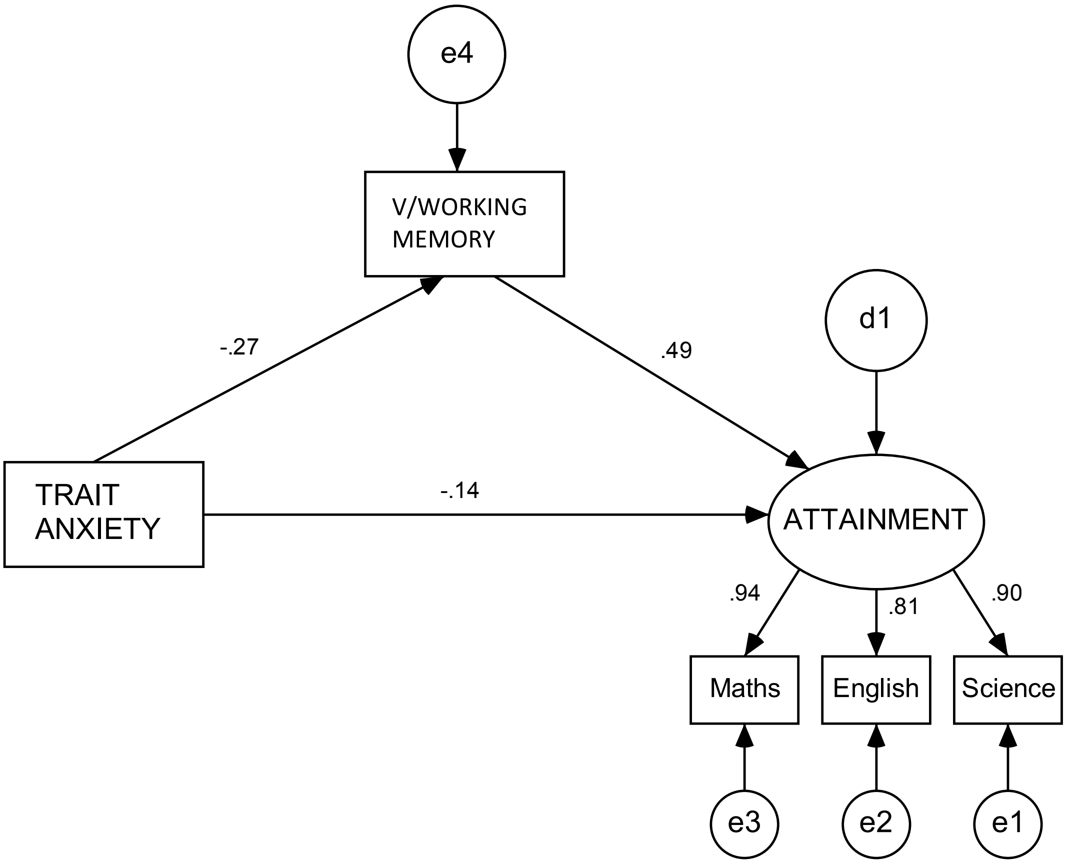


FIGURE 4.2. A structural equation model diagram showing the mediated relationship between trait anxiety and the attainment tests. Trait anxiety was measured by the self-report measure (the STAIC). Maths, English and Science measure SAT KS2 results. V/WORKING MEMORY indicates verbal working memory which was measured by a backwards digit span test. The path values are standardised regression weights and the

The effect of age was checked for by introducing an age-in-months variable into the model. This variable was allowed to independently predict the attainment latent variable and the indirect effect was then re-calculated. This alternative model provided a good fit to the data (χ^2 = 5.91, *df* = 8, χ^2 /*df* = 0.74, *p* = .66, CFI = 1.00, RMSEA = .00) which was not dissimilar to the original global model (Figure 4.2). In this model the indirect effect remained (β = -.13, *p* = .05). The path from age-in-months was positive but not significant (β = .08, *p* = .48). A nested model with the age-in-months path constrained to equal zero was compared against the global model and found not to be significantly different ($\Delta\chi^2$ = .41, Δ*df* = 1, *p* = .52). Age was therefore deemed not to be important in the model and was not considered further.

In a similar fashion to the age analysis, the attention variable was added to the global model and allowed to independently predict the attainment latent variable. The fit to the data of this model was reasonable (χ^2 = 9.49, *df* = 8, χ^2/df = 1.19, *p* = .30, CFI = .99, RMSEA = .06) and the indirect effect remained significant (β = -.12, *p* < .05). There was a positive path from attention to the attainment latent variable, although this was not significant (β = .31, *p* = .08). A nested model with the attention path constrained to equal zero was a significantly worse fit to the data ($\Delta\chi^2$ = 5.67, Δ*df* = 1, *p* = .02) suggesting that attention was important in the model and should be considered further. The single attention path in this model was from attention to the attainment latent variable. Therefore, it can be concluded that the reason for retaining attention in the model was that it was predicting attainment and not necessarily because it was associated with trait anxiety. To address this issue further, a mediation model was specified that was identical to the working memory model illustrated in Figure 4.2, with the exception that working memory was replaced with attention. This attention meditation model was a good fit to the data (χ^2 = 3.92, *df* = 4, χ^2/df = .98, *p* = .42, CFI = 1.00, RMSEA = .00). However, there was no significant indirect effect (β = -.05, *p* = .23) in the attention model. This suggests that attention is potentially important in predicting attainment but not important in explaining the relationship between trait anxiety and attainment.

A model specifying state anxiety as mediating the effects of trait anxiety through working memory to attainment was not a good fit to the data (χ^2 = 13.14, *df* = 8, χ^2/df = 1.64, *p* = .10, CFI = .96, RMSEA = .12) and revealed a non-significant indirect effect that was close to zero (β = -.001, *p* = .82). There was therefore no evidence to support the notion that state anxiety was acting as a mediator.

An additional multi-group analysis tested the effect of gender on the three structural paths in the global model. These paths were constrained to be equal across the gender groups and this model was compared to the global model. The chi squared difference test, comparing the two models, was not significant ($\Delta\chi^2$ = 2.25, Δ*df* = 3, *p* = .52), which suggested that there were no meaningful differences between genders.

In order to ascertain the true extent of the indirect effect, using the statistically significant standardised regression weight alone is insufficient. In addition we must ask how much of the initial association between trait anxiety and attainment is explained by the mediator. In the attainment model, the total effect of trait anxiety on attainment was negative although non-significant (β = -.27, p = .06). The standardised indirect effect was β = -.13, which amounts to 48% of the total effect. This result mirrors the path analysis results which suggested that the mediated effect of verbal working memory amounted to approximately 50%.

The cognitive abilities test model (Figure 4.3) was also an excellent fit to the data (χ^2 = 1.64, df = 4, χ^2/df = 0.41, p = .80, CFI = 1.00, RMSEA = .00). There was a significant indirect effect from trait anxiety to cognitive abilities via verbal working memory (β = -.13, p < .05), and a nested model constraining the mediation paths to equal zero was a significantly poorer fit to the data when compared to the global model ($\Delta\chi^2$ = 15.29, Δdf = 2, p < .01). When age-in-months was added to the model there was still good fit to the data (χ^2 = 5.83, df = 8, χ^2/df = 0.73, p = .67, CFI = 1.00, RMSEA = .00). The path from age-in-months to the cognitive abilities latent variable was positive but not significant (β = .08, p = .63). The contribution that age made to the model was formally assessed with a chi square difference test. A model constraining the age path to equal zero was found not to be significantly different from the global model ($\Delta\chi^2$ = .39, Δdf = 1, p < .53) and the indirect effect remained significant (β = -.13, p < .05). Therefore age was not considered further.

Attention was added to the global model in the same way as age. The resulting model was a good fit to the data (χ^2 = 4.83, df = 8, χ^2/df = 0.60, p = .775, CFI = 1.00, RMSEA = .00) and the indirect effect remained significant (β = -.12, p < .05). The attention path regression weight was positive but not significant (β = .20, p = .18). A model constraining the path from attention to the cognitive abilities latent variable to equal zero, was compared with the global model and no significant difference was found ($\Delta\chi^2$ = 2.31, Δdf = 1, p < .13). Attention was not considered further.

A model specifying state anxiety as mediating the effects of trait anxiety through working memory to cognitive abilities was a good fit to the data (χ^2 = 6.19, *df* = 8, χ^2 /*df* = 0.77, *p* = .63, CFI = 1.00, RMSEA = .00) but did not include a significant indirect effect (β = -.001, *p* = .82). There was therefore no evidence to support the notion that state anxiety was acting as a mediator in the cognitive abilities tests model.

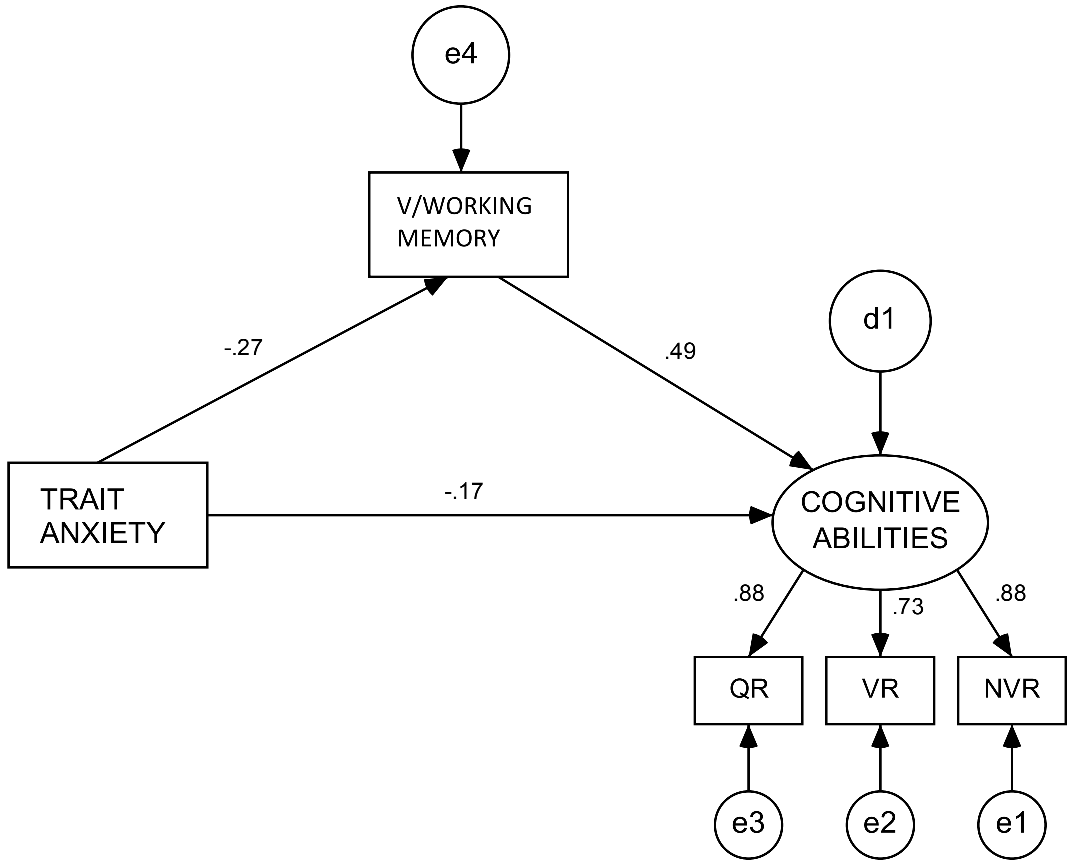


FIGURE 4.3. A structural equation model diagram showing the mediated relationship between trait anxiety and the cognitive abilities tests VR = verbal reasoning, QR = quantitative reasoning and NVR = nonverbal reasoning all measured using the CAT. Trait anxiety was measured by the self-report measure (the STAIC). V/WORKING MEMORY indicates verbal working memory which was measured by a backwards digit span test. The path values are standardised regression weights and the indicator paths represent factor loadings.

A multi-group analysis assessing the effect of gender on the structural paths found no significant difference between the constrained and unconstrained models

($\Delta\chi^2$ = 1.98, Δdf = 3, p = .58). The total effect of trait anxiety on cognitive abilities was negative although non-significant (β = -.30, p = .07). The standardised indirect effect was β = -.13, which amounts to 43% of the total effect.

4.5.3 Spatial structural equation models.

The spatial working memory-attainment model provided a good fit to the data (χ^2 = 3.92, df = 4, χ^2/df = 0.98, p = .42, CFI = 1.00, RMSEA = .00), however there were no significant indirect effects (β = -.03, p = .19). Formally testing the hypothesis that the mediation paths were not significantly adding to the model, a nested model, with the meditational paths constrained to equal zero, was compared against the global model and found not to be significant ($\Delta\chi^2$ = 2.40, Δdf = 2, p = .30).

The spatial working memory-cognitive abilities model also provided a moderate fit to the data (χ^2 = 5.21, df = 4, χ^2/df = 1.30, p = .27, CFI = .99, RMSEA = .08), but again there was no significant indirect effect of trait anxiety on the academic performance measures through spatial working memory (β = -.03, p = .14). A nested model, constraining the mediation paths to equal zero confirmed the absence of any mediation ($\Delta\chi^2$ = 3.44, Δdf = 2, p = .18) in this model.

4.6 Chapter summary.

The path analysis in the present study found that the association between trait anxiety and academic performance was partially mediated by verbal working memory on three tests (maths, nonverbal reasoning and quantitative reasoning). There was also a suggestion in this analysis of similar partial mediation, although not statistically significant, on the remaining three tests (English, science, verbal reasoning).

The structural equation models provided further evidence to support the plausibility of the mediation model. Two separate good-fitting models showed that verbal working memory mediated the relationship between anxiety and academic performance when measuring attainment (maths, English and science) and cognitive ability (verbal, quantitative and nonverbal reasoning).

Several alternative models were also compared to the hypothesised model. First, a constrained model hypothesising that the mediation paths were unimportant was disconfirmed, thus bolstering the results from the paths analysis. A model controlling for the effects of age on the endogenous variable (attainment or cognitive abilities) was found not to alter the verbal working memory mediation effects, ruling out age as an alternative explanation for the effects. However, it should be noted that the age range was very narrow in this study. It is possible, although unlikely, that anxiety has a different or no effect with younger or older children/adults. A muliti-group analysis tested the hypothesis that the mediation effect would be different for boys and girls. No differences were found. A model controlling for the effect of attention was also specified and although adding attention to the model improved its fit to the data, it was found that attention was beneficial for academic performance (significant for attainment, but not cognitive abilities) rather than related to anxiety. An alternative model hypothesised that attention would mediate the relationship between trait anxiety and academic performance in the same way that working memory had. There was no evidence for attention acting as a mediator in this context.

Overall, the results of the present study show that the indirect effect of trait anxiety on academic performance, through verbal working memory, is likely to amount to at least half that of the simple association between trait anxiety and academic performance. Contrary to an assumption of PET, there was no evidence to suggest that state anxiety mediated the effects of trait anxiety on performance. These results suggest that the personality trait of anxiety is more important than the reported state of anxiety at any given time. However, it should be noted that the order of the testing schedule raises a potential problem with any interpretation of effects of state anxiety that may have arisen. The state anxiety measure was administered after the performance measures and so given an association between state anxiety and performance (which did not appear in this study) the most likely interpretation of such data would have been that poor performance caused anxiety.

Using cross-sectional data it highlighted that one important mechanism through which anxiety affects school performance is working memory (see also

Aronen et al., 2005). Given the cross-sectional nature of the present study, however, it was not possible to draw any conclusions regarding causal relationships between anxiety and academic performance. Longitudinal studies are needed to fully understand the relationship between anxiety and academic performance. Chapter Seven tests the relationship between emotion and academic performance over time in order to tease out the causal relations between variables.

In conclusion, the present study specifically tested the hypothesis, influenced by the PET, that the relationship between trait anxiety and academic performance could be mediated by working memory. Consistent with the hypothesis, the results showed that verbal working memory did mediate the trait anxiety – academic performance relationship. This mediation occurred with verbal but not spatial working memory and accounted for approximately half of the initial association.

The verbal working memory mediation effect was shown to be robust, remaining statistically significant whilst controlling for age and gender and attention. In addition, an alternative model hypothesising that attention would mediate the trait anxiety – academic performance association did not produce significant mediation effects. The present findings are broadly consistent with PET and demonstrate that anxiety was more related to working memory processes that tap the phonological loop and the central executive, rather than the visuospatial sketchpad (Eysenck et al., 2007).

CHAPTER FIVE: EMOTION, WORKING MEMORY AND HIGH STRESS REACTIVITY.

5.1 Introduction.

The majority of research into emotion and academic underachievement has focused on anxiety. For example, investigating test anxiety in university undergraduates, Keogh et al. (2004) found that worry was negatively correlated with written examinations and anxiety, more generally, was negatively correlated with coursework in psychology undergraduates. Chapter One highlighted a meta-analysis by Seipp (1991) that showed the correlations between anxiety and academic performance tend to vary in size and direction. That is, although the weighted average was r = -.21, effect sizes ranged from extreme negative (r = -.66) to extreme positive (r = .37). This heterogeneity may simply represent sample specific nature of participants, measures of anxiety of academic performance. However, this could also indicate the presence of non-trivial moderating factors. Chapter Two showed research that suggests that one of these moderating factors could be stress reactivity.

Although the focus in research has tended to be on anxiety, depression has also been found to be associated with an increased risk of academic failure for adolescents and young adults (Fröjd et al., 2008; Glied & Pine, 2002). For example, a study by Andrews and Wilding (2004) found that mid-course depression in university students predicted a decrease in exam performance. However, this relation may not indicate a causal role for depression in lowered academic performance as both depression measures and academic performance measures in this study may have been negatively affected by earlier academic failure.

The results in Chapter Four and presented elsewhere (Owens, Stevenson, Norgate, & Hadwin, 2008) showed that one mechanism that may be important in explaining the negative relationship between high emotion levels and academic performance is working memory. That is, working memory may partially mediate the relationship between emotion and academic performance. Chapter Two highlighted that this work stemmed from two related interference theories; processing efficiency theory (PET; Eysenck & Calvo, 1992; Eysenck et al., 2007) and the resource allocation model (RAM; Ellis, Moore, Varner, Ottaway, & Becker, 1997). Both theories predict that high levels of emotion (anxiety and depression) can interfere with cognitive processes, draining resources and ultimately lead to significant decrements in test performance. In PET this interference is proposed to lead predominantly to problems of efficiency on working memory tasks, but effectiveness can also be affected. While PET focuses on anxious affect, RAM considers depressed mood.

Chapter Four showed that verbal working memory plays an important role in understanding the relationship between negative affect (trait anxiety) and academic performance. It has also been noted that the poor performance typically found for high trait- and/or test-anxious individuals is especially pronounced under stressful conditions (Eysenck & Calvo, 1992). For example, Deffenbacher (1978) found an anxiety x stress interaction on an anagram solving task such that the high anxious solved fewer anagrams only in the high stress condition. It was also found that the high anxious in the high stress condition reported more interference from 'emotionality', defined as attention to physiological cues such as upset stomach, perspiring and a racing heart. Worry in this context can be defined as: "the cognitive elements of the anxiety experience, such as negative expectations and cognitive concerns about oneself, the situation at hand, and potential consequences". While emotionality refers to, "one's *perception* of the physiological-affective elements of the anxiety experience, that is, indications of autonomic arousal and unpleasant feeling states such as nervousness and tension." (Morris et al., 1981, p.541, italics added).

In terms of linear associations between emotional factors and performance, Morris and Liebert (1970) found that emotionality was less predictive than worry of grade scores for psychology undergraduates. In their study II they found the overall correlation between anxiety and performance was r = -.33. However, with worry partialled out the correlation dropped to r = -.08. Conversely with emotionality partialled out the correlation was less attenuated (r = -.23). Indeed, a review by Morris (Morris et al., 1981) concluded that the inverse relationship between anxiety and various performance variables was largely explained by worry and not emotionality. It should be remembered here, that emotionality is the perception of bodily symptoms and not necessarily physiological arousal per se.

However as Eysenck and Calvo (1992, p. 413) point out: “ it has been extremely difficult to find any psychophysiological differences between groups high and low in trait anxiety or in the closely related personality dimension of neuroticism.” For example, Holroyd, Westbrook, Wolf and Badhorn (1978) found that although high versus low anxious individuals reported more anxious arousal in response to a testing situation using anagrams and the Stroop test, the two groups did not differ in their physiological response (electro-dermal activity and heart rate variability). It therefore seems likely that the stress reactivity of an individual to an evaluative testing situation is linearly related to test performance to a lesser extent than cognitive variables such as worry. It is more likely that stress reactivity will act as a moderating factor, such that any detrimental effects of negative affect on performance will be seen most clearly when stress is high.

More recently, it has also begun to emerge that a sustained stress response associated with negative affect can adversely affect cognition via the action of the hypothalamic-pituitary-axis (HPA) (Pine, 1999; Roozendaal, 2000). The end result of which in humans is elevated cortisol. Cortisol in children has been shown to follow the typical diurnal circadian rhythm seen in adults where the secretion of cortisol is highest in the morning and then reduces rapidly and tails off towards the evening. For example, Kiess et al. (1995) measured salivary cortisol levels at three points in a single day (0800, 1300 and 1800). They found the diurnal rhythm in several age ranges including 1 - 5 year-olds (9.8, 3.8 and 2.6, respectively), 5 - 8 year-olds (10.9, 4.9 and 2.7) and 8 - 18 year-olds (10.9, 5.0 and 3.1). This pattern was not present in children <1 year old (19.8, 16.7 and 17.5). Another study showed that in a sample of children aged 2.2 to 18.5 years there were no age-related differences in mean cortisol serum levels and no association between pubertal stage and diurnal rhythm of cortisol (Knutsson et al., 1997).

The hypersecretion of cortisol is one of the more consistent biomarkers of depression (Foreman & Goodyer, 1988; Holsboer, 2000). A recent study, for example, found elevated cortisol levels in individuals with a family history of depression (Mannie, Harmer, & Cowen, 2007). For anxiety, the picture is less clear. For example, post-traumatic stress disorder studies have tended to find evidence for lowered cortisol levels (e.g. Bonne et al., 2003), while Greaves-Lord et al. (2007) found that it was only children with persistent anxiety problems who displayed higher morning cortisol levels and awakening response. Mixed results were found in a recent study by Kallen et al. (2008) assessing clinically anxious children. The results showed that girls with lower anxiety evinced a higher morning cortisol rise, harm avoidance predicted lower cortisol concentrations after awakening, separation anxiety scores predicted higher noon cortisol levels and physical anxiety scores predicted lower noon cortisol levels. However, Granger, Weisz and Kauneckis (1994) found that in a stressful situation (a parent-child discussion conflict task) social anxiety was related to higher subsequent salivary cortisol levels in adolescents with emotional problems.

Inhalation of carbon dioxide (CO_2) has been shown to produce panic attacks in panic disorder patients (Papp, Klein, & Gorman, 1993). Using this paradigm, Coplan et al. (2002) administered 5% CO_2 to children/adolescents and found that those individuals susceptible to the CO_2 inhalation in terms of developing a panic attack also showed elevations in salivary cortisol.

Although the research examining the linear relation between anxiety and cortisol has been equivocal, there is now a growing body of research showing that both acute and chronic effects of cortisol can have a deleterious impact on working memory functioning (Al'absi, Hugdahl, & Lovallo, 2002; Domes, Rothfischer, Reichwald, & Hautzinger, 2005; Lupien et al., 1999; McEwen & Sapolsky, 1995; Schoofs, Preuss, & Wolf, 2008). There have to date, however, been few studies looking specifically at emotion and working memory or learning in children. One study, by Quas, Bauer and Boyce (2004) measured stress reactivity in 4 to 6 year old children and found that cortisol reactivity was related to poorer episodic memory. After a two week period, cortisol reactivity was associated with fewer correct scores more “don’t know” answers on a factual verbal memory test for prior week one events. Lupien et al. (2001) found that low social economic status (SES) children had higher mean morning cortisol levels than their high SES counterparts, although this did not translate into differences in memory performance.

One advantage of using cortisol as a marker of stress reactivity is that it overcomes the known problem of an overreliance on self-report (Nisbett & Wilson, 1977). It may also be that self-report measures of the current state of emotion may prove insensitive to the magnitude of affect experienced during a cognitive task. Physiological measures may provide a better measure of online affect (Shackman et al., 2006).

In the present study it was expected that individual differences in stress reactivity to a testing situation, as measured by cortisol, would moderate the relationships between emotion, working memory and academic performance such that an inverse link between emotion and working memory and emotion and academic performance would only be apparent in the high stress reactivity group.

More specifically, the aim of the present chapter was threefold. First, it extended work from Chapter Three to consider the relationship between anxiety and depression with academic performance. Secondly, it tested whether an underlying general source of disruption to working memory and academic performance was associated with both anxious and depressive feelings in schoolchildren. This is a mediation hypothesis in that emotion is thought to negatively affect academic performance through working memory. Finally, the study investigated whether the negative effects of emotion on working memory and academic performance would be qualified by stress reactivity. That is, the direct emotion – academic performance link and mediation via working memory was expected to be clearest for those individuals who show stress reactivity to a test situation. Thus, a mediation effect of emotion on academic performance via working memory only in the high stress group would be equivalent to a moderated mediation effect.

A final issue to be addressed involved the complexity of the working memory measures. In Chapter Four, it was found that the mediating role of working memory was clearest for verbal rather than spatial tasks. However, a difficulty with this interpretation was that the verbal working memory task was more complex than the spatial. The impaired performance of high anxious individuals is found more consistently when the task is difficult than when it is easy, and this difficulty is thought to reflect greater demand on the central executive component of working memory (see Eysenck & Calvo, 1992). The current chapter therefore controlled for this potential confound by utilising verbal and spatial tasks that are more clearly matched in terms of complexity.

5.2. Method.

5.2.1 Participants.

Thirty one pupils (15 boys, 16 girls) were recruited from a single secondary schools in Hampshire, UK. Children were aged between 12 to 13 years (mean = 12.4 years, SD = 0.5).

5.2.2 Self-report Measures of Emotion.

The self-report measures of emotion were the same as those used in Chapter Three and included the state-trait anxiety inventory for children (STAIC), the revised child anxiety and depression scale (RCADS) and the children's test anxiety scale (CTAS).

5.2.3 Working Memory Tasks.

The Automated Working Memory Assessment (AWMA). The AWMA (Alloway, 2007) is comprised of 12 tests and is designed to tap into the three components of working memory, as proposed by Baddeley and Hitch (1974); the central executive, the phonological loop, and the visuospatial sketchpad.

The forwards and backwards digit recall, listening recall and spatial span tests were used from this battery to tap a range a verbal and spatial working memory processes. For the digit span tests, children are verbally presented with sequences of digits, and are asked to repeat them in the same/reverse order. The first block of trials on the forward digit span contains one digit (two digits for backwards digit span), and one digit is added over successive trials. The test stops after the ninth trial (sixth trial for backwards digit span), or until the child makes enough errors (three) on a given level to invoke the stop rule. At this point the test stops automatically.

The number of lists correctly recalled is scored. The range is 0 to 54 (0 to 36 for backwards digit span).

For the listening recall test, children hear a series of individual sentences and judges if each is true or false. At the end of each trial the child attempts to recall the last word in each sentence in the correct order. Two dependent variables were used for the listening recall task; recall and precision. Scores range from 0 to 36 for the recall, and 0 to 126 for precision (true or false judgement).

In the spatial span test the child views two shapes where the shape on the right has a red dot on it. The aim is to identify whether the shapes are the same or opposite to each other. The shapes may be rotated. At the end of the trial the child must recall the position of the red dot(s). Two dependent variables were used for the spatial span task; span and precision. The scores range from 0 to 42 for identifying whether the shapes were the same or opposite (precision) and 0 to 168 for recalling the position of the red dots (span).

These tests have been found to have acceptable test-retest reliability (four weeks apart) with correlations ranging from r = .64 (backwards digit span), r = .81 (listening recall), .82 (spatial span) to r = .84 (forward digit span) (Alloway, Gathercole, & Pickering, 2006).

The Cambridge neuropsychological test automated battery (CANTAB). This instrument is the same as used in Chapter Four which uses non-verbal tasks to measure a range of executive functions that include psychomotor speed, fine motor accuracy, spatial memory span, spatial working memory, set-shifting ability, planning and inhibition, and pattern and spatial recognition memory. Scoring on the tasks is automated by the software.

The spatial span forwards and reverse tasks were used from the CANTAB in the present study. This test is a computerised version of the Corsi blocks tapping test (Milner, 1971). Children are asked to follow sequences of squares that light up on the screen (minimum two, maximum nine) and then copy the sequence in either the same or the reverse sequence depending on the condition, after the computer has finished. The test stops after three incorrect attempts at a given sequence level. The total span length was used as the dependent variable (two to nine). The forward and backwards tests were used in the present study.

The verbal and spatial tests were chosen in order to be approximately equal in complexity. For example, the AWMA spatial span task is an equivalent of the listening recall test. Forwards and backwards spatial span tests from the CANTAB were used as equivalents to the forwards and backwards digit span tests from the AWMA.

5.2.4 Academic Performance.

National curriculum - standard assessment tests (SATs). As in Chapters Three and Four, national curriculum KS2 test results were used as indicators of academic competence. At the end of KS2 (from 7 to 11 years) pupils take standardised tests in maths, English, and science.

The wide range achievement test 4 (WRAT). First published in 1946, the WRAT is an established measure of the basic academic skills necessary for learning. The current WRAT version (Wilkinson & Robertson, 2006) is comprised of four subtests including word reading, sentence comprehension, spelling and math computation. There are also parallel forms for the WRAT, a green form and a blue form. The green form was used in this analysis.

The WRAT 4 has been extensively validated by Wilkinson and Robertson (2006). Good internal consistency has been demonstrated for all subtests. The subtests on the green form were found to have good reliability as evidenced by high Cronbach's alpha values, including word reading ($\alpha = .92$), sentence comprehension ($\alpha = .90$), spelling ($\alpha = .90$) and math computation ($\alpha = .87$). Convergent reliability was demonstrated with significant correlations between the WRAT 4 subtests and relevant subtests of other achievement tests including the Wechsler Individual Achievement Test II, the Woodcock-Johnson III Tests of Achievement and the Kaufman Test of Educational Achievement: Second Edition Comprehensive and Brief Forms. The median correlations were significant between the comparison tests and word reading ($r = .71$), sentence comprehension ($r = .60$), spelling ($r = .77$) and math computation ($r = .74$).

All the subtests correlated well with each other and for 5-18 year olds the intercorrelations were as follows: Word reading and sentence comprehension (r = .72), word reading and spelling (r = .79), word reading and math computation (r = .61), sentence comprehension and spelling (r = .58), sentence comprehension and math computation (r = .56) and spelling and math computation (r = .65) (Wilkinson & Robertson, 2006).

In the present study the math computation (hereafter referred to as WRAT maths) and spelling (WRAT spelling) subtests were used to obtain a summary of academic performance along with the SATs. The maths subtest is comprised of 40 maths problems which become progressively more difficult. The participants have 15 minutes to complete as many problems as they can. The maximum score is 40 plus 15 points which are automatically awarded to children within this age range, making a total of 55 points. In the spelling test, 42 words are listed for correct spelling that increase in difficulty. The experimenter reads aloud the word, then a set sentence containing the word and then reads the word aloud for a second time. The scoring on the spelling test is similar to the maths test in that there are 15 automatic points awarded to children of this age and a further 42 points available for correct spelling. The maximum score is therefore 57.

5.2.5 Stress reactivity.

Saliva samples were collected in Sarstedt Salivette sampling devices (Sarstedt Inc., Rommelsdorf, Germany). The device uses a cotton roll that the participant is asked to chew on for approximately one minute in order to collect saliva samples. The roll is placed inside the plastic container in preparation for centrifuge and assay. Samples were then frozen to remove the effects of mucins in the sample. After thawing, the samples were centrifuged at 3000 rpm to remove debris and were analysed in duplicate using an in-house Delfia (Dissociation enhanced fluoroimmunoassay) technique. Assay results were considered acceptable if duplicate measurements of a sample were less than 15%. All assays included three levels of Quality Control material to ensure accuracy and precision within and between batches. Analysis of salivary cortisol was performed by the Endocrine Unit, at Southampton General Hospital.

The salivary cortisol was measured in nanomoles per litre (nmol/litre). That is, one billionth of a mole (6.02×10^{23}) of cortisol per litre of saliva.

5.2.6 Procedure.

Ethical consent for the study was obtained from the School of Psychology Ethics Committee, University of Southampton. Parental consent was obtained via information letters/consent slips (Appendix B5) that were sent to a random selection of child's parents/guardians. Participants were first tested in two equal groups in the library of the school. The study was briefly explained to the pupils who were then asked to complete a consent form (Appendix B6). These sessions included testing for the emotion self-report measures (STAIC, RCADS and CTAS) and the WRAT spelling and WRAT maths subtests.

On subsequent days, individuals were tested on the working memory tasks, salivary cortisol and state anxiety measures. These sessions started at approximately 11am or 1pm in order to minimise the effect of the natural diurnal cortisol rhythm. After a brief explanation of the session, the first cortisol measurement was taken. Subsequently, the working memory tasks were presented on a laptop. At the end of the session, the second cortisol measurement was taken. After a further 10 minutes, the final cortisol measurement was taken and the STAIC-S anxiety measure was administered.

The procedure was counterbalanced so that half the participants were tested in the morning and half in the afternoon. Furthermore, half of the morning and afternoon groups were male and female. The order of the working memory tasks was counterbalanced so that half the participants in the morning completed the AWMA first and half of the participants in the afternoon completed the CANTAB first. Participants were shown a debriefing statement at the end of the testing and encouraged to ask questions about the study. SATs results that had already been administered by the school were collected at the end of the study.

5.3 Data Analysis.

To test the mediation hypothesis, bootstrapping was used to calculate bias-corrected p values for the indirect effect of emotion on the academic performance measures, via working memory (spatial and verbal). One thousand bootstrapped resamples were requested by default. Model fit in the structural equation models was assessed as in previous chapters using several goodness of fit indices. To recap, these included χ^2 and associated p - value, χ^2/df, the Comparative Fit Index (CFI) and the Root Mean Square Error Approximation (RMSEA). Goodness of fit was judged with a non-significant χ^2 value. As χ^2 is affected by sample size the χ^2 ratio is also reported (χ^2/df) which will be <2 given a well-fitting model (Tabachnick & Fidell, 2007). The CFI index will be > .95 if a good model fit is obtained (Hu & Bentler, 1999). Bollen and Curran (2006) reiterated previous guidelines that suggest that an RMSEA value of <.05 indicates a very good fit while those greater than .10 represent a poor fit. Values in between these two parameters suggest a moderate fit.

In addition, a chi square difference test ($\Delta\chi^2$) assessed the change of fit when a nested model was specified that constrained the weights for the paths to and from the mediator to be zero. This provided a test of the null hypothesis that mediation by working memory would not significantly add to the model fit. A significant $\Delta\chi^2$ indicates that the inclusion of mediating paths improves the model fit.

The moderated mediation hypothesis was assessed using a multi-group analysis, where the stress reactivity measure taken immediately at the beginning of testing (cortisol A) was dichotomised to produce low and high groups. The mediation was assessed in the two groups and therefore a moderated mediation was tested. The moderation of mediation was assessed by calculating indirect effects of emotion on academic performance via working memory in the two stress reactivity groups separately. A significant indirect effect in one stress group (hypothesised to be in the high group) but not the other would indicate the presence of moderated mediation.

In assessing the main effect of emotion on academic performance, the coefficients in the single structural path in a given model were compared using a critical ratio test. This test compares parameter estimates divided by an estimate of the standard error of the difference. The resulting statistic is treated as a z score, so that values greater than 1.96 (+ or – sign) are significant at the $p < .05$ level.

Modification indices in AMOS 16.0 identify parameters that if specified would result in a minimum increase in model chi square. The modification indices were considered only when it made theoretical sense to do so.

5.4 Results.

The pattern of associations between study variables was assessed using Pearson correlation coefficients (r). The correlational results are presented in Table 5.1. The results showed that the academic performance variables were all closely associated. The intercorrelations between these measures ranged from $r = .33$ to $r = .89$ and were significant in all cases except between the WRAT spelling and maths subtests ($r = .33$).

The emotion self-report variables were positively correlated with one another (range = $r = .34$ to .71). The associations were significant in all cases except in the association between RCADS depression and STAIC-S state anxiety ($r = .34$).

The correlations between emotion self-report measures and the academic performance tests showed a mixed pattern. In this study, Bonferroni corrections have not been used to adjust for multiple testing. The issue of whether or not to adjust for multiple testing is a complex one that has been widely debated. Perneger (1998) argues that such adjustments are overly conservative and unnecessary unless testing for significant associations in the absence of pre-established hypotheses.

The RCADS depression was negatively related to WRAT maths, SATs maths and SATs science (range = $r = -.21$ to -.31). However, these correlations were not significant. There were low correlations between RCADS depression and WRAT spelling ($r = .07$) and SATs English ($r = .09$). STAIC-T trait anxiety was similarly negatively, but not significantly, related to the maths and science tests (range = $r = -.23$ to -.31). The correlations were low between trait anxiety and WRAT spelling ($r = .07$) and SATs English ($r = .07$). CTAS test anxiety was negatively but not significantly related to the maths and science tests (range = $r = -.16$ to -.25). The correlations between test anxiety and WRAT spelling and SATs English were much weaker ($r = -$

.02) and (r = -.09). STAIC-S state anxiety was very weakly associated with all academic performance tests (range = r = .01 to .15).

There was a mixed pattern of results when assessing the relationships between the emotion self-report measures and the working memory measures. RCADS depression was negatively, but not significantly related to backwards digit span, AWMA spatial span, spatial span precision and CANTAB forward and backwards spatial span (range = r = -.15 to -.31). RCADS was weakly associated with forward digit span, listening recall and listening recall precision (range = r = .01 to .07). STAIC-T trait anxiety was negatively related to backwards digit span, AWMA spatial precision and the CANTAB forwards and backwards spatial span measures (range = r = -.14 to -.38). The association between trait anxiety and spatial span precision was significant (r = -.38). Trait anxiety was weakly associated with forward digit span, listening recall, listening recall precision and AWMA spatial span (range = r = -.08 to .09). CTAS test anxiety was negatively related to backwards digit span, AWMA spatial span, spatial span precision and CANTAB backwards spatial span (range = r = -.10 to -.41). The association between test anxiety and spatial span precision was significant (r = -.41). Test anxiety was weakly associated with forward digit span, listening recall, listening recall precision and CANTAB forward spatial span (range = r = .03 to -.07).

Table 5.1. *Zero-order Correlations Between Study Variables.*

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. WRAT Maths	—																				
2. WRAT Spelling	.33	—																			
3. SATs Maths	.84**	.37*	—																		
4. SATs English	.64**	.60**	.73**	—																	
5. SATs Science	.78**	.47**	.89**	.71**	—																
6. Forward digit span[1]	.36*	.55**	.41*	.51**	.43*	—															
7. Backward digit span[1]	.29	.27	.43*	.34	.35	.21	—														
8. Listening recall[1]	.31	.03	.27	.24	.20	.11	.48**	—													
9. LR precision[1]	.28	-.04	.21	.22	.15	.09	.42*	.98**	—												
10. Spatial span[1]	.48**	-.10	.43*	.32	.34	.11	-.04	.36*	.34	—											
11. SP precision[1]	.62**	.05	.60**	.40*	.46**	.04	.29	.20	.18	.62**	—										
12. Forward Spatial span[2]	.15	.27	.26	.25	.22	.32	-.04	-.06	-.10	.05	.02	—									
13.Backward Spatial span[2]	.41*	.30	.23	.25	.27	.13	-.10	-.14	-.20	-.03	.12	.05	—								
14.Cortisol A	.11	.06	.10	.14	.05	-.22	.12	-.13	-.12	-.18	.24	.11	.22	—							
15.Cortisol B	.01	-.09	.04	-.06	-.06	-.14	-.00	.05	-.04	.06	.14	.26	-.13	.74**	—						
16.Cortisol C	-.13	.01	-.13	-.03	-.12	-.21	-.04	-.08	-.07	-.13	.01	.18	-.03	.74**	.86**	—					
17.Age in months	.11	.37*	.13	.42*	.10	.19	-.13	-.15	-.13	-.10	-.12	.27	.36*	.01	-.22	-.07	—				
18.RCADS	-.20	.07	-.31	.09	-.21	.01	-.27	.07	.07	-.15	-.31	-.24	-.17	-.01	-.08	-.08	.08	—			
19.STAIC-T	-.31	.07	-.23	.07	-.23	.09	-.20	-.08	-.08	-.09	-.38*	-.14	-.31	-.18	-.14	-.19	.13	.71**	—		
20.STAIC-S	.01	.15	-.03	-.03	.08	.08	.08	-.05	-.05	.03	-.06	-.17	-.20	-.01	.00	.03	-.09	.34	.45*	—	
21.CTAS	-.25	-.02	-.23	-.09	-.16	-.05	-.25	.03	.03	-.10	-.41*	-.07	-.28	.03	.18	.21	-.11	.53**	.64**	.47**	—

Note. *$p < .05$; **$p < .01$. $N = 31$.
[1]AWMA
[2]CANTAB

The range of correlations between the working memory measures was *r* = .02 to .98. There were several significant correlations including those between backwards digit span and listening recall (*r* = .48), backwards digit span and listening recall precision (*r* = .42), listening recall and AWMA spatial span (*r* = .36), and AWMA spatial span and spatial span precision (*r* = .62). There was also a very large correlation approaching unity between listening recall and listening recall precision (*r* = .98).

Working memory was moderately associated with academic performance. Forward digit span was positively and significantly related to each academic test (range = *r* = .36 to .55). Backwards digit span was similarly related to the academic performance tests (range = *r* = .21 to .43), although this was only significant for SATs maths. Listening recall was moderately (but not significantly) correlated with the academic performance tests (range = *r* = .03 to .31). The pattern was similar for listening recall precision (range = *r* = -.04 to .28). There were no significant correlations and the lowest association (with WRAT spelling) was negative and close to zero. The AWMA spatial span measure was moderately correlated with most academic performance tests (range = *r* = .32 to .48), significantly so only with WRAT maths and SATs maths. The pattern was similar with AWMA spatial span precision, but the relationships were stronger and all significant (range = *r* = .40 to .62) with the exception of WRAT spelling (*r* = .05). The forward and backwards spatial span measures on the CANTAB were moderately associated with the academic performance tests (range = *r* = .15 to .41), with the correlation between backwards spatial span and WRAT maths being the only significant one.

The stress reactivity measures taken immediately before the testing began (cortisol A), immediately after the testing had finished (cortisol B) and 10 minutes after testing had finished (C), were highly correlated with one another (range = *r* = .74 - .86), but no consistent pattern emerged of linear association between stress reactivity and the other study variables.

Correlations with age in months were small and inconsistent with most study variable sets. The exception was with the academic performance tests where age was positively related (range = r = .10 to .42), and significantly so with SATs English (r = .42) and WRAT spelling (r = .37).

5.4.1 Emotion and academic performance: Structural equation models.

A structural model was specified to assess the relationship between emotion and academic performance. The hypothesised model is illustrated in Figure 5.1. This preliminary model aimed to replicate the findings in Chapters Three and Four where a negative relationship between emotion and academic performance was found. State anxiety was not included as the correlational results showed it was very weakly related to academic performance.

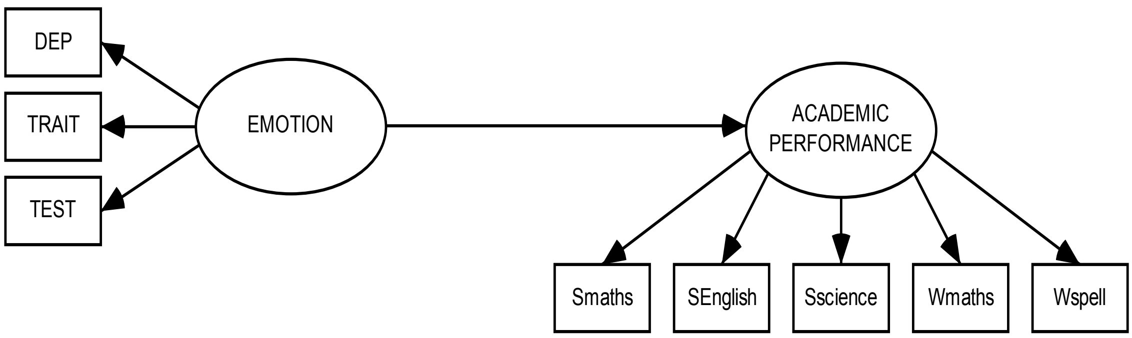


FIGURE 5.1. An illustration of the model hypothesising a negative association between self-report emotions and academic performance. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Smaths, SEnglish and Sscience are SAT KS2 results. Wmaths and Wspell are the maths and spelling subtests of the WRAT.

Overall, the specified emotion-academic performance model (Figure 5.2) was not a good fit to the data (χ^2 = 30.87, df = 19, χ^2/df = 1.62, p = .04, CFI =.92, RMSEA = .14). The exact fit of the chi square test was significant, although the ratio between chi square and degrees of freedom was less than 2. The approximate fit indices of the CFI and RMSEA were too low and high, respectively, to indicate a well-fitting model.

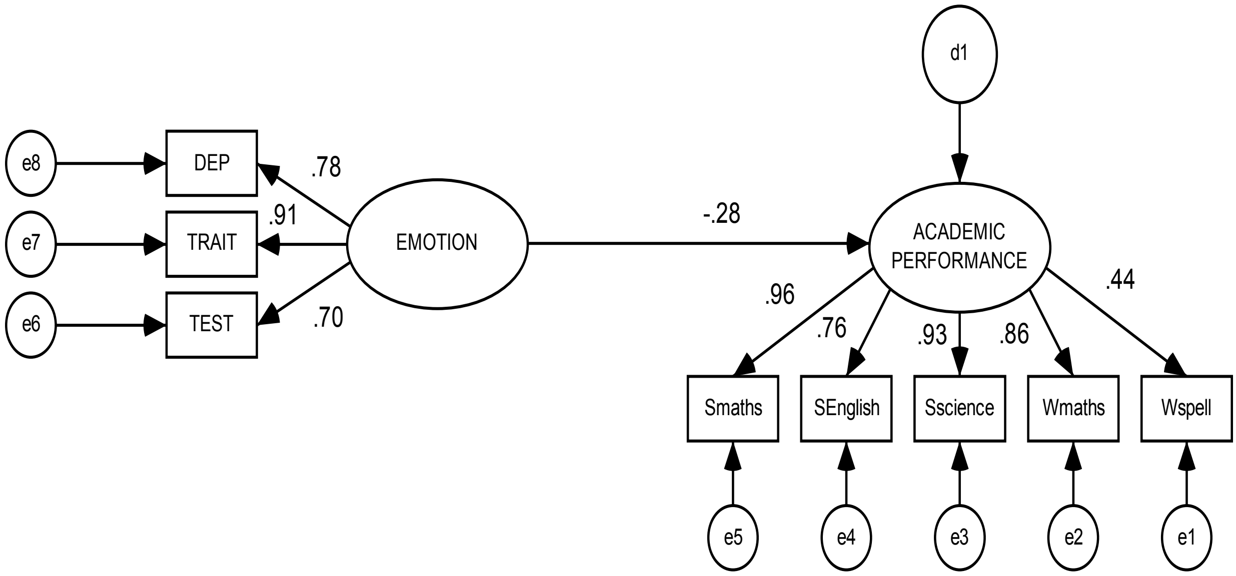


FIGURE 5.2. A structural equation model diagram showing the relationship between emotion and academic performance. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Smaths, SEnglish and Sscience are SAT KS2 results. Wmaths and Wspell = WRAT maths and spelling subtests.

The structural path between emotion and academic performance was negative, as expected, but not significant (β = -.28, *p* = .18). Modification indices identified that allowing WRAT spelling and SATs English to covary would reduce the chi square for the model by at least 6.7 points. Given the theoretical similarity of these two tests, the model was re-specified with WRAT spelling and SATs English allowed to covary. This model was found to be an improved fit to the data (χ^2 = 23.00, *df* = 18, χ^2/df = 1.24, *p* = .19, CFI =.97, RMSEA = .10). The path between emotion and academic performance was negative but did not reach significance (β = -.29, *p* = .08).

In order to explore the data further a hypothesis was made that excluding the spelling and English tests from the analysis would improve model fit. The rationale behind this hypothesis was based on the pattern in the correlational analyses that suggested that the emotion variables were substantially less related to English and spelling (largest *r* = .15). This revised emotion – academic performance model (Figure 5.3) was a good fit to the data (χ^2 = 9.95, *df* = 8, χ^2/df = 1.24, *p* = .27, CFI =.98, RMSEA

= .09). There was also a significant direct path between emotion and academic performance (β = -.30, $p < .05$).

To test whether the relationship between emotion and academic performance would be moderated by stress reactivity a multi-group analysis was carried out testing the revised emotion – academic performance model (excluding WRAT spelling and SATs English). The overall model was not a good fit to the data ($\chi^2 = 31.06$, $df = 16$, $\chi^2/df = 1.94$, $p = .01$, CFI =.89, RMSEA = .18). In the low stress reactivity group there was a small negative path between emotion and academic performance (β = -.09, $p = .55$). In the high stress group however, there was a larger and significant negative path between emotion and academic performance (β = -.63, $p < .01$). A critical ratio test showed that the two paths between emotion and academic performance in each of the stress reactivity groups (high and low) were not significantly different from one another (C.R. = -.11, $P > .05$).

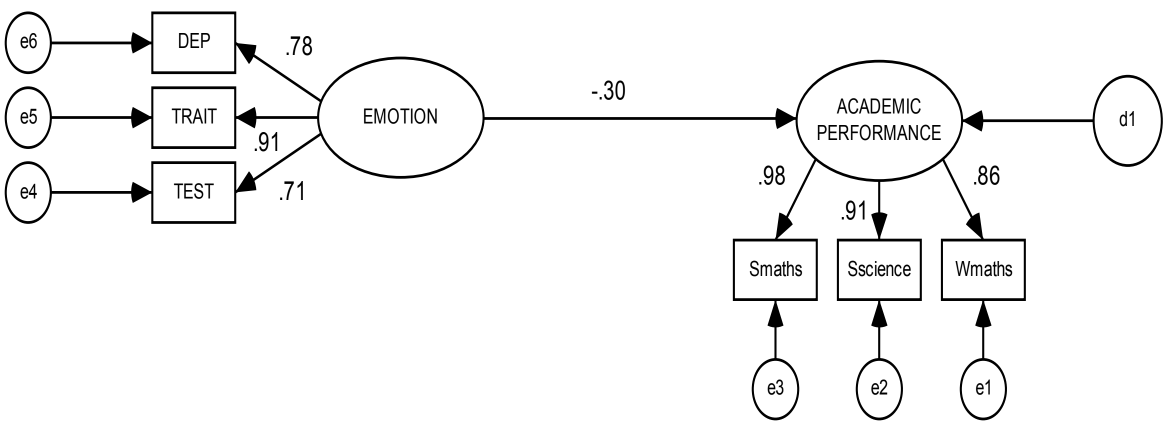


FIGURE 5.3. The revised structural equation model showing the simple relationship between emotion and academic performance. Included is a significant association between emotion and academic performance ($p < .05$). DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. SScience, Smaths are SAT KS2 results. Wmaths = the WRAT maths subtest.

5.4.2 Verbal working memory: A test of mediation.

A model was specified to test whether verbal working memory would mediate the negative relationship found in the revised emotion – academic performance model. Although the working memory variables were not all well-correlated, there are substantial benefits in using a latent variable framework. Psychological constructs are usually multifaceted and working memory is no exception. Using a single indicator to measure working memory may not capture the full conceptual map of what is a complex concept. More generally, structural equation modelling allows for less biased error-free estimates of paths between variables. This hypothesised model is illustrated in Figure 5.4.

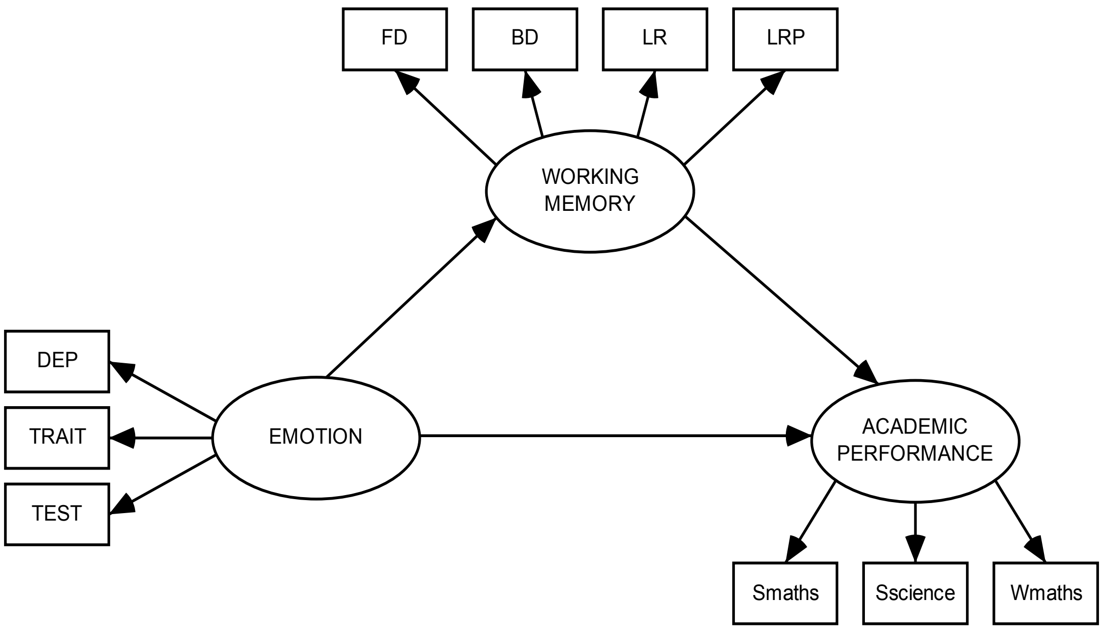


FIGURE 5.4. An illustration of the hypothesised verbal working memory mediation model. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Smaths and Sscience are SAT KS2 results. Wmaths is the maths subtest of the WRAT. FD = forward digit span, BD = backwards digit span, LR = listening recall and LRP = listening recall precision.

It was expected that there would be a negative indirect path from the emotion latent variable via the verbal working memory variable to the academic performance endogenous variable. The model as specified (see Figure 5.5) was an excellent fit to the data (χ^2 = 31.49, *df* = 32, χ^2 /*df* = .98, *p* = .49, CFI =1.00, RMSEA = .00). However, there was no indirect effect (β = .00, *p* = .78) which was slightly positive.

A further model was specified (not shown) excluding the listening recall precision variable, because this variable was correlated to near unity with the listening recall variable (*r* = .98, see Table 5.1) and could have caused problems with estimating parameters.

This model was also an excellent fit to the data (χ^2 = 24.59, *df* = 24, χ^2 /*df* = 1.02, *p* = .43, CFI =1.00, RMSEA = .03). The indirect effect was negative, but not significant (β = -.13, *p* = .29), although a model constraining the paths to and from the mediator (verbal working memory) to be zero was a significantly worse fit to the data ($\Delta\chi^2$ = 7.05, Δ*df* = 2, *p* < .05). Therefore the mediational paths were significantly adding to the model (see section 5.3).

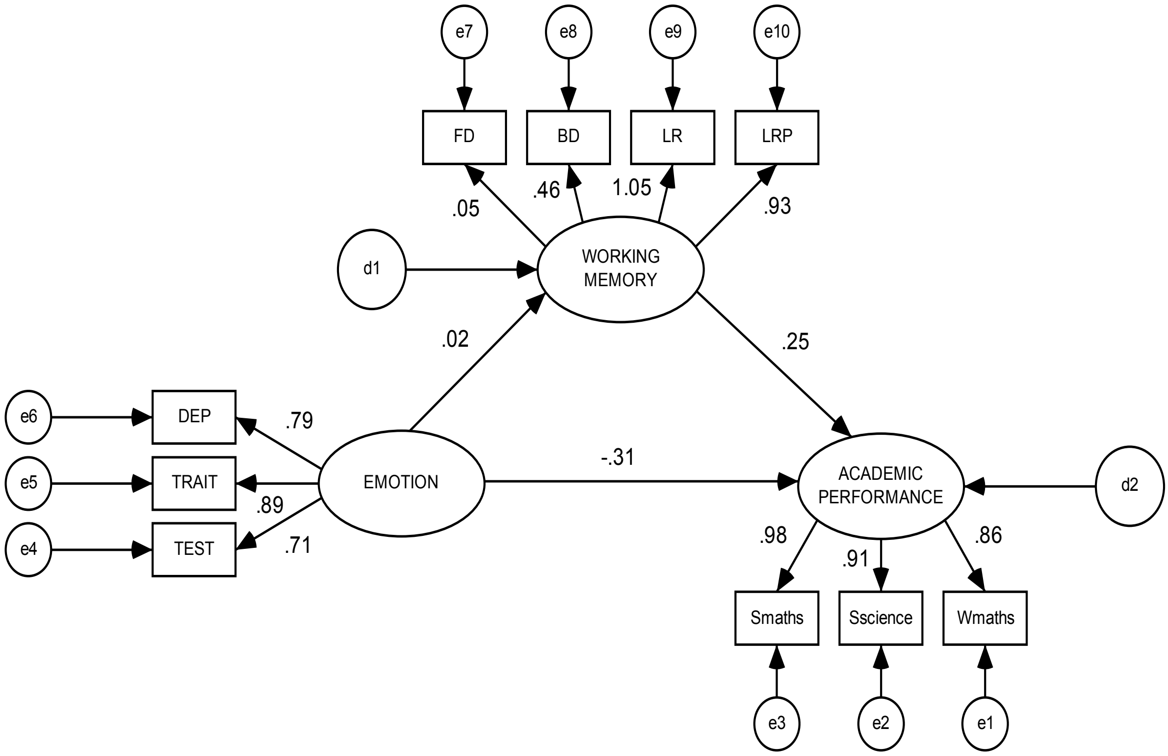


FIGURE 5.5. The initial structural equation model diagram showing the relationship between emotion, verbal working memory and academic performance. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Smaths, SEnglish and Sscience are SAT KS2 results. Wmaths and Wspell = WRAT maths and spelling subtests. FD = forward digit span, BD = backwards digit span, LR = listening recall and LRP = listening recall precision.

A further revised model was considered. The correlational results (Table 5.1) showed that when considering the range of four verbal working memory variables, the emotion measures were substantially correlated with the backwards digit span measure in particular. Consistent with findings from Chapter Four, it was therefore hypothesised that this measure, used as a single indicator for verbal working memory, may provide the best fit to the data. This single indicator revised verbal working memory model (shown in Figure 5.6) was an excellent fit to the data (χ^2 = 11.44, df = 12, χ^2/df = .95, p = .49, CFI =1.00, RMSEA = .00). There was an indirect path from emotion to academic performance via verbal working memory (β = -.10; p = .08), which did not reach significance. However, a model constraining the paths to and from the mediator to equal zero proved to be a significantly worse fit to the data ($\Delta\chi^2$ = 6.40, Δdf = 2, p < .05).

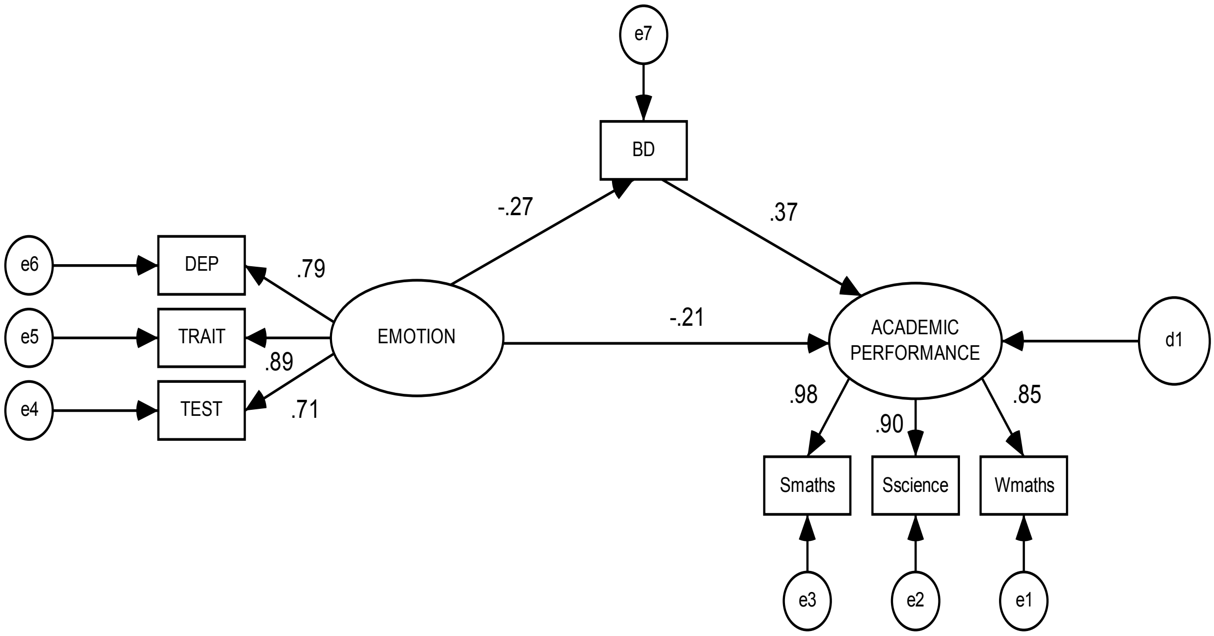


FIGURE 5.6. The single indicator verbal working memory structural equation model. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Sscience and Smaths are SAT KS2 results. Wmaths = the WRAT maths subtest. BD = backwards digit span.

As the results of the correlational analysis also suggested that age was to some extent correlated with the academic performance tests, the revised working memory model was re-tested controlling for age. The results of this model showed that the model was an excellent fit to the data (χ^2 = 14.79, *df* = 16, χ^2 /*df* = 1.94, *p* = .68, CFI =1.00, RMSEA = .00). The indirect effect remained significant; essentially unchanged (β = -.10; *p* = .08). Age was positively related to academic performance although this was not significant (β = .20; *p* = .30). Age was not considered further in the verbal working memory mediation model.

To test whether the revised model was moderated by stress reactivity, a mulitigroup analysis was carried out by stress reactivity group (high versus low). The fit for this model was not good on most measures (χ^2 = 36.78, *df* = 24, χ^2 /*df* = 1.53, *p* = .05, CFI =.90, RMSEA = .14). As the bootstrapped re-samples failed to converge for this simultaneous model, the amount of resamples requested was systematically reduced from the default used (1000) until a solution was found. Three hundred resamples were used. In the low stress reactivity group there was no indirect effect (β = .00, *p* = .73). Conversely, in the high stress reactivity group there was a significant indirect effect of emotion on academic performance via the single indicator verbal working memory (β = -.18, *p* < .05). In addition, a model constraining the paths to and from the mediator to equal zero also proved to be a significantly worse fit to the data ($\Delta\chi^2$ = 6.13, Δ*df* = 2, *p* < .05).

5.4.3 Spatial working memory.

The hypothesised spatial working memory model is presented in Figure 5.7. This model hypothesises that spatial working memory will mediate the relationship between emotion and academic performance. The model specified (Figure 5.8) was found to be an excellent fit to the data (χ^2 = 34.12, *df* = 32, χ^2 /*df* = 1.07, *p* = .37, CFI =.99, RMSEA = .05). There was a negative indirect effect, which was not significant (β = -.27; *p* = .15). A model constraining the paths to and from the mediator to equal zero was a significantly worse fit to the data than the unconstrained model ($\Delta\chi^2$ = 10.94, Δ*df* = 2, *p* < .01).

To explore the data further, a revised model was tested with the forward spatial span measure removed from the spatial working memory latent variable, as this variable's factor loading was considerably lower than other indicators in the model. The model was then re-specified. This revised spatial working memory model (Figure 5.9) was a good fit to the data (χ^2 = 29.45, *df* = 24, χ^2 /*df* = 1.23, *p* = .20, CFI =.96, RMSEA = .09). There was also a significant indirect effect (β = -.26; *p* < .05). In addition, a model constraining the paths to and from the spatial working memory latent variable proved to be a significantly worse fit to the data than the unconstrained model ($\Delta\chi^2$ = 15.06, Δ*df* = 2, *p* < .01).

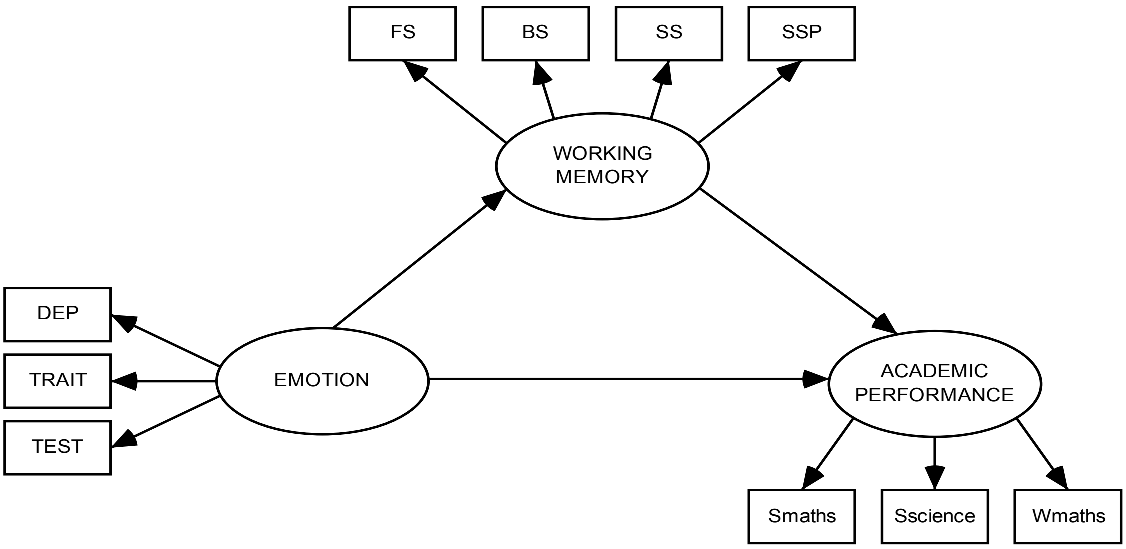


FIGURE 5.7. The hypothesised spatial working memory mediation model. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Science, Smaths are SAT KS2 results. Wmaths = the WRAT maths subtest. FS = forward spatial span as measured by the CANTAB, BS = backwards spatial span as measured by the CANTAB, SS = spatial span as measured by the AWMA and SSP = spatial span precision as measured by the AWMA.

As age had been previously shown to be positively correlated with academic performance, a model was specified controlling for age. The model was a good fit to the data (χ^2 = 39.19, *df* = 32, χ^2/df = 1.22, *p* = .18, CFI =.95, RMSEA = .09) and the indirect effect remained significant (β = -.26; *p* < .05). Age was not considered further.

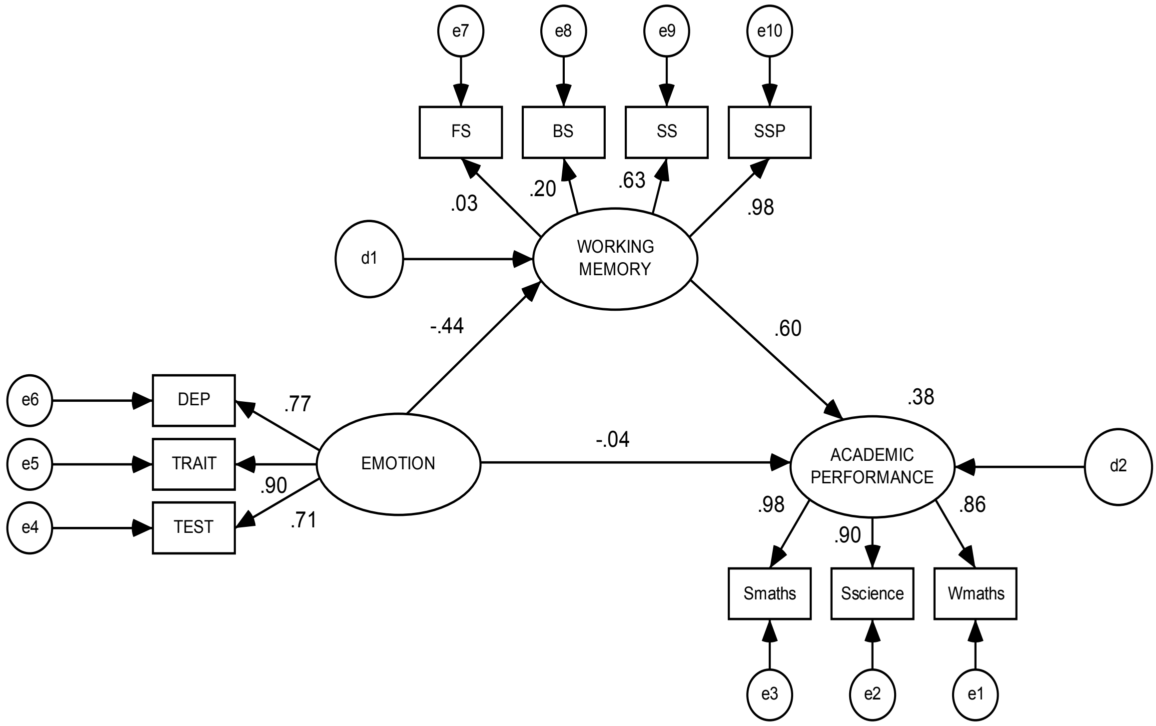


FIGURE 5.8. An initial structural equation model diagram showing the relationship between emotion verbal working memory and academic performance. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Smaths, SEnglish and Sscience are SAT KS2 results. Wmaths and Wspell = WRAT maths and spelling subtests. FS = forward spatial span. BS = backward spatial span. SS = AWMA spatial span. SSP = spatial span precision.

To assess whether the indirect effect in the spatial working memory model would be moderated by stress reactivity, a multigroup analysis was carried out using stress reactivity group (low versus high). The multigroup model was a poor fit to the data (χ^2 = 67.28, *df* = 48, χ^2 /*df* = 1.40, *p* = .03, CFI =.89, RMSEA = .12). The indirect effect was similar for the low (β = -.18) and high (β = -.14) stress reactivity groups.

In this simultaneously estimated model, the bootstrapping procedure failed to produce bias-corrected p-values for the high stress reactivity group. This was due to the error variance in the spatial span precision being reported as negative; a mathematical impossibility known as a Heywood case. The likely cause of the Heywood case was the small sample size. To obtain *p*-values for the indirect effects, the spatial working memory model was re-run with the variance for the spatial span precision error term constrained to be equal in both stress reactivity groups. This resulted in estimates for the indirect effect that approximated the unconstrained model. The indirect effects again were similar in the low (β = -.18; *p* = .17) and high (β = -.13; *p* = .32) stress reactivity groups. Neither was significantly different from zero.

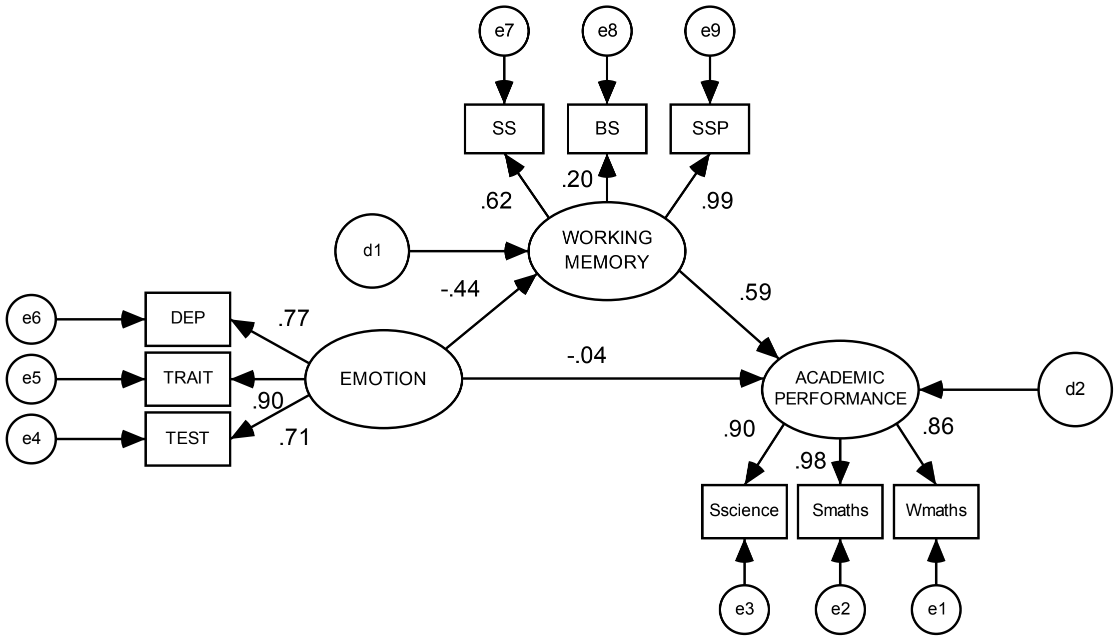


FIGURE 5.9. A structural equation model showing the spatial working memory mediating the effect of emotion on academic performance. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Sscience, Smaths are SAT KS2 results. Wmaths = the WRAT maths subtest. SS = AWMA spatial span. BS = backward spatial span. SSP = spatial span precision.

5.5 Chapter summary.

Following cognitive resource draining theories (Ellis & Ashbrook, 1988; Eysenck & Calvo, 1992) the present study assessed the relationship between emotion and academic performance and the mediating role of working memory. In addition, it tested the possibility that this mediating model was moderated by stress reactivity.

Consistent with Chapters Three and Four, the results of the present chapter found a negative association between emotion and academic performance, where this relationship was clearest on maths and science tests. This is likely to a reflection of the complex nature of maths and science and more specifically that CE resources were required for the successful completion of these tests. PET suggests that anxiety will more often negatively affect task performance that depends on CE processes.

The second main finding in the results was that the negative emotion – academic performance link was partially explained by working memory. There was evidence to suggest that spatial working memory that tapped the VSSP and CE components of working memory could mediate the emotion-academic performance relationship. In this analysis the extent of the mediation was large, accounting for the majority of the initial negative link between emotion and academic performance. This result suggests that working memory is a very important component in explaining how negative affect impinges on academic performance.

There was a trend in the results for an indirect verbal working memory mediation pathway (p = .08) It is possible that the lack of significance is due to the reduced power resulting from the group analysis, which resulted in 15 and 16 participants in each group. Further work should increase the sample size and attempt to replicate this finding. Further supporting evidence for verbal working memory mediation was obtained with a chi square difference test that showed that keeping the mediation paths in the model improved overall fit. With verbal working memory, the size of the mediated effect was β = -.10, and accounted for approximately 30% of the initial relationship between emotion and academic performance. This finding also replicates the results found in Chapter Four and presented elsewhere (Owens et al., 2008), where 50% of the relationship between trait anxiety and academic performance was explained by verbal working memory.

The present study also indicated that the associations found between emotion and academic performance were moderated by stress reactivity. Although there were no main effects of cortisol on working memory or academic performance, cortisol moderated the relationship between emotion and performance so that it was more clearly negative in the high stress reactivity group. Specifically, a multigroup analysis of the emotion – academic performance relationship showed a non-significant path in the low stress reactivity group ($\beta = -.09$, $p = .55$) and a stronger significant path in the high stress reactivity group ($\beta = -.63$, $p < .01$). The results of the stress reactivity analyses were exploratory, however, and dichotomising participants resulted in small sample sizes in each group. In addition, some models failed to converge or bootstrapped estimates were not easily computed. Future research should aim to explore these associations in a larger sample. Nevertheless the results suggest that stress reactivity is an important qualifying factor that sees the emergence of the mediation results.

The absence of any correlation between the cortisol measures and other study variables is striking. The fact that cortisol acted as a moderating factor only suggests that it is only at the high end of the continuum of stress reactivity that other effects become apparent. In this study, those effects were the association between emotion and academic performance and the mediation of emotion on academic performance via working memory. This reveals a more complex relationship that cortisol has with other variables such as anxiety and working memory. Other research has also found no simple association between cortisol and trait anxiety (Buske-Kirschbaum et al., 2004) or between cortisol and anxiety or depression (Vedhara et al., 2003), suggesting that the relationship with cortisol should be more complex. A recent study for example, has shown that the timing of assessing the correlation between cortisol and anxiety is crucial. Maximum anxiety-cortisol cross-correlations were found to be lagged by 27 to 45 minutes (Schlotz et al., 2008).

The moderation effect on the mediation analysis was also clearest via verbal working memory. In general terms this finding is consistent with evidence that shows that the relation between negative affect and cognitive performance is closer when stress is high (Deffenbacher, 1978; Eysenck & Calvo, 1992). There was no evidence that this moderated indirect effect would generalise to spatial working memory.

CHAPTER SIX: WORKING MEMORY AND STRESS REACTIVITY AS MODERATORS OF THE EMOTION-ACADEMIC PERFORMANCE RELATIONSHIP.

6.1 Introduction.

The main aim of the present chapter is to replicate the findings of the thesis thus far using a larger sample. The specific predictions will now be outlined. Consistent with Chapter Three, Four and Five, it was predicted that higher emotions would be negatively associated with academic performance and that this negative association would be partially mediated by working memory. In addition, the potential moderating effects of stress reactivity that were demonstrated in Chapter Five were replicated. The results of Chapter Five suggested that the mediation of the emotion-academic performance association was moderated by stress reactivity and that this relationship was more pronounced for verbal, rather than spatial working memory tests. That is, stronger and more negative relationships between emotion and academic performance were found, via verbal working memory, for a high stress reactivity group.

The second aim was to test an emotion x working memory interaction hypothesis. Thus far, the empirical chapters of this thesis have been concerned with the linear association between emotion and academic performance and whether this association can in part be explained by working memory. Chapter Two reviewed evidence to suggest that those individuals with relatively low working memory ability and relatively high levels of emotion will be particularly affected by the interference of emotion on working memory when performing academic tests. For example, Tobias (1985) argued that optimal performance on academic tests comes from students with good study or test-taking skills and low test anxiety. It is argued that such students have the greatest proportion of cognitive capacity available for these task demands. Conversely, students with a combination of high test anxiety/study skills make maximum demands on their cognitive capacity, “possibly exceeding available capacity for dealing with the task” (Tobias, 1985, p.139). By extension, those with high emotion and low working memory capacity are likely to be the worst performers on academic tests.

Therefore this chapter also tested whether a combination of relatively poor working memory capacity and relatively high emotion levels would be associated with lower academic performance, net of any main effects of either variable. It was expected that the interaction would be stronger on tests that make high demands on working memory as a wealth of research has suggested that the effect of anxiety and depressed mood on performance is exacerbated on difficult tasks (Darke, 1988; Eysenck & Calvo, 1992; Mathews & MacLeod, 1994; Seibert & Ellis, 1991).

The data presented in this chapter are cross-sectional, largely coming from the time one (T1) point of the longitudinal study described in Chapter Seven. The interaction hypothesis was also tested in a separate sample (section 6.4). The sample used for this replication was the same used in Chapter Four for the mediation analysis.

6.2 Method.

6.2.1 Participants.

Informed written parental consent was obtained for 96 children from two secondary schools in Hampshire and one in Dorset. In addition, participating children also provided informed written consent. Children were aged between 12 and 14 (mean age = 13 years and 10 months, *SD* = 7.88 months, range = 12 years and 0 months to 14 years and 9 months) and included 52 boys and 44 girls.

6.2.2 Emotion measures.

The emotion self-report measures used were the same as those used in Chapters Three and Five. These included the state-trait anxiety inventory for children, the children's test anxiety scale and the revised child anxiety and depression scale.

6.2.3 Working memory

The working memory measures in the present study were taken from the same batteries as in Chapter Five. They were the AWMA and the CANTAB.

6.2.4 Academic performance measures.

The wide range achievement test 4 (WRAT). Following Chapter Five, the maths and spelling subtests from the WRAT were used.

Raven's standard progressive matrices (SPM) and the Mill Hill vocabulary test (MHV). The SPM is designed to measure the eductive component of general intelligence, where eductive reasoning is defined as the ability to forge new insights, discern meaning in confusion and identify relationships (Raven, Raven, & Court, 1998). The SPM consists of 60 problems which all involve analysing a series of spatial designs with a part missing. The participant must select the correct missing part from a number of options. The scores range from 0-60. The overall correlation between the MHV and other IQ tests such as the WISC tends to be in the order of r= .80 or .90, while the correlation between the MHV and the SPM tends to be approximately r= .50 (Raven, 2000). In the present sample the correlation between the MHV and SPM was r= .43.

The MHV is a verbal measure of reproductive ability. Set A of the junior form was used in the present study. This test consists of a series of 34 words and for each the participant must identify the only synonym from a choice of six words. The participant must choose the matching synonym and indicate their choice by filling in the relevant circle. For example, from: fly, crack, wood, dunce, fruit and step, fruit is the correct synonym for tomato. Scores range from 1 to 34.

6.2.5 Stress reactivity.

Saliva samples were collected in Sarstedt Salivette sampling devices (Sarstedt Inc., Rommelsdorf, Germany). The device uses a cotton roll that the participant is asked to chew on for approximately one minute in order to collect saliva samples. The roll is placed inside the plastic container in preparation for centrifuge and assay. Samples were then frozen to remove the effects of mucins in the sample. Analysis of salivary cortisol in this study was performed by the Technical University of Dresden, Germany.

6.2.6 Procedure.

Participants were first tested in groups of a maximum of 10 children on the WRAT maths, WRAT spelling, MHV and SPM academic tests. At the end of the testing session, the state form of the STAIC was administered. On separate days thereafter, the participants were tested individually on the working memory measures, the emotion questionnaires and the cortisol samples were taken. The individual testing took place in a quiet area of the school such as an office or library. On arrival, each participant was informed as to what the session would entail and then immediately before the first working memory test was administered, the first cortisol sample was taken and the time recorded. Immediately after the last working memory test had been completed, the second cortisol sample was taken and the time recorded. At this point, the emotion questionnaires were given to the participants and explanations of the items were given if needed. After 10 minutes the third and final cortisol sample was taken. Finally, the second state form of the STAIC was administered. Participants were given water to drink after each sample and given a sugar free sweet at the end of the session.

6.2.7 Data analysis.

To assess the extent to which working memory mediated the relationship between emotion and academic performance, the present chapter used a similar analytic strategy to that adopted in Chapter Five. The direct association between emotion and academic performance was first assessed. Next the differential emotion-academic performance links were tested by stress reactivity groups using a multigroup analysis. Direct effects found were tested for mediation by working memory as in Chapter Five.

To assess the question of whether those with low working memory capacity and high emotion in combination would show the lowest academic performance, a series of 2 (high versus low working memory) x 2 (high versus low self-reported emotion) ANOVA interactions was carried out. The meaning of these interactions was explored through inspection of means by the four possible combination groups. That is: high emotion/high working memory, low emotion/low working memory, low emotion/high working memory and high emotion/ low working memory. The ANOVA F ratio relating to the interaction is of primary concern. This analysis assesses the association of the interaction between emotion and working memory over and above the contribution of both of these variables independently.

In order to test the interaction analysis using an alternative statistical method, and also by way of reducing the number of variables and summarising any significant interactions found, a latent variable strategy for interactions was subsequently adopted (Little, Card, Bovaird, Preacher, & Crandall, 2007). The general approach involves specifying latent variables for the predictors, or exogenous variables, and calculating an interaction term derived from the two latent variables. The specific procedure is outlined below.

The first step involves specifying a latent variable for each set of predictors. In the current analysis, the two latent variables were emotion and working memory. Next the indicator variables comprising the latent variables are each required to be centred. That is, the means must be subtracted from each score. This step is important in reducing problems of muliticollinearity in the structural equation model. The next step requires the calculation of all possible products between the indicators of the two latent variables that are to be involved in the interaction. Assuming the first latent variable has three indicators and the second latent variable has 4 indicators, this will result in 12 product terms. The next step involves orthogonalising the product terms by regressing them onto the 12 indicators. This removes any information that is related to main effects found in the indicators. The unstandardised residuals of these 12 regression analyses are saved as new, orthogonalised variables. The 12 indicators are then introduced into the structural equation model to form a new interaction term latent variable. For the interaction to be measured in an unbiased way certain indicators of the interaction latent variable are set to covary with one another. Specifically the interaction term indicators that share a common main effect indicator must be allowed to covary.

Two models were specified. Both included the three emotion variables of trait anxiety, test anxiety and depression and four working memory variables. In order to limit the complexity of the model and to reduce the number of variables and relationships being tested, a balance of verbal and spatial working memory variables were chosen as indicators of the working memory latent variable. They were: forward and backwards digit span, and forward and backwards spatial span. The first 'high working memory demand' model included WRAT maths and the Raven's SPM in a single latent variable. The second comparison, 'low working memory demand' model used WRAT spelling and the MHV vocabulary test to form a latent variable.

As with all structural equation models throughout this thesis, each model in this study begins with a specific hypothesis derived from theory. The initial model is assessed primarily in terms of its goodness-of-fit. Initial models are not always good-fitting and in such cases, post-hoc revisions are made to the models based on the evidence provided by the data in the model itself. For example, if an initial model is a poor fit to the data, modification indices might suggest that modifying the model by allowing measures to covary would improve the overall fit of the model. This adjustment could be made if the measures in question were theoretically similar in nature. Another example, might be if a measure in a latent variable has a very low factor loading, a modification to the model could be made that removed the measure in question

6.3 Results.

The correlations between study variables are shown in Table 6.1. The academic performance tests were all significantly correlated with one another (range = r = .33 to .63), as were the majority of working memory measures (range = r = .25 to .62). The exception being the correlation between forward digit span and backward spatial span (r = .18). Most working memory variables were positively and significantly associated with the academic performance variables (range = r = .22 to .53). The exceptions were between forward spatial span with spelling (r = .15) and MHV (r = .18) and between backward spatial span and spelling (r = .03) and MHV (r = .13). The self-report emotion variables were all positively and significantly associated with one another (range = r = .29 to .72).

Age was largely uncorrelated with the other study variables (range = r = -.09 to .17), with the exception of the significant positive correlation between age and spelling (r = .28). The emotion variables were generally not significantly associated with the academic performance measures (range = r = .02 to .20). However, trait anxiety was positively and significantly correlated with spelling. The state anxiety measure taken at individual testing was positive and significantly associated with three academic performance measures administered in groups on different days (range = r = .26 to .31). The correlation between state anxiety at individual testing and WRAT maths at group testing was the exception and was not significant (r = .19). These correlations should be interpreted with caution as the state measure refers to a different day to the academic performance testing day.

Depression and trait anxiety were positively and significantly related to spatial span (r = .39 and r = .30 respectively) as was the state anxiety measure for individual testing with listening recall (r = .25).

The stress reactivity measures (cortisol) were positively and significantly correlated with one another (range = r = .60 to .92) but not significantly linearly related to the other study variables (range = r = .00 to .19), with one exception which was in the opposite direction to that expected (depression and cortisol B r = -.21). The first cortisol measure (cortisol A) was on average the highest value (mean =5.08), compared with the cortisol B (mean = 5.07) and cortisol C (mean = 4.38) measurements. The decline in cortisol levels at the end of testing was a statistically significant one as measured by a repeated measures ANOVA ($F(2) = 5.48$, $p < .05$) where the p-value was adjusted for non-sphericity using the Greenhouse-Geisser statistic.

Table 6.1. *Correlations Between Study Variables.*

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Maths	—																	
2. Spelling	.53**	—																
3. MHV	.54**	.63**	—															
4. SPM	.51**	.33**	.43**	—														
5. Forward digit span[1]	.31**	.53**	.44**	.29**	—													
6. Backward digit span[1]	.45**	.53**	.46**	.37**	.62**	—												
7. Listening recall[1]	.42**	.28**	.45**	.44**	.49**	.58**	—											
8. Spatial span[1]	.42**	.29**	.37**	.30**	.32**	.27**	.40**	—										
9. Forward Spatial span[2]	.22*	.15	.18	.23*	.25*	.35**	.43**	.37**	—									
10.Backward Spatial span[2]	.30**	.03	.13	.23*	.18	.28**	.27**	.32**	.42**	—								
11.Cortisol A	.08	.05	.01	.01	.00	.05	-.03	.01	.05	.15	—							
12.Cortisol B	.15	.15	.03	.11	.03	.09	-.01	-.09	-.13	-.13	.72**	—						
13.Cortisol C	.17	.19	.07	.08	.08	.11	.03	-.10	.11	.06	.60**	.92**	—					
14.Age in months	.15	.28*	.14	.05	.08	.03	.10	.10	.09	.20	-.01	.09	.10	—				
15.RCADS	.05	.17	.08	.00	.03	.08	.15	.39**	.11	.09	-.09	-.21*	-.18	.11	—			
16.STAIC T	.05	.29**	.20	.08	.00	.17	.14	.30**	.05	.05	.00	.00	.02	.07	.72**	—		
17.STAIC-S Individual	.19	.28**	.26*	.31**	.02	.19	.25**	.16	.09	.20	.08	.00	-.01	.17	.40**	.42**	—	
18.STAIC-S Group	.06	.10	.08	.20	-.11	.05	.17	.15	.20	.09	.07	.03	.02	.09	.41**	.43**	.47**	—
19.CTAS	-.05	.06	.04	.02	-.02	.05	.09	.12	.10	.12	-.01	.00	.00	-.09	.56**	.65**	.29**	.39**

Note. *$p < .05$; **$p < .01$. $N = 50$.
[1]AWMA
[2]CANTAB

6.3.1 The mediation hypotheses.

The emotion-academic performance relationship that was tested is shown in Figure 6.1.

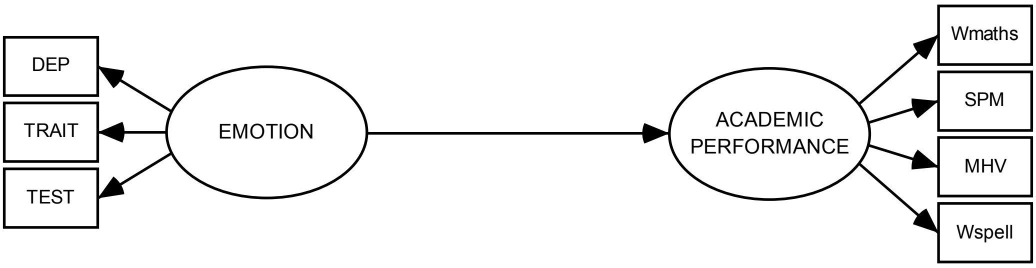


Figure 6.1. The hypothesised emotion-academic performance model. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Wmaths and Wspell are the maths and spelling subtests of the WRAT.MHV = Mill Hill Vocabulary test, SPM = Raven's Standard Progressive Matrices.

The specified structural equation model proved to be a moderate fit to the data (χ^2 = 20.91, *df* = 13, χ^2 /*df* = 1.61, *p* = .08, CFI =.97, RMSEA = .08). However, modification indices indicated that allowing the error variance associated with WRAT maths and Raven's SPM to covary would increase the chi square by at least 5.8 points. A revised model was specified (Figure 6.2) with WRAT maths and Raven's SPM error variances allowed to covary.

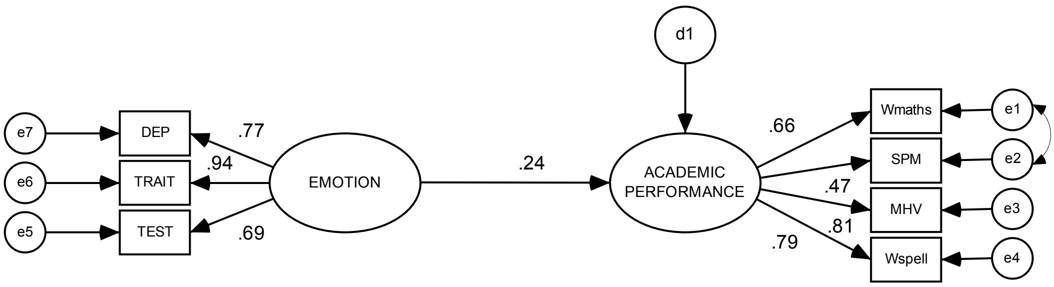


Figure 6.2. The specified emotion-academic performance model. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Wmaths and Wspell are the maths and spelling subtests of the WRAT.MHV = Mill Hill Vocabulary test, SPM = Raven's Standard Progressive Matrices.

This revised model was an excellent fit to the data (χ^2 = 14.03, *df* = 12, χ^2 /*df* = 1.17, *p* = .23, CFI =.99, RMSEA = .04) and included a positive path from emotion to academic performance that was close to significance (β = .24 *p* = .05).

A multigroup analysis compared the emotion-academic performance relationship by stress reactivity group. This model was a good fit to the data (χ^2 = 32.34, *df* = 24, χ^2 /*df* = 1.34, *p* = .12, CFI =.97, RMSEA = .06) and revealed a positive structural path in the low stress reactivity group (β = .39; *p* < .05) and a negative path in the high stress reactivity group which was not significant (β = -.10 *p* = .59). A systematic examination of the contribution of the association by each emotion variable revealed that the trait anxiety variable appeared to attenuate the size of the structural path in the high stress reactivity group. Therefore a further revised model was explored by removing trait anxiety. This model was a good fit to the data (χ^2 = 18.23, *df* = 14, χ^2 /*df* = 1.30, *p* = .20, CFI =.97, RMSEA = .06) and included a significant negative path (see Figure 6.3) in the high stress reactivity group (β = -.41; *p* = .05). In the low stress reactivity group the path was positive although marginally significant (β = .32; *p* = .05). Three hundred bootstrapped samples were used to specify this model. A pairwise parameter estimate analysis revealed that the paths in the two groups were significantly different from one another (C.R. = -2.02, *p* < .05).

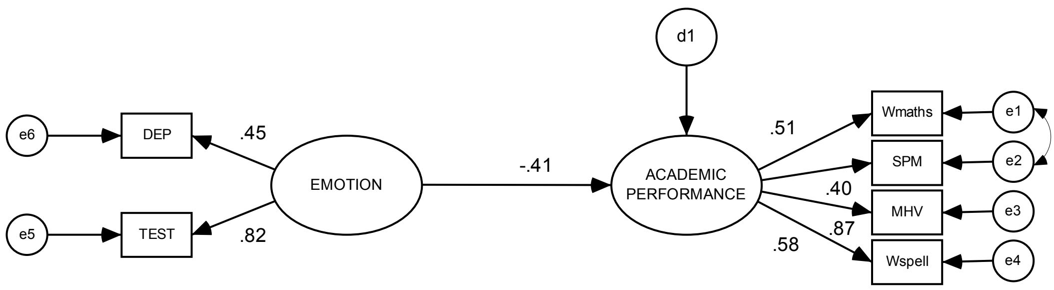


Figure 6.3. The result of the stress reactivity multigroup analysis. The path diagram shown represents the significant emotion-academic performance relationship in the high stress reactivity group. DEP = depression measured by the RCADS. TRAIT = trait anxiety measured by the STAIC-T and TEST = test anxiety measured by the CTAS. Wmaths and Wspell are the maths and spelling subtests of the WRAT.MHV = Mill Hill Vocabulary test, SPM = Raven's Standard Progressive Matrices.

The extent to which these significant paths in each stress reactivity group were mediated by working memory was then tested. The hypothesised verbal working memory mediation model is shown in Figure 6.4.

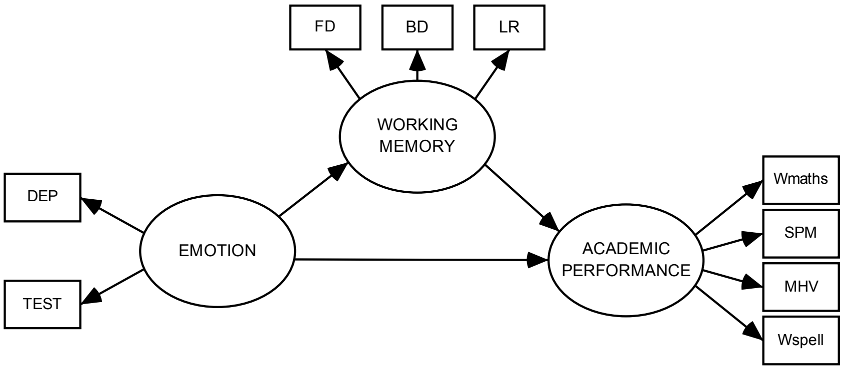


Figure 6.4. The hypothesised verbal working memory mediation model in the high stress reactivity group. DEP = depression measured by the RCADS and TEST = test anxiety measured by the CTAS. FD = forward digit span, BD = backwards digit span, LR = listening recall. Wmaths and Wspell are the maths and spelling subtests of the WRAT. MHV = Mill Hill Vocabulary test, SPM = Raven's Standard Progressive Matrices.

The specified model was an excellent fit to the data (χ^2 = 48.93, *df* = 46, χ^2 /*df* = 1.06, *p* = .36, CFI =.99, RMSEA = .03) and is shown in Figure 6.5 for the high stress group. There was a positive indirect path in the low stress reactivity group (β = .23; *p* = .06) which did not reach significance and a significant negative indirect path in the high stress reactivity group (β = -.45; *p* < .05). A model constraining the paths to and from the mediator in the high stress reactivity group to equal zero was a significantly worse fit to the data than the unconstrained model ($\Delta\chi^2$ = 20.12, Δ*df* = 2, *p* < .001) confirming that the mediation paths were important in the model. The extent of the mediation in this analysis was total. That is the entire negative emotion-academic performance path was explained via an indirect verbal working memory path. A further constrained model was specified to test whether the mediation models in high and low stress reactivity groups were in fact significantly different from one another. This was achieved by constraining the three structural paths in the low group to be equal to the three respective paths in the high group. This model was a significantly poorer fit to the data than the unconstrained model ($\Delta\chi^2$ = 8.61, Δdf = 3, p < .05) indicating that the two models (low and high stress reactivity) were significantly different from one another.

The overall fit of the spatial working memory mediation model was good (χ^2 = 54.33, df = 46, χ^2/df = 1.18, p = .19, CFI =.96, RMSEA = .05), although there was no evidence for mediation of the significant negative association between emotion and academic performance by working memory in the high stress reactivity group (β = .07).

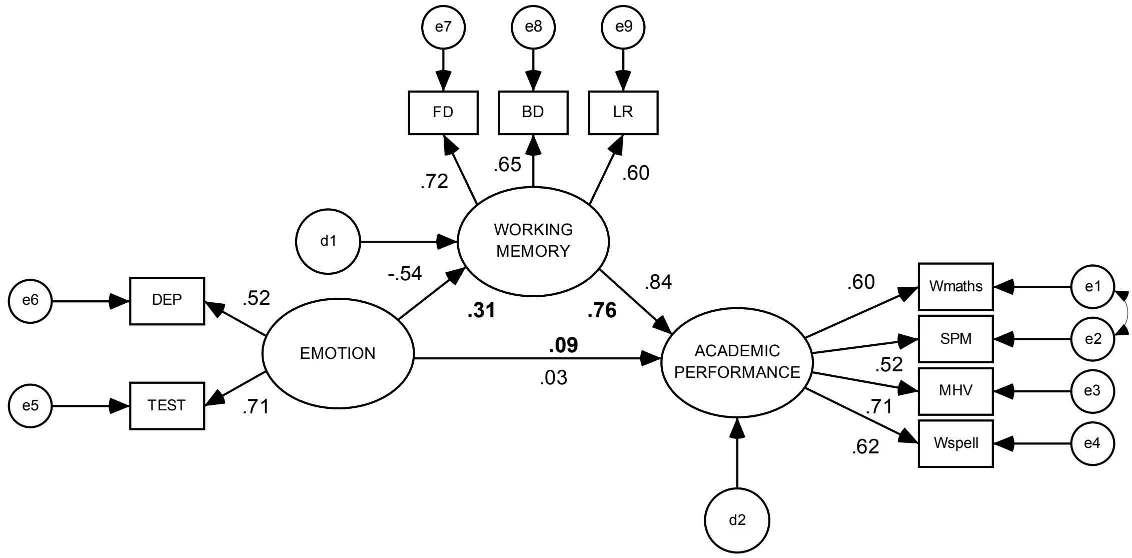


Figure 6.5. The specified verbal working memory mediation model in the high stress reactivity group. DEP = depression measured by the RCADS and TEST = test anxiety measured by the CTAS. FD = forward digit span, BD = backwards digit span, LR = listening recall. Wmaths and Wspell are the maths and spelling subtests of the WRAT. MHV = Mill Hill Vocabulary test, SPM = Raven's Standard Progressive Matrices. Key path estimates for the low stress reactivity group are given in the centre of the diagram and are in bold.

6.3.2 Emotion x working memory interactions: Trait anxiety.

The results of the interaction analysis for trait anxiety and working memory on the high demand working memory tests are shown in Table 6.2. The most salient feature in the results is that, on every academic performance measure, the difference between working memory groups was most pronounced in the high trait anxiety group. In absolute terms the lowest academic performance mean scores were found in the high trait anxiety/low working memory combination groups. This was true for every working memory variable. In addition, the highest mean scores were found in the high trait anxiety/high working memory groups.

The estimated marginal means, F ratios and associated *p* – values for each interaction are shown in Table 6.2. There were several significant trait anxiety x working memory interactions on the WRAT maths test including trait anxiety x backwards digit span ($F(1,92) = 7.7$, $p < .01$), trait anxiety x backward spatial span ($F(1,92) = 5.6$, $p < .05$) and trait anxiety x listening recall ($F(1,92) = 4.2$, $p < .05$). There were also significant interactions on the Raven's SPM including trait anxiety x backward digit span ($F(1,92) = 6.5$, $p < .05$), trait anxiety x forward spatial span ($F(1,92) = 6.4$, $p < .05$) and trait anxiety x backward spatial span ($F(1,92) = 4.5$, $p < .05$). There were no interaction effects on the MHV test or the WRAT spelling test (see Table C.1 in Appendix C).

To probe the interaction further, simple one-way ANOVAs were carried out assessing the difference in the working memory groups at low and high trait anxiety separately. Only significant interactions were probed and only ANOVAs resulting in $p<.1$ are reported here.

In the high trait anxiety group, there was a significant difference between backwards digit recall groups on the WRAT maths test ($F(1,44) = 21.6$, $p < .001$). There were no differences within the low trait anxiety group ($F(1,48) = 0.2$, $p = .67$). Similarly, there was a significant difference on the WRAT maths test for the listening recall groups in the high trait anxiety group ($F(1,44) = 13.9$, $p < .01$) but not in the low anxious group ($F(1,48) = 0.5$, $p = .47$). The pattern was the same for the backwards spatial span groups within the high trait anxiety group ($F(1,44) = 18.1$, $p < .001$) compared with the low trait anxiety group ($F(1,48) = 0.6$, $p = .42$).

Table 6.2. *The interaction between trait anxiety and working memory on high working memory demand academic performance tests.*

	High Trait Anxiety/High Working Memory	*Low Trait Anxiety/Low Working Memory*	*Low Trait Anxiety/High Working Memory*	*High Trait Anxiety/Low Working Memory*	F ratio (df)	P value
Maths						
AWMA Forward digit span	40.81 (5.75)	37.00(4.51)	38.86 (6.30)	35.96 (4.53)	1.92 (1,92)	.17
AWMA Backward digit span	40.85 (4.39)	37.52 (4.39)	38.17 (4.39)	34.37 (4.39)	7.74 (1,92)	.01*
AWMA Listening recall	41.42 (4.85)	37.22 (4.27)	38.33 (6.22)	35.89 (5.03)	4.24 (1,92)	.05*
AWMA Spatial span	40.39 (5.52)	35.81 (4.94)	40.30 (4.32)	35.88 (5.23)	0.00 (1,92)	.99
CANTAB Forward Spatial span	40.38 (5.39)	37.68 (5.78)	37.96 (5.09)	36.32 (5.22)	2.95 (1,92)	.09
CANTAB Backward Spatial span	40.37 (4.82)	37.20 (6.14)	38.44 (4.56)	34.06 (4.73)	5.56 (1,92)	.02*
Raven's SPM						
AWMA Forward digit span	47.00 (5.12)	43.29 (6.03)	46.41 (5.55)	42.68 (7.74)	0.22 (1,92)	.64
AWMA Backward digit span	47.63 (5.21)	44.22 (6.33)	45.17 (5.21)	40.42 (7.03)	6.54 (1,92)	.01*
AWMA Listening recall	48.37 (5.73)	43.09 (6.15)	46.00 (5.24)	42.04 (6.31)	1.93 (1,92)	.17
AWMA Spatial span	46.74 (6.08)	43.38 (6.09)	46.35 (5.72)	41.82 (6.93)	0.52 (1,82)	.47
CANTAB Forward Spatial span	47.52 (5.78)	45.20 (6.54)	44.12 (5.16)	42.24 (7.04)	6.67 (1,92)	.01*
CANTAB Backward Spatial span	46.57 (4.92)	44.64 (5.05)	44.68 (6.58)	41.06 (8.78)	4.45 (1,92)	.04*

*Note.**p < .05

On the Raven's SPM, the pattern of results was repeated. In the low trait anxiety group there was no difference between backwards digit span groups in their performance on the test. Conversely for the high trait anxiety group, the difference was large and statistically significant ($F(1,44) = 16.0$, $p < .01$). In the high trait anxiety group there was a significant difference between the forward spatial span groups ($F(1,44) = 7.6$, $p < .01$). There was no forward spatial span group difference in the low trait anxiety group ($F(1,48) = 0.4$, $p = .52$). For the backwards spatial span, there was a significant group difference on the Raven's SPM scores only for the high trait anxiety group ($F(1,44) = 7.5$, $p < .01$), and not for the low trait anxiety group ($F(1,48) = 0.0$, $p = .98$).

6.3.3 Depression.

There were significant depression x working memory interactions on academic tests. The pattern of results for depression was similar to that found for trait anxiety. That is, the differences between working memory groups on academic performance tests were only seen for those with relatively high levels of depression. The estimated marginal means for the group analysis along with F ratios and associated *p* – values for the interactions are shown in Table 6.3.

There were seven statistically significant interactions between depression and working memory on academic performance tests. On the WRAT maths test there was a significant depression x forward spatial span interaction ($F(1,92) = 6.9$, $p < .05$) and a significant depression x backward spatial span interaction ($F(1,92) = 4.9$, $p < .05$). There was also a significant depression x AWMA spatial span interaction ($F(1,92) = 7.3$, $p < .01$). On the Raven's SPM there was a significant depression x forward digit span interaction ($F(1,92) = 6.5$, $p < .05$), a significant depression x forward spatial span interaction ($F(1,92) = 5.2$, $p < .05$), a significant depression x backward spatial span interaction ($F(1,92) = 4.7$, $p < .05$) and a significant depression x AWMA spatial span interaction ($F(1,92) = 7.4$, $p < .01$). There was a single depression x forward digit span interaction on the MHV test ($F(1,92) = 6.4$, $p < .05$) and a single depression x forward spatial span interaction ($F(1,92) = 5.0$, $p < .05$) on the WRAT spelling test (Table 6.4).

Table 6.3. *The interaction between depression and working memory on high working memory demand academic performance tests.*

	High Depression/High Working Memory	*Low Depression/Low Working Memory*	*Low Depression/High Working Memory*	*High Depression/Low Working Memory*	F ratio (df)	P value
Maths						
AWMA Forward digit span	40.41 (6.97)	37.64 (3.89)	39.42 (5.46)	35.50 (4.83)	2.01 (1,92)	.15
AWMA Backward digit span	39.23 (6.49)	36.87 (4.60)	39.93 (4.59)	35.57 (5.34)	0.08 (1,92)	.78
AWMA Listening recall	39.43 (4.53)	37.38 (4.53)	39.76 (4.85)	35.54 (4.78)	0.49 (1,92)	.49
AWMA Spatial span	40.56 (4.93)	37.85 (3.84)	40.06 (5.08)	32.76 (5.11)	7.34 (1,92)	.01**
CANTAB Forward Spatial span	40.05 (6.26)	38.85 (5.28)	38.24 (4.32)	35.00 (5.09)	6.94 (1,92)	.01*
CANTAB Backward Spatial span	40.22 (5.27)	37.84 (5.51)	38.97 (4.36)	34.36 (5.64)	4.93 (1,92)	.03*
Raven's SPM						
AWMA Forward digit span	47.53 (6.35)	45.56 (4.46)	46.15 (4.52)	40.71 (7.55)	6.49 (1,92)	.01*
AWMA Backward digit span	46.45 (6.61)	45.04 (4.80)	46.54 (4.12)	40.26 (7.76)	3.77 (1,92)	.05
AWMA Listening recall	46.48 (6.92)	44.38 (4.37)	47.40 (4.08)	40.50 (7.56)	1.53 (1,92)	.22
AWMA Spatial span	46.52 (6.72)	45.50 (4.66)	46.61 (4.54)	38.59 (6.55)	7.43 (1,82)	.01**
CANTAB Forward Spatial span	45.90 (6.43)	46.23 (3.89)	45.48 (5.03)	41.00 (8.28)	5.17 (1,92)	.03*
CANTAB Backward Spatial span	45.74 (6.97)	46.16 (3.88)	45.69 (4.82)	40.73 (7.94)	4.73 (1,92)	.03*

*Note.**p < .05; **p<.01

Probing the significant interactions further, it was found that in the high depression group, there was a significant difference between the AWMA spatial span groups on the WRAT maths test ($F(1,40) = 24.6$, $p < .001$). There was also a significant difference between the forwards spatial span groups ($F(1,43) = 8.9$, $p < .01$), as well as the backwards spatial span groups ($F(1,43) = 13.0$, $p = .001$) on WRAT maths. There were no significant working memory group differences in the low depression group (*p*s > .1) on the WRAT maths test.

There were significant differences between the forward digit span groups, in the high depression group, on the Raven's SPM ($F(1,43) = 9.7$, $p < .01$). There were also significant differences between the AWMA spatial span groups on the Raven's SPM ($F(1,40) = 14.38$, $p < .001$), as well as between the forward spatial span groups ($F(1,43) = 4.8$, $p < .05$) and backwards spatial span groups ($F(1,43) = 5.1$, $p < .05$). There were no significant working memory group differences in the low depression group (*p*s > .1) on the Raven's SPM test.

On the WRAT spelling test, there was no significant difference between the forward spatial span groups in the low depression group. There was only a trend for a group difference in the high depression group however ($F(1,43) = 3.0$, $p = .09$). The significance of the interaction was likely to have been driven by the overall difference between combination groups. Those with high depression/low working memory scored the lowest of all combination groups on the WRAT spelling test.

On the MHV test, there was a significant difference between the forward digit span groups in the high depression group ($F(1,43) = 21.7$, $p < .001$). There was a relatively smaller but significant group difference in the low depression group ($F(1,43) = 4.5$, $p < .05$).

Table 6.4. *The interaction between depression and working memory on low working memory demand academic performance tests.*

	High Depression/High Working Memory	*Low Depression/Low Working Memory*	*Low Depression/High Working Memory*	*High Depression/Low Working Memory*	F ratio (df)	P value
Spelling						
AWMA Forward digit span	42.71 (5.45)	37.08 (3.71)	41.27 (4.83)	36.86 (5.10)	0.70 (1,92)	.41
AWMA Backward digit span	41.32 (6.30)	37.78 (4.08)	40.39 (5.04)	36.91 (4.71)	0.74 (1,92)	.39
AWMA Listening recall	41.43 (5.82)	38.50 (4.06)	39.96 (5.39)	37.00 (5.28)	1.99 (1,92)	.16
AWMA Spatial span	40.20 (6.30)	39.15 (4.42)	39.50 (4.54)	37.41 (5.32)	1.13 (1,82)	.29
CANTAB Forward Spatial span	40.67 (6.48)	40.12 (4.89)	38.28 (4.55)	37.67 (5.10)	5.07 (1,92)	.03*
CANTAB Backward Spatial span	39.83 (6.97)	38.84 (4.99)	39.44 (4.70)	38.27 (4.60)	0.19 (1,92)	.67
MHV						
AWMA Forward digit span	24.35 (2.98)	19.96 (2.85)	21.88 (3.60)	18.61 (4.52)	6.41 (1,92)	.01*
AWMA Backward digit span	22.82 (4.37)	20.00 (3.37)	21.71 (3.22)	18.83 (4.58)	2.04 (1,92)	.16
AWMA Listening recall	23.10 (3.90)	19.96 (3.09)	21.96 (3.40)	18.75 (4.78)	2.24 (1,92)	.14
AWMA Spatial span	22.28 (4.83)	19.92 (3.12)	22.06 (2.96)	18.35 (4.39)	1.09 (1,82)	.30
CANTAB Forward Spatial span	21.81 (4.42)	20.92 (3.32)	20.96 (3.48)	19.88 (5.14)	1.26 (1,92)	.26
CANTAB Backward Spatial span	21.48 (5.48)	20.11 (4.09)	21.44 (2.80)	20.05 (4.12)	0.00 (1,92)	.95

*Note.***p* < .05

6.3.4 Test anxiety.

The pattern of results persisted with the test anxiety and working memory analysis showing that working memory group differences on academic test performance would only appear at relatively high levels of test anxiety. In the present results these associations were only found on the Raven's SPM and not the WRAT maths test. The results of the test anxiety x working memory interaction analyses are presented in Table 6.5. Although the high test anxiety/low working memory combination group evinced the lowest mean scores on the WRAT maths test, there were no significant interactions using any working memory variable.

On the Raven's SPM, however, five of the six interactions were statistically significant. These included the forward digit span x test anxiety interaction ($F(1,92) = 5.2$, $p < .05$), the backwards digit span x test anxiety interaction ($F(1,92) = 9.5$, $p < .01$) and a significant listening recall x test anxiety interaction ($F(1,92) = 10.7$, $p < .01$). On the spatial working memory measures, there were also significant interactions between test anxiety and the forward spatial span ($F(1,92) = 4.8$, $p < .05$) and backwards spatial span measures ($F(1,92) = 5.3$, $p < .05$).

As with the previous interaction analyses, the significant interactions were probed by examining group differences in low and high test anxiety groups separately. There were significant differences between forward digit span groups in the high test anxiety group ($F(1,46) = 9.9$, $p < .01$) but not in the low test anxiety group ($F(1,46) = 0.4$, $p = 0.5$). There were also significant working memory group differences in the high test anxiety group for backwards digit span ($F(1,46) = 15.5$, $p < .001$) and listening recall ($F(1,46) = 19.0$, $p < .001$), forward spatial span ($F(1,46) = 5.0$, $p < .05$) and backwards spatial span ($F(1,46) = 6.7$, $p < .05$). No group differences on these variables were found in the low test anxiety group (*p*s > .1).

There were no significant interactions on the spelling or MHV, low working memory demand academic tests. The results of these analyses are shown in Table C.2 in Appendix C.

Table 6.5. *The interaction between test anxiety and working memory on high working memory demand academic performance tests.*

	High Test Anxiety/High Working Memory	*Low Test Anxiety/Low Working Memory*	*Low Test Anxiety/High Working Memory*	*High Test Anxiety/Low Working Memory*	F ratio (df)	P value
Maths						
AWMA Forward digit span	39.37 (7.48)	36.88 (4.50)	40.17 (4.76)	36.21 (4.56)	0.00(1,92)	.95
AWMA Backward digit span	39.07 (6.11)	36.92 (4.63)	40.26 (4.62)	35.38 (5.34)	0.03(1,92)	.87
AWMA Listening recall	39.14 (6.88)	36.91 (4.39)	40.00 (4.92)	36.15 (5.01)	0.00(1,92)	.97
AWMA Spatial span	40.05 (5.74)	36.41 (3.97)	40.64 (4.15)	35.24 (5.94)	0.07(1,82)	.79
CANTAB Forward Spatial span	38.67 (5.92)	37.69 (5.00)	39.50 (4.65)	36.25 (5.99)	0.08(1,92)	.79
CANTAB Backward Spatial span	39.48 (5.27)	37.36 (5.43)	39.50 (4.22)	34.37 (5.90)	1.93(1,92)	.17
Raven's SPM						
AWMA Forward digit span	48.11 (5.46)	44.71 (4.53)	45.58 (4.99)	41.59 (7.85)	5.20(1,92)	.03*
AWMA Backward digit span	47.52 (5.29)	45.00 (4.40)	45.30 (5.17)	39.86 (8.15)	9.53(1,92)	.00**
AWMA Listening recall	48.81 (5.98)	44.83 (4.90)	45.44 (4.66)	40.56 (6.87)	10.67(1,92)	.00**
AWMA Spatial span	46.86 (6.67)	44.14 (4.66)	46.27 (5.07)	41.33 (7.68)	1.65(1,82)	.20
CANTAB Forward Spatial span	46.54 (6.55)	45.50 (5.03)	44.73 (4.44)	41.79 (8.05)	4.76(1,92)	.03*
CANTAB Backward Spatial span	46.34 (6.60)	45.32 (4.92)	45.00 (4.66)	40.84 (8.10)	5.28(1,92)	.02*

*Note.***p* < .05; ***p*<.01

6.3.5 The high working memory demands structural equation model.

The higher working memory demand tests (WRAT maths and SPM) were then analysed separately in a structural equation interaction model. This model is based on a procedure outlined by Little et al. (2007) and described in section 6.2.7 To reiterate, the model includes latent variables which each have a direct path to academic performance. These paths represent the main effects of emotion and working memory on academic performance. Crucially, there is an interaction latent variable which is derived essentially by multiplying the emotion and working memory latent variables together. This interaction variable includes a path to the academic performance variable. The estimate obtained from the interaction variable path has the main effects of emotion and working memory controlled for. A schematic illustration of the hypothesised emotion – working memory interaction model is shown in Figure 6.6. In these analyses, the *p*-value is reported to three decimal places so that it was sensitive enough to assess change when introducing additional variables to the overall model.

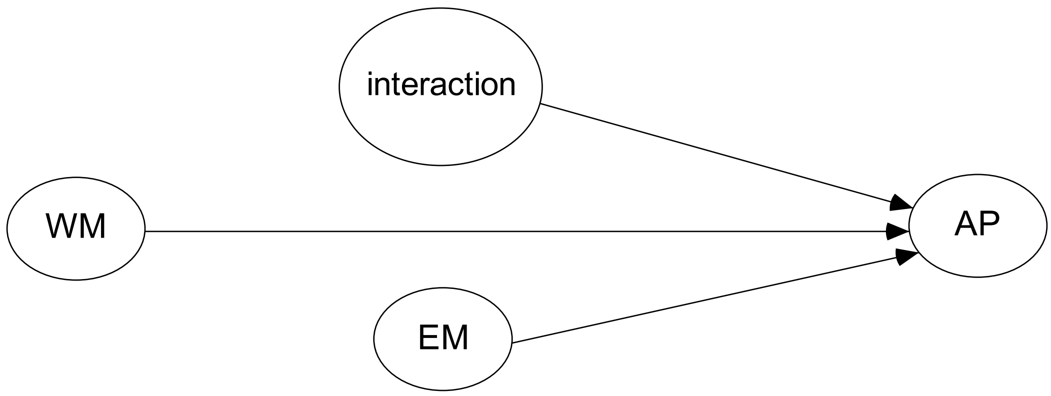


FIGURE 6.6. A schematic representation of the hypothesised emotion-working memory interaction structural equation model. WM refers to working memory, EM represents emotion and interaction is a latent variable interaction term representing the product of the WM and EM latent variables. All variables are allowed to predict the AP (academic performance) endogenous variable. Evidence of an interaction between emotion and working memory in association with academic performance is gained if the path from interaction to AP is significant.

To compare models, the AIC statistic is also reported. The Akaike Information Criterion (AIC) value cannot be interpreted alone but is a relative fit index useful in comparing non-nested models (where one model is *not* a subset of another). The difference between AIC values for models to be compared can be expressed as an AIC difference (Δ_i). The Δ_i is equal to AIC_i - AIC_{min}, where AIC_i is a given model and AIC_{min} is the model with the smallest AIC. The larger the Δ_i the less plausible it is that the model under scrutiny (AIC_i) is the best one. Rules of thumb indicate that a model with a Δ_i of between 0 - 2 has substantial empirical support, a Δ_i of between 4 - 7 has considerably less support, and a model with $\Delta_i >$ 10 has essentially no empirical support and might be omitted from further investigation (Burnham & Anderson, 2002).

The specified high working memory demand model was an excellent fit to the data (χ^2 = 99.14, *df* = 156, χ^2 /*df* = .64, *p* = 1.00, CFI =1.00, RMSEA = .00) and included a significant path from the interaction term latent variable to the academic performance latent variable (β = .28, *p* = .026). Inspection of the factor loadings for the interaction latent variable revealed that the test anxiety x backward spatial span orthogonalised variable was small and non-significant (*p* = .16). It was decided to exclude this variable from the interaction latent variable and the analysis was re-run. The revised model (illustrated in Figure 6.7) provided an excellent fit to the data (χ^2 = 92.74, *df* = 142, χ^2 /*df* = .65, *p* = 1.00, CFI =1.00, RMSEA = .00). There was a significant path from working memory to academic performance (β = .66, *p* < .05) and no significant path from emotion to academic performance (β = -.03, *p* = .813). This revised model also included a slightly more significant path from the interaction latent variable to the high demands tests latent variable (β = .30, *p* = .019).

To assess the influence of potential nuisance variables and more instrumental variables, a series of comparison models was specified. The time of day, age, gender, task order and school attended were thought to be nuisance variables, possibly affecting the path estimates in the model but of no particular theoretical interest. State anxiety was thought to be more instrumental in the sense that it could theoretically influence the model. State anxiety has been proposed to mediate the negative effects of trait anxiety on cognitive performance (Eysenck & Calvo, 1992). Models were specified with each additional variable introduced individually and then a final model was specified with all additional variables entered simultaneously. The interaction effects were not significantly reduced when controlling for these variables although in each case the interaction was significantly related to academic performance : age (β = .30, p = .016) time of day (β = .29, p = .023), gender (β = .29, p = .021), task order (β = .29, p = .019), school attended (β = .30, p = .017), state anxiety at group testing (β = .30, p = .016), state anxiety at individual testing (β = .28, p = .020).

With all additional control variables entered into the model predicting the high demands tests simultaneously, the interaction effect between emotion and working memory remained significant (β = .25, p = .028). The comparative fit of these different models is given in Table 6.6. An AIC analysis showed that the simpler interaction model was the best fitting out of those specified. The alternative models could be discarded as the AIC discrepancy between the specified and alternative models was >10 in each case.

The low working memory demand model was identical to the high demand model with the exception that academic performance was measured by WRAT spelling and the MHV test. This model was also a good fit to the data (χ^2 = 96.51, df = 156, χ^2/df = .62, p = 1.00, CFI =1.00, RMSEA = .00). There was no evidence for an emotion x working memory interaction in this model (β = .04, p = .72). However, there was a positive main effect of emotion on academic performance (β = .21, p = .043) as well as working memory on academic performance (β = .72, p < .001).

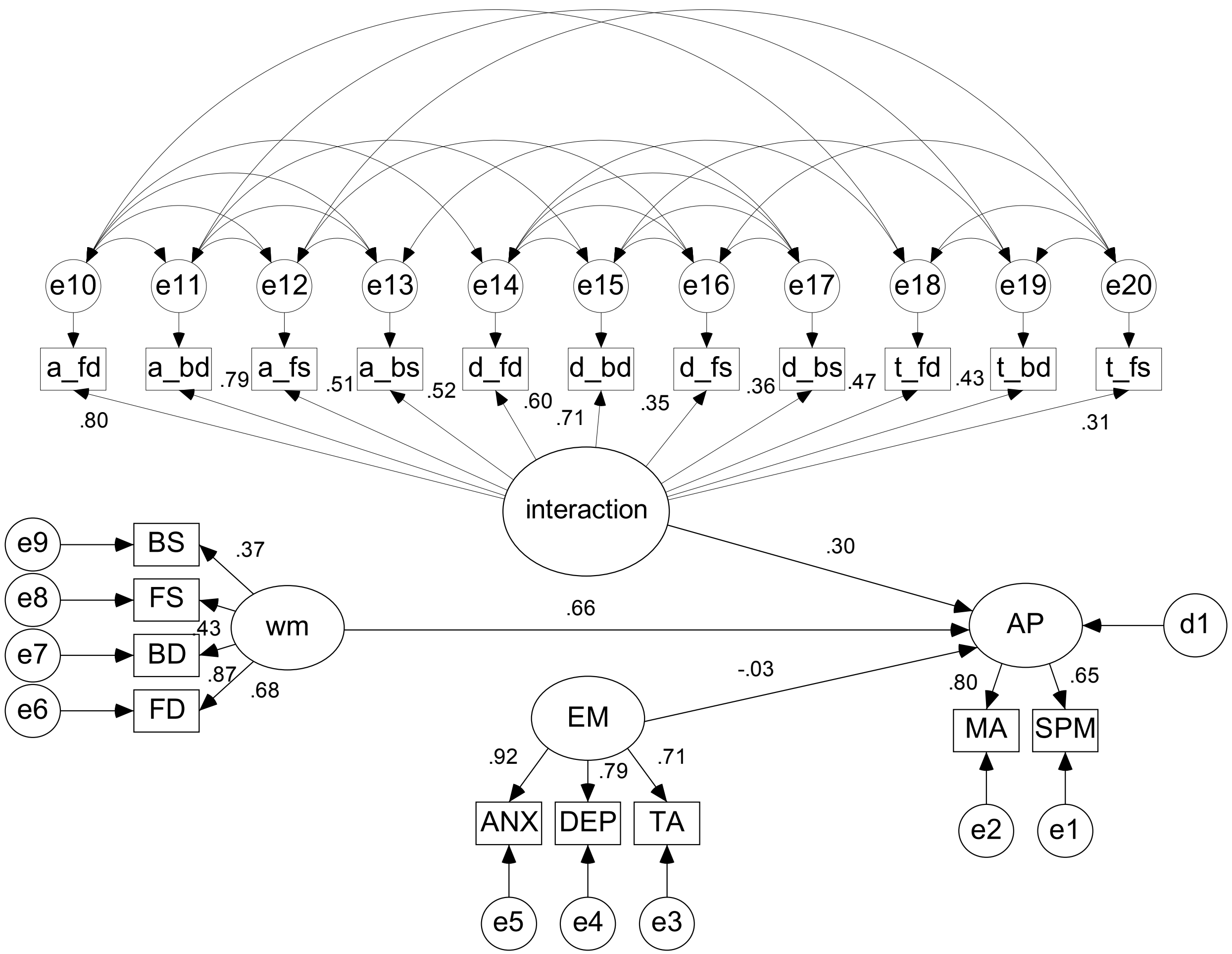


FIGURE 6.7. The high demand structural equation model diagram showing the interaction between emotion and working memory. WM = working memory; BS = backward spatial span, FS = forward spatial span, BD = backward digit span, FD = forward digit span. EM = emotion; ANX = trait anxiety, DEP = depression, TA = test anxiety. AP = academic performance; MA = WRAT maths, SPM = Raven's standard progressive matrices. Interaction = latent variable representing the interaction between emotion and working memory; the indicators of the interaction latent variable are orthogonalised products of EM and WM latent variable indicators; a = trait anxiety, d = depression, t = test anxiety.

Table 6.6. *A comparison of models using the AIC statistic.*

Model	χ^2	df	p	RMSEA	CFI	AIC	Δ_i AIC
1. Emotion by working memory interaction	92.74	142	1.00	.00	1.00	228.74	—
2. Emotion by working memory interaction + task order	105.90	161	1.00	.00	1.00	245.90	17.16†
3. Emotion by working memory interaction + age	112.48	161	1.00	.00	1.00	252.48	23.74†
4. Emotion by working memory interaction + gender	113.47	161	1.00	.00	1.00	253.47	24.73†
5. Emotion by working memory interaction + school attended	117.19	161	.99	.00	1.00	257.19	28.45†
6. Emotion by working memory interaction + time of day	118.99	161	.99	.00	1.00	258.99	30.25†
7. Emotion by working memory interaction + state anxiety at individual	132.57	161	.95	.00	1.00	272.57	43.83†
8. Emotion by working memory interaction + state anxiety at group	146.28	161	.79	.00	1.00	286.28	57.54†
9. 1+2+3+4+5+6+7+8	518.44	322	.00	.08	.83	686.44	457.70†

† Model eligible for elimination using AIC Δ_i >10 criterion

6.4 Interim section: A reanalysis of data presented in Chapter Four.

The emotion x working memory interaction was tested in a separate sample. The finding that high emotion coupled with low working memory was related to the lowest academic performance scores on the one hand, and that high emotion and high working memory was related to the highest average scores was particularly interesting. This pattern suggests that, depending on working memory level, emotion may have a facilitative or debilitative effect on academic performance. The data presented in Chapter Four were reanalysed to test the interaction hypothesis in a separate sample to obtain a clearer picture of the pattern in the data. The data were analysed in exactly the same way as in section 6.3 of the current chapter. The variables used in Chapter Four were trait anxiety and backwards digit span for emotion and working memory respectively. The academic performance measures used were SATs maths, English and science, and CAT quantitative, verbal and nonverbal reasoning test scores.

6.4.1 Results of the reanalysis.

The means, standard deviations and results of the 2 x 2 ANOVAs are presented in Table 6.7. Inspection of the estimated means in Table 6.7 shows that the high trait anxiety/low working memory combination group scored the lowest of all groups on the academic performance tests. Conversely, the high trait anxiety/high working memory combination group scored the highest of all. There was a significant interaction between trait anxiety and backwards digit recall on the SATs maths test ($F(1,46) = 4.3$, $p < .05$). Within the high trait anxiety groups, there was a significant difference between the working memory groups on the SATs maths test ($F(1,17) = 17.04$, $p < .01$). There was no difference in the low trait anxiety group ($F(1,29) = 2.4$, $p = .13$).

There was a significant interaction between trait anxiety and working memory on the quantitative reasoning test ($F(1,46) = 6.2$, $p < .05$). Within the high trait anxiety group, there was a significant difference between the working memory groups on the quantitative reasoning test ($F(1,17) = 19.1$, $p < .001$). There was no group difference in the low trait anxiety group ($F(1,29) = 0.8$, $p = .37$).

Table 6.7. *The interaction between trait anxiety and verbal working memory (backwards digit span) on academic performance tests.*

	High Trait Anxiety/High Working Memory	*Low Trait Anxiety/Low Working Memory*	*Low Trait Anxiety/High Working Memory*	*High Trait Anxiety/Low Working Memory*	F ratio (df)	P value
Maths						
Maths	76.82 (15.60)	60.34 (17.53)	70.29 (18.32)	45.90 (16.90)	4.30 (1,46)	.04*
English	63.63 (18.34)	50.20 (13.77)	61.98 (10.91)	41.60 (14.32)	1.57 (1,46)	.22
Science	65.67 (9.49)	58.00 (14.14)	64.20 (9.27)	54.01 (10.05)	0.69 (1,46)	.41
Quantitative reasoning	110.78 (11.37)	100.44 (13.86)	104.80 (12.90)	88.00 (11.30)	6.20 (1,46)	.02*
Verbal reasoning	112.56 (14.05)	99.88 (14.03)	105.87 (12.28)	93.00 (12.53)	3.09 (1,46)	.09
Nonverbal reasoning	109.11 (15.81)	102.12 (16.86)	107.27 (16.10)	93.70 (11.93)	1.28 (1,46)	.26

*Note.***p* < .05
N=50

6.5 Chapter summary.

The present chapter aimed to assess the linear relationships between self-reported emotions and academic performance. In addition, it explored the role of stress reactivity in this relationship. The chapter further tested whether the interaction between emotion and working memory was associated with differences in academic performance. The test of interaction effects was also replicated in a separate sample (a reanalysis of data presented in Chapter Four).

Unlike the results of the three preceding chapters, the overall association between emotion and academic performance in the present study was not negative. Contrary to previous findings, the pattern in the results suggested a trend for a positive relationship. For example, in the interaction analysis there was a significant positive pathway between emotion and academic performance for tests that have a low working memory demand (i.e. spelling and vocabulary). This suggests that the complexity of the test is important in determining whether effects on academic performance will be negative or positive. In the mediation analysis, there was also a positive path from emotion to working memory in the low stress reactivity group (see Figure 6.5), suggesting that when stress is low emotion may have a facilitative effect on academic test performance. Other researchers have found positive relationships between emotion and academic performance. For example, the meta-analysis of Seipp (1991) showed that the majority of effects representing the relationship between anxiety and academic performance were negative, but she also highlighted null and positive effects. The present analyses show that moderating factors of working memory and stress reactivity should be considered when discriminating between facilitative and debilitative effects of emotion on academic performance.

The linear relationship between emotion and academic performance in the present study was only negative when stress reactivity was high. This replicates the result found in Chapter Five and is consistent with previous research. For example, Deffenbacher (1978) found that a high anxious group solved less anagrams only in a high stress condition. There was a trend to suggest that the relationship was positive in the low stress reactivity group. There was also a striking similarity in the pattern of data for the mediated effects (which were moderated by stress reactivity) for both Chapters Five and the present chapter. Furthermore, the results here, together with those in Chapter Five, highlight that the negative association between emotion and academic performance was mediated by verbal and not spatial working memory in those with high stress reactivity.

The interaction results of this chapter demonstrate that working memory and emotion interact with one another to produce associations with academic performance that are not found when only considering the main effects of each variable. This effect was found for the WRAT maths subtest and the SPM IQ test (high working memory demand) and not for the WRAT spelling and MHV vocabulary tests (low working memory demand). The pattern in the data was consistent in showing that high levels of emotion and low levels of working memory were associated with lowered academic performance. This finding is consistent with PET (Eysenck & Calvo, 1992) and others (e.g. Tobias, 1985) to support the proposition that individuals with an already lowered working memory capacity or ability are more likely to suffer the negative effects of emotion.

Conversely and somewhat unexpectedly, those with high working memory and high emotion performed higher than the other possible combination groups on the high demand academic tests. PET proposes that although worry may have a detrimental effect on cognitive performance in terms of efficiency and effectiveness, there is an additional motivational factor in anxiety that may attenuate the reduction in performance. It could be that those with high anxiety were indeed driven by a motivation to perform well, or more precisely, driven by anxiety to not perform poorly. This is the perspective from PET and is the most likely interpretation of the results. However, motivation was not explicitly measured in this thesis. The addendum or caveat to PET from the data in this study might be that one must have the working memory capacity to be able to increase performance in the light of increased anxiety.

The interactive association between emotion and working memory on academic performance tests was found to be robust. This association was found using two statistical techniques and a reanalysis of the data from a separate sample reported in Chapter Four showed similar evidence of the interaction effect. Using structural equation modelling, potential confounding variables were incrementally added to the original model. Adding the variables attenuated the interaction path slightly but not significantly. The additional variables included task order, gender, age, time of day and school attended. These variables were considered to be potential confounding factors that needed to be eliminated from the analysis. Two further variables of state anxiety and were added to the model as it was possible that they would be instrumental to the relationship. State anxiety may have reduced the interaction effect as from a theoretical perspective, the worry and intrusive thoughts that accompany emotional traits are thought to be accompanied by state anxiety at the time of testing (Eysenck & Calvo, 1992). The results did not support this conclusion. This could have been due to the fact that the state measure was taken at the end of testing and the experience of anxiety during testing that some children would have had may have then subsided. The lack of correlation between the measures of cortisol in this study and self-report measures may also point to the limitations of relying on self-report.

In conclusion, the results of the present chapter show that the link between emotion and academic performance is complicated by two key factors; the first being working memory and the second stress reactivity. The interaction results show that both emotion and working memory in combination must be considered in order to better understand individual differences in academic performance. Furthermore negative effects of emotion are more likely to occur on tasks that make heavy demands on working memory. The mediation results primarily show that negative effects of emotion on academic performance can be partially explained by working memory. The moderated mediation result suggests that this mediation is clearest when stress is high. There is a suggestion in the data that when tests make only low demands on working memory or when stress is low emotion may have a facilitative effect on performance. However, this issue needs further study.

CHAPTER SEVEN: A LONGITUDINAL ANALYSIS.

7.1 Introduction.

Although there is evidence to suggest that anxiety causes lowered academic performance (Hembree, 1988) the causal status of anxiety is nevertheless still uncertain (Putwain, 2007a). One way to address the problem of causality in terms of emotion and academic performance is to use a longitudinal design. Unfortunately there have only been a limited number of longitudinal studies addressing the impact of anxiety on academic test performance (McDonald, 2001). One longitudinal study (Grover, Ginsburg, & Ialongo, 2007) measured a sample of 149 five year-olds in terms of their anxious behaviour/shyness and academic functioning indexed by standardised tests of reading and maths. The children were assessed again at follow-up seven years later. The results showed that teacher-identified anxious youth were nearly three times more likely than non-anxious youth to score in the lowest third for reading and maths at the initial time point. At follow-up, anxious youth were three times more likely to be in the lowest third for reading and nearly two and a half times for maths. This study suggests that anxiety can cause lowered academic performance.

The aim of the present chapter was to address the shortcoming in the literature by carrying out a longitudinal analysis on the effects of emotion on academic performance with special reference to working memory. Two models were specified; the first model was concerned with the mediational hypothesis tested cross-sectionally in Chapters Four, Five and Six, and the second with the emotion x working memory interaction hypothesis also evaluated cross-sectionally in Chapter Six.

The first longitudinal concern of this chapter was the mediational hypothesis. This hypothesis states that emotion will negatively impact academic performance through its action on working memory. This notion is implicit in much of the literature (e.g. Eysenck & Calvo, 1992), although was made explicit recently by Aronen et al. (2005). This study measured both anxiety and depression and the authors suggested that both may be associated with lowered academic performance by first affecting working memory. It was shown in Chapter Four that backward digit span (tapping the PL and CE components of working memory) partially mediated the negative link between trait anxiety and academic performance. In Chapter Five it was shown that this mediation was clearest when stress reactivity was high and when verbal working memory measures were used in the analysis (tapping the PL and CE components of working memory). This result was replicated in Chapter Six, with the additional finding that the mediation effect was clearest with depression and test anxiety combined.

The second longitudinal concern of this chapter was the interaction hypothesis. Following the work of Tobias (1985), it is suggested here that those individuals with high emotion and low cognitive capacity will be the worst academic performers. There is some evidence for this position. Smith et al. (1990), for example, found that underlying concerns and negative thoughts negatively predicted course grades in an introductory psychology course for undergraduates. This finding was in addition to the contribution of ability measured by the scholastic aptitude test. As both ability and negative emotional cognitions were important in explaining course grades, the authors of this study suggested that future research should include both academic deficit as well as cognitive interference from anxiety elements. A similar study found that both maths ability and test anxiety made substantial contributions to variance in a statistics exam (Musch & Bröder, 1999). Although maths ability was the strongest predictor of statistics exam scores the authors concluded that : "nevertheless a purely deficit-based account seems untenable because interfering effects of test anxiety during the examination did also contribute an important portion of variance" (Musch & Bröder, 1999, p.111-112). Longitudinal studies were urged in this study, in order to tease out the causal relationship between emotion and academic performance. In particular it was suggested that while some students may be characterised by a purely deficit model, others might be best described by an interference model or both. The present chapter, therefore, tested whether there would be interactive effects between emotion and working memory on academic performance, as well as main effects of working memory and emotion.

There are then two plausible accounts of the emotion – academic performance relationship. One is the mediation account and the other is best described as an interaction account. These two accounts are not competing hypotheses but in a sense are parallel. The mediation analysis is asking the question via what mechanism does the relationship between emotion and performance operate when it exists? This relationship is further complicated by the apparent requisite of stress being present to elicit negative effects of emotion on performance. On the other hand, the interaction analysis asks under what circumstances emotion is most likely to negatively affect performance? The hypothesised answer to this question is when working memory is low. The present chapter therefore tested both the mediational and emotion x working memory interaction hypotheses over two time points. To recap, the interaction hypothesis suggests that emotion and working memory in combination will predict future academic performance. The mediational hypothesis suggests that emotion will predict later academic performance via working memory.

7.2 Method.

7.2.1 Participants.

The participants were drawn from the same sample of 96 used in Chapter Six. In the event, 83 participants from the original sample (87%) were included in the present longitudinal analysis. The attrition was due to a number of factors. These included participants whose family had moved away from the area, time constraints on study completion, participants' requests to drop out from the study to concentrate more on school work before exams and several cases (N = 5) had substantial missing data due to an uncompleted testing session.

7.2.2 Procedure.

Throughout this chapter "T1" denotes the first time point of data collection and "T2" denotes the second time point. The procedure followed at T2 was identical to that followed at T1 and is reported in Chapter Six. The average time between T1 and T2 testing was 37.1 weeks (SD = 2.24; range = 33 – 39 weeks).

7.3 Data analysis.

The data were analysed in a structural equation modelling framework using AMOS 16.0. Given the size of the longitudinal models (essentially double that of previous cross-sectional models), there was some statistical pressure on the dataset. Specifically, if the ratio of parameters to sample size becomes too low in a structural model then the parameter estimates may become unreliable. This pressure was particularly evident for the interaction model which included an interaction term with a large number of parameters to be estimated. Therefore latent variables were kept to a minimum in the present analysis and only specified for the academic performance variables with two indicators each. For the remaining variables, a decision was made to use the sum of the standardised scores (z scores) for each indicator variable of a latent variable. In keeping with Chapter Six these variables were depression, test anxiety and trait anxiety for emotion and forward and backwards digit span and forward and backwards spatial span for working memory. In both the mediation and interaction analyses, academic performance was first measured using the tests that are assumed to make high demands on working memory (the maths test and the Raven's SPM test). As a comparison to the high demand models, similar models were run with the academic performance tests assumed to make low demands on working memory (the spelling test and the MHV test).

In the mediation analysis, the z scores of the variables shown to be important in the emotion - working memory - academic performance mediation link in Chapter Six were summed to create emotion and working memory variables. For the emotion variables these were depression and test anxiety. For working memory these were the verbal measures of forwards and backwards digit span and listening recall. An indirect effect of emotion on T1 academic performance via verbal working memory is expected, as this is a replication of the result in Chapter Six with only a small reduction in sample size. This cross-sectional finding in the absence of a longitudinal effect would suggest a transient indirect effect. In the case of longitudinal mediation (model illustrated in Figure 7.1), an indirect effect on T2 academic performance would suggest a more chronic indirect effect of emotion on academic performance. In addition, a path from T1 academic performance to T2 emotion was specified to test the alternative, deficit hypothesis that poor academic performance would predict higher levels of emotion. The indirect effects were calculated automatically by the AMOS programme. An indirect effect is calculated by multiplying the standardised regression weights along an indirect path. In the case of multiple indirect paths, the products of the weights along an indirect path are summed to arrive at a single standardised indirect effect.

As a preliminary step in the interaction analysis, the known emotion x working memory interaction on T1 academic performance (see Chapter Six) and the potential for an interaction effect at T2 academic performance were explored using group differences (high and low emotion) on T1 and T2 maths and SPM scores. These differences were calculated separately for high and low working memory groups.

In the interaction analysis (illustrated in Figure 7.4), the path from the T1 interaction term to T2 academic performance was of particular interest. A significant path here would suggest that the interaction predicts future academic performance. The size of this interaction coefficient controls for the main effects of emotion and working memory as well as prior academic performance.

7.4 The mediation model.

The hypothesised mediation model is illustrated in Figure 7.1. This model tests the prediction that there will be a negative indirect effect of emotion on academic performance at T1 and also at T2.

The initial mediation model was a moderate fit to the data (χ^2 = 34.15, *df* = 22, χ^2/df = 1.55, *p* = .05, CFI =.96, RMSEA = .08), however, the bootstrapped samples failed to converge at any number. The source of the problem was identified as the academic performance latent variables. In order to run the bootstrapping procedure and therefore calculate *p*-values for the indirect effect, the sum of the z scores for maths and SPM were used in single variables for T1 and T2 academic performance. One thousand bootstrapped samples were requested.

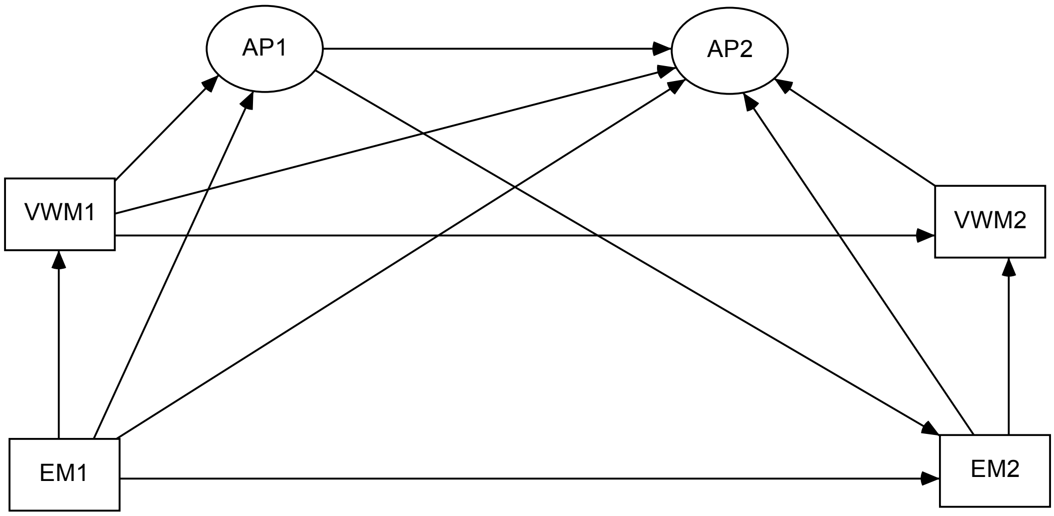


FIGURE 7.1. The hypothesised mediation model. VWM1 = T1 verbal working memory; EM1 = T1 emotion comprised of depression and test anxiety; AP1 = T1 academic performance. Variables to the right of the diagram labelled with 2 are the T2 equivalents of T1 variables.

This model (Figure 7.2) was a good fit to the data (χ^2 = 8.63, df = 6, χ^2/df = 1.44, p = .20, CFI =.99, RMSEA = .07). In the high stress reactivity group there was a significant indirect effect of T1 emotion on T1 academic performance (β = -.17, $p <$ .05) and T2 academic performance (β = -.47, $p < .01$). The predictors explained 34% of academic performance at T1 and 72% at T2. There were no significant indirect effects on academic performance in the low stress reactivity group. T1 academic performance did not significantly predict T2 emotion in either the high or low stress reactivity group.

Both significant indirect effects were found in the high stress reactivity group only. The T1 indirect effect was relatively simple to interpret, having only working memory to pass through. It showed that emotion was negatively associated with T1 academic performance via T1 working memory. The T2 indirect effect, of T1 emotion on T2 academic performance however, was more complex and had a total of 10 indirect pathways. The four most important pathways in the T2 indirect effect, as determined by a summation of the products of the coefficients in the pathway, will be discussed. Together, these four pathways accounted for 95% of the total T1 emotion to T2 academic performance indirect effect. Two paths included working memory as mediators while two paths were working memory independent.

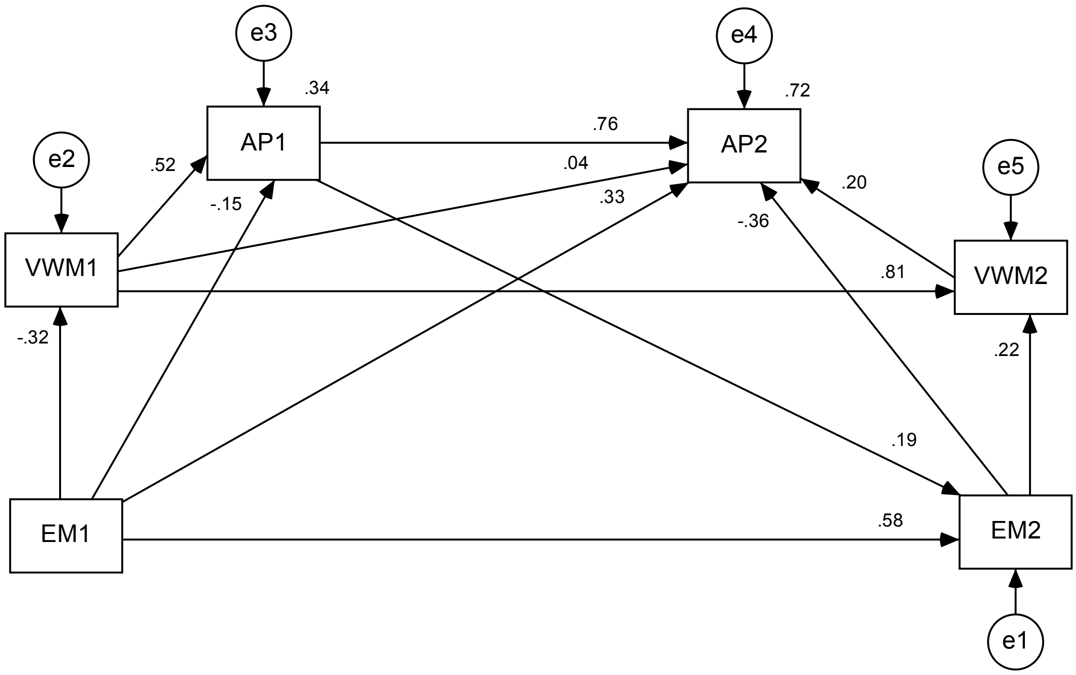


FIGURE 7.2. The high stress reactivity mediation model. VWM1 = T1 verbal working memory; EM1 = T1 emotion comprised of depression and test anxiety; AP1 = T1 academic performance. Variables to the right of the diagram labelled with 2 are the T2 equivalents of T1 variables.

Firstly, there was a sizeable pathway from T1 emotion to T1 working memory to T1 academic performance to T2 academic performance (β = -.12). This suggests that emotion can negatively impact on working memory, which in turn affects immediate and future academic performance. The second path was from T1 emotion to T1 working memory to T2 working memory to T2 academic performance (β = -.05), suggesting an effect through working memory over time. The third important route was from T1 emotion to T1 academic performance to T2 academic performance (β = -.11), suggesting an influence of emotion on academic performance that was independent of working memory. The last pathway was from T1 emotion to T2 emotion to T2 academic performance (β = -.20). This suggests a longitudinal pathway that is also independent of working memory. A notable feature of the data was that the path between T1 emotion and T1 working memory was negative and significant (β = -.32, p <.05), while the path from T2 emotion to T2 working memory was *positive* and significant (β = .22, p <.05). To some extent this difference is a reflection of the complexity of the model. There is a path from T1 emotion to T1 working memory to T2 working memory as well as the direct path from T2 emotion to T2 working memory described above. Without the T1 pathway predicting T2 working memory the T2 emotion to T2 working memory path is negative although not significant (β = -.03, p <.89). This suggests that the relationship between emotion and working memory can change over time within individuals.

The low demand working memory model was a poor fit to the data on most measures (χ^2 = 20.34, df = 6, χ^2/df = 3.39, p < .01, CFI =.95, RMSEA = .17). Modification indices revealed no potential improvements to the model fit. The fit of this model was deemed too poor to be acceptable. However, a negative indirect effect between T1 emotion, via T1 working memory, to T1 academic performance was found in the high stress reactivity group (β = -.15, p < .05). There were no significant paths from the emotion variables or significant indirect effects from the emotion measures in the low stress reactivity group (Figure D.1 in Appendix D).

A further model was specified to test whether there was a cumulative effect of stress reactivity (Figure 7.3). That is, whether those individuals in the high stress group at both T1 and T2 would show the strongest indirect effects of emotion on academic performance. Therefore the mediation model was re-specified with a sample containing the children that were in the high stress reactivity group at both T1 and T2. The cumulative model had the effect of reducing the sample size to N = 22 which is very low. For this reason this analysis was exploratory only. The model was only a moderate fit to the data (χ^2 = 4.91, df = 3, χ^2/df = 1.64, p = .18, CFI =.98, RMSEA = .17). However, there was a similar pattern for the high stress group in this cumulative model to the pattern found for the high stress group at T1 only model. There was a significant indirect effect of T1 emotion via working memory on T1 academic performance (β = -.31, $p < .05$) and a significant indirect effect of T1 emotion on T2 academic performance (β = -.62, $p < .01$). These estimates were almost twice as large as in the T1 high stress group model. There was no significant negative indirect effect of T2 emotion via T2 working memory on T2 academic performance. In fact this indirect path was marginally positive (β = .05, $p = .22$). There was only a significant direct path from T2 emotion to T2 academic performance (β = -.60, $p < .01$).

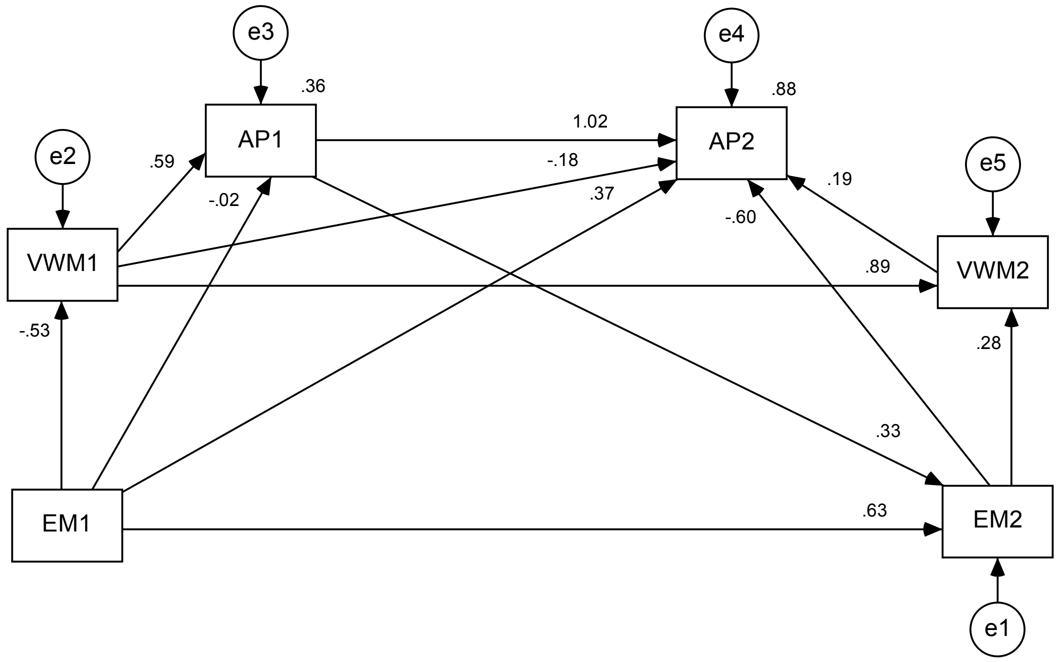


FIGURE 7.3. The cumulative high stress reactivity mediation model. The sample included individuals who were in the high stress group and both T1 and T2. VWM1 = T1 verbal working memory; EM1 = T1 emotion comprised of depression and test anxiety; AP1 = T1 academic performance. Variables to the right of the diagram labelled with 2 are the T2 equivalents of T1 variables.

7.5 The interaction model.

The preliminary analysis will be reported first. In the low working memory group the high emotion group scored significantly lower than the low emotion group on T1 maths ($F(1,40) = 5.9$, $p < .05$) and T1 SPM ($F(1,40) = 5.7$, $p < .05$). There were also similar group differences between the high and low emotion groups within the low working memory group at T2 maths ($F(1,40) = 4.7$, $p < .05$) and T2 SPM ($F(1,40) = 7.2$, $p < .05$). In contrast, in the high working memory group there were no significant group differences between the high and low emotion groups on any academic performance measures (*p*s > .10). The means, standard deviations and associated *p*-values are shown in Table 7.1.

Table 7.1. *Preliminary interaction analysis: Mean high demand working memory academic test differences between high and low emotion groups by working memory group at T1 and T2.*

	High Working Memory				*Low Working Memory*			
	High Emotion	*Low Emotion*	F ratio (df)	*P*-value	*High Emotion*	*Low Emotion*	F ratio (df)	*P*-value
Raven's SPM T1	46.33 (5.68)	46.55 (5.08)	.02 (1,39)	.90	40.65 (7.51)	45.18 (4.59)	5.68 (1,40)	.02*
WRAT Maths T1	39.71 (5.82)	41.05 (4.50)	.67 (1,39)	.42	34.05 (4.42)	37.18 (3.94)	5.90 (1,40)	.02*
Raven's SPM T2	43.90 (7.42)	46.65 (3.63)	2.22 (1,39)	.14	38.15 (8.29)	43.50 (4.09)	7.23 (1,40)	.01*
WRAT Maths T2	41.52 (5.69)	42.75 (4.03)	.63 (1,39)	.43	35.45 (4.06)	38.27 (4.34)	4.72 (1,40)	.04*

*Note.**$p < .05$

The full hypothesised interaction model is presented in Figure 7.4.

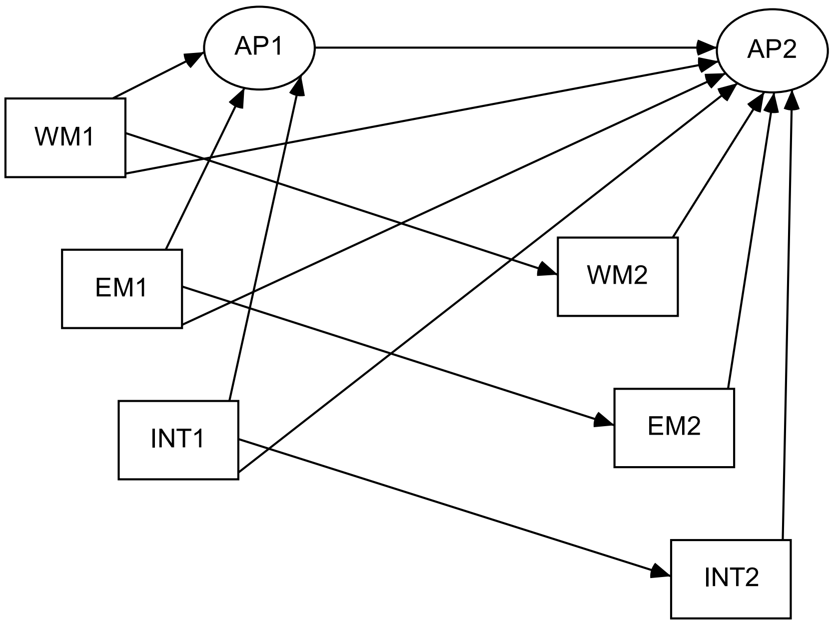


FIGURE 7.4. An illustration of the hypothesised emotion x working memory interaction model. WM1 = T1 working memory; EM1 = T1 emotion; INT1 = T1 interaction between emotion and working memory; AP1 = T1 academic performance. Variables to the right of the diagram labelled with 2 are the T2 equivalents of T1 variables.

The initial interaction structural equation model corresponding to Figure 7.4 was specified and found to be a moderate fit to the data (χ^2 = 44.48, *df* = 26, χ^2 /*df* = 1.71, *p* = .01, CFI =.95, RMSEA = .09). Modification indices showed that an additional path from the T1 interaction variable to T2 emotion would improve the model fit by reducing the chi square by at least 5.69 points. In addition, it was also highlighted that a path from T1 academic performance to T2 working memory would improve the model fit by reducing the chi square by at least 4.18 points. These paths were added and the model was rerun. The resulting model was a good fit to the data (χ^2 = 29.43, *df* = 24, χ^2 /*df* = 1.23, *p* = .20, CFI =.99, RMSEA = .05).

The final revised model is shown in Figure 7.5. The path coefficients in this model will now be described.

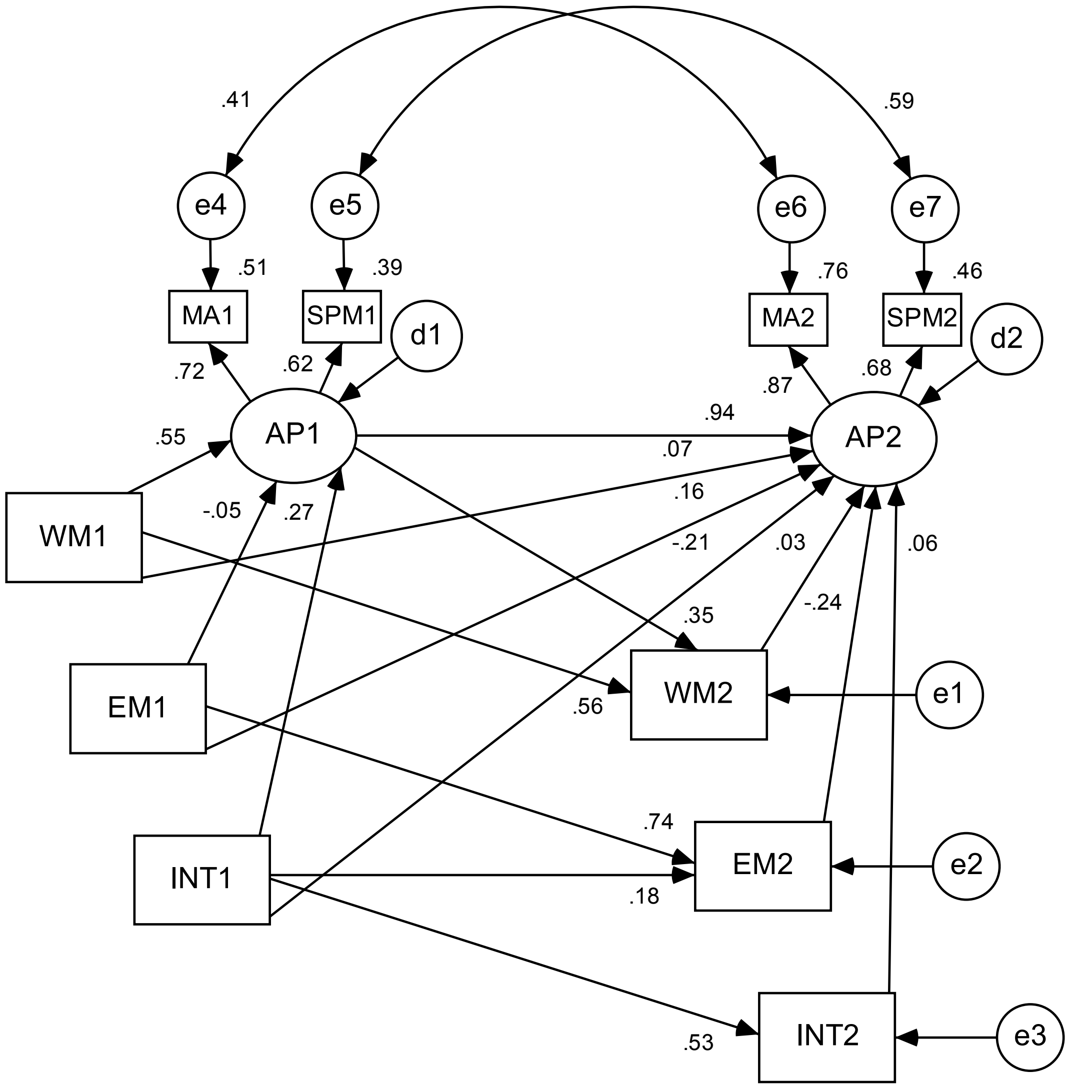


FIGURE 7.5. The revised high demand working memory interaction model. WM1 = T1 working memory; EM1 = T1 emotion; INT1 = T1 interaction between emotion and working memory; AP1 = T1 academic performance. Academic performance is comprised of the maths test and the Raven's SPM test in this high demand model. Variables to the right of the diagram labelled with 2 are the T2 equivalents of T1 variables.

Emotion was related to itself over time (β = .74, $p < .01$), as was working memory (β = .56, $p < .01$), academic performance (β = .94, $p < .01$) and the interaction term (β = .53, $p < .01$). T1 working memory was positively related to academic performance at T1 (β = .55, $p < .01$) and T1 emotion was not (β = -.05, $p = .65$).

There was a significant path from the interaction term at T1 to academic performance at T1 (β = .27, $p < .05$). T1 working memory was not directly related to academic performance at T2 (β = .07, $p = .58$). However, there was a substantial indirect effect (β = .54, $p <.05$) of T1 working memory on T2 academic performance via T1 academic performance and T2 working memory. T1 emotion did not predict T2 academic performance (β = .16, $p = .12$).

The T1 emotion x working memory interaction significantly predicted academic performance at T2 (β = -.21, $p < .05$). This interaction effect predicted T2 academic performance in addition to working memory and emotion at both time points and was also net of academic performance at T1. The model as a whole explained 37% of the variance in T1 academic performance and 97% in T2 academic performance. The discrepancy between the two variances is due to the autocorrelation between T1 and T2 academic performance. That is, less variance of T1 academic performance is explained than at T2 primarily because academic performance prior to T1 is not known and therefore not controlled for. At T2, there were no associations between T2 working memory and T2 academic performance (β = .07, $p = .58$) performance. There was no significant T2 emotion x working memory interaction associated with academic test scores at T2 (β = .06, $p = .42$). There was, however, a significant path from T2 emotion to T2 academic performance (β = -.24, $p < .05$).

The low working memory demand model was a good fit to the data (χ^2 = 36.17, df = 26, χ^2/df = 1.39, p = .09, CFI =.97, RMSEA = .07) but did not include any significant paths from emotion or the emotion x working memory interaction variables to either academic performance latent variable (ps > .1). This model was not considered further and is illustrated in Figure D.2 in Appendix D.

7.6 Chapter Summary.

The aim of the present study was to assess whether emotion would be linked to academic performance over time as well as simply cross-sectionally. Two fundamental models were tested. The first was a moderated mediation model and the second was an emotion x working memory interaction model.

The mediation model was also a close fit to the data. There was a significant indirect path from T1 emotion to T1 academic performance (β = -.17, $p < .05$) and also between T1 emotion to T2 academic performance (β = -.47, $p < .01$). This result suggests both concurrent and chronic effects of emotion on performance. The latter chronic effect, over time, suggests that high negative affect causes lowered academic performance. The time sequence of the model is temporally consistent with this conclusion and the nature of the model shows that prior academic performance is controlled for as well as concurrent measures of self-reported emotion. The finding is therefore robust. There may be other factors not included in the model that are influential in the pathway from high emotion to low academic performance, such as parental support, motivation, or avoidance behaviours. However, these are uncontrolled variables in this study. The T1 mediation effect revealed an indirect path from emotion to academic performance through working memory. This finding replicates and extends that of Chapters Four, Five and Six. The longitudinal indirect effect was more complex. Four main pathways from T1 emotion to T2 academic performance explained most of the overall indirect effect. Two of the pathways were by way of working memory, which generally supports the mediational hypothesis. That is, that high emotion causes disruption in working memory processes which in tun cause lowered academic performance. The fact that the emotion variable included depression, as well as test anxiety, supports the view that both anxiety and depressive symptoms may be involved in a negative link with working memory and academic performance (Aronen et al., 2005; Christopher & MacDonald, 2005). In addition, the working memory measures included in this model were verbal and two out of three were designed to tap CE resources. This result is consistent with the assumptions of PET which proposes that negative effects of anxiety on performance will be most often seen on the PL and CE.

The two further indirect pathways from T1 to T2 academic performance did not include working memory. The first pathway went from T1 emotion to T2 academic performance via T1 academic performance. This finding suggests that there could be other factors involved in the negative emotion causal effect on performance over and above working memory. The final indirect pathway showed an influence from T1 emotion to T2 emotion and then directly to T2 academic performance but not through T2 working memory. It should be noted that previous working memory was controlled for and the effect via T2 working memory may have been diluted for this reason. Nevertheless other factors are likely to be involved in the relationship between emotion and academic performance. One potential mechanism could be avoidance which is a central feature of anxiety (Barlow, 2000; Rapee, 2002) and also depression (Ottenbreit & Dobson, 2004). It has been shown, for example, that maths anxious individuals tend to avoid maths by taking fewer maths classes (Ashcraft, 2002). In support of this point Turner et al. (2002) showed that avoiding help- seeking and avoiding novelty were negatively correlated with maths grades (r = -.33 and r = -.19 respectively).

Consistent with Chapter Five and Six, the mediation effects were only seen when stress reactivity was high. This finding is also consistent with previous systematic investigations of the negative effects of stress on performance (Deffenbacher, 1978) as well as many studies that manipulate stress as part of the general procedure to their experiments (Derakshan & Eysenck, 1998; Eysenck et al., 2005; Ikeda et al., 1996). This suggests that high negative affect can cause lowered academic performance, through a disruption of working memory, under the condition that stress levels are high.

A cumulative model explored the possibility that those individuals who were consistently stressed (in the high stress reactivity group at T1 and T2) would show the strongest negative mediation effects. The results supported this conclusion as both indirect effects in this model were approximately twice as large as those same paths in the T1 high stress reactivity group model. Therefore emotion causes lowered academic performance via working memory when stress is high. Furthermore, when stress is chronic, the causal effects of emotion on lowered academic performance may be stronger still.

The interaction and mediation effects of emotion and working memory were both expected to be seen on the tests assumed to make heavy demands of CE resources. This was the case in the both sets of analyses. This result is consistent with previous research suggesting that negative effects of emotion will emerge for difficult tasks (Ellis, 1985; Eysenck & Calvo, 1992). The specific association between mediation and interaction effects on the maths test is also consistent with the maths anxiety research (Ashcraft & Krause, 2007; Ashcraft & Kirk, 2001), as well as other anxiety research that has used maths or statistics as an outcome (Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998; Musch & Bröder, 1999). Similarly, the negative effects of emotion on the Raven's IQ test is consistent with many studies that have used IQ tests as performance indicators (Darke, 1988; Hembree, 1988; Hopko et al., 2005; Mandler & Sarason, 1952).

Maths has been shown to be particularly related to CE working memory processes in children (Gathercole et al., 2004). Working memory is likely to be involved in successful completion of the SPM as some researchers argue that working memory equates with IQ or at least is its primary determinant (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002). Interestingly, the Raven's SPM manual also notes the negative influence of emotion on testing (Raven, 2000).

An additional factor that separates the two types of academic performance (high and low working memory demand tests) is timing. Both the SPM and the maths test were strictly timed. This timing element might work to increase emotion and subsequent task-irrelevant thoughts, thus being a significant factor in explaining the negative effect of emotion on performance. There is some evidence that the timing of tests is likely to increase the negative influence of emotion on performance (McDonald, 2001; Zeidner, 1998) and timing is often mentioned as a concern by students with test anxiety (Powers, 1986). However, future research should explore more clearly the role of timing in performance and anxiety.

The results also highlighted a significant indirect effect of T1 emotion on T1 academic performance via working memory on the spelling and vocabulary tests in the high stress group. Spelling does involve working memory processes (Service & Turpeinen, 2001) and it is possible that a substantial amount of working memory was used in the spelling test for a disruption by emotion to influence performance scores. The vocabulary test is unlikely to involve much working memory, although it does involve the PL. An alternative explanation for the data could be that the negative link with emotion is involving other working memory processes. For example the episodic buffer is proposed to act as a gateway to long term memory (Baddeley, 2000). It is possible that this component is affected in the case of spelling and vocabulary.

Cross-sectional effects of emotion on academic performance alone in either model suggest a transient effect, whereas indirect effects of emotion on academic performance over time suggest more chronic effects. Moreover, cross sectional analyses are unable to speak directly to the causality problem. For example, an alternative explanation for the cross sectional data could be that poor academic performance causes high levels of emotion. These problems of interpretation were addressed in this longitudinal analysis, which found no significant path between T1 academic performance and T2 emotion. This would have suggested that performing poorly at T1 increased negative affect at T2. However, this was not the case. Overall the results suggest that in addition to transient effects of emotion on academic performance, emotion may also have a chronic negative effect over time under certain circumstances. When emotion is high and working memory is low, the result is lowered academic performance. More generally, emotion can have a negative indirect effect on academic performance when stress is high.

The interaction model was also a good fit to the data on all model fit indices. The most striking feature in the interaction model was the strong autocorrelation between T1 and T2 academic performance ($\beta = .94$, $p < .01$). This shows that the majority of the variance in T2 academic performance was explained by prior academic performance (88%). Consistent with previous findings (Gathercole et al., 2004) working memory was also shown to be predictive of academic performance. This was illustrated by an indirect effect of T1 working memory on T2 academic performance via T1 academic performance. In other words, the results suggest that working memory aids academic performance at T1 which then carries over to T2 academic performance. The predictive value of T2 working memory in explaining T2 academic performance was small ($\beta = .03$, $p = .84$). However, this can be explained by the fact that previous working memory and its indirect effect through T1 academic performance was controlled for in the model.

The most significant finding in the interaction model was the significant T1 interaction path to T2 academic performance, suggesting that the emotion x working memory interaction predicted academic performance over time. The size of the coefficient in this path controls for emotion, working memory, as well as previous academic performance. This path coefficient was negative, suggesting that any positive effects of emotion in the interaction due to high working memory seen at T1 (described below), were cancelled out over time by the negative effect of high emotion and low working memory in combination. This finding is in keeping with the suggestion made by previous studies that cognitive capacity, as well as emotion per se, should be taken into account when studying the emotion – academic performance link (Musch & Bröder, 1999; Smith, Arnkoff, & Wright, 1990; Tobias, 1985). The results lend support to the hypothesis derived from Tobias (1985) that individuals with high emotion and low working memory will be the lowest academic performers. The results are also consistent with the two previous studies that assessed the relative contributions of ability and anxiety to academic performance (Musch & Bröder, 1999; Smith et al., 1990). Both these studies showed that academic ability was a strong predictor of performance, although the influence of anxiety was shown to be either stronger than ability or too substantial to be discarded from future research. The results of the present chapter show that prior academic ability is the most important predictor of future academic performance, followed by working memory. Over and above these factors, however, the interaction between emotion and working memory makes a significant contribution to variance in later academic scores. The meaning of the significant interaction over time is that having both low working memory capacity and high negative affect causes lower academic performance, more than having either of the two components separately.

There was also a significant T1 emotion x working memory interaction on T1 academic performance scores. This was essentially a replication of the result described in detail in Chapter Six but with a reduced sample size. Similar to the results found in Chapter 6, the interaction path was positive in these results. This finding was a reflection of the fact that in addition to those with high emotion and low working memory performing the worst of all, those with high emotion and high working memory tended to perform better than any other combination group. This suggests that emotion can have a positive influence on performance if working memory capability is high. This finding fits with PET to suggest that individuals with high anxiety are motivated to devote additional resources to tasks to increase performance and avoid the negative consequences of task failure. If sufficient working memory resources are available for these individuals, as for the high working memory group, then the additional effort could pay dividends in terms of better test performance. Future research should explore more fully the role of individual effort or motivation to understand this result more clearly. There were no significant interaction paths in the low demand working memory models suggesting that negative effects of emotion x working memory are more likely to occur when the academic tests are more demanding of working memory such as maths or IQ tests.

In conclusion, this chapter has supported other research that suggests that high levels of affect can negatively affect academic functioning over time (Grover et al., 2007). Moreover, this chapter has highlighted two models that may explain links between anxiety, working memory and academic performance. It showed that negative associations between emotion, working memory and ultimately academic performance may be both concurrent and chronic. The interaction model found that high levels of emotion coupled with low working memory capacity may have a causal influence on future academic performance. The mediational model indicated that when stress is high, emotion may negatively influence later academic performance via working memory. In both models, these effects were found to be more pronounced on tasks that make use of either PL, CE processes or both. In order to further test the causal status of emotion on academic performance, further experimental and longitudinal study designs would be beneficial. This work is especially needed in the UK as relatively little of the research into emotion and learning has been carried out in this country (Putwain, 2007b). An example of such an experiment would be by using a working memory training sessions and ending in IQ testing, over a period of time. A memory test for a word list, for example, could be added to test the negative effects of negative affect on long term memory. The experiment could utilise randomisation of children/adults to a stress induction group and normal control. Should the experimental group show weaker gains on the performance measures then this would bolster the argument that high emotion causes poor performance.

CHAPTER EIGHT: GENERAL DISCUSSION

8.1 Summary.

The aim of this thesis was to understand the negative link between emotion and academic performance through empirical investigation. A summary of the main findings of each chapter is given in Table 8.1. The first empirical chapter (Chapter Three) assessed the relationship between emotion and academic performance using three self-report measures of emotion including trait anxiety, depression and test anxiety. Academic performance was measured by standardised national curriculum tests and cognitive abilities tests. Chapter Four explored the relationship between trait anxiety and academic performance further and tested whether working memory would mediate this link. Chapter Five was an extension of the two previous chapters (Chapters Three and Four) and assessed the link between emotion (trait anxiety, depression and test anxiety) verbal and spatial working memory and academic performance. In addition, stress reactivity was measured using the physiological index cortisol. Stress reactivity was assessed as a moderating influence on the relationship between emotion and academic performance and the mediation via working memory. Chapter Six replicated the tests of processes identified in previous chapters, but with a larger sample size and assessed whether having both high emotion and low working memory would be associated with the lowest academic performance. The analysis in Chapter Seven tested the central hypotheses of the thesis in a longitudinal framework, testing whether emotion would negatively affect academic performance over time.

The initial focus of this thesis was to evaluate the size and direction of the association between emotion and academic performance. This aspect of the thesis will be discussed before the main hypotheses of the thesis are outlined and addressed. Previous research has suggested that the direction of effect between anxiety and academic performance is usually negative, but sometimes positive (Seipp, 1991). In short, this mixed pattern of results is what was found in this thesis; where the simple unmoderated associations between emotion and academic performance were negative in three out of four samples (Chapters Three, Four and Five).

Table 8.1. *A summary of the findings in each chapter of this thesis.*		
Chapter	**Aim**	**Result**
Chapter Three	To assess the relationship between emotion and academic performance.	Test anxiety, trait anxiety and depression were all negatively linked to cognitive ability and attainment tests. Structural models showed that latent variables combining all three emotions produced the largest estimates of the relationship (*N* = 84).
Chapter Four	To test the prediction found in the PET that working memory would mediate the relationship between emotion and academic performance.	Verbal working memory (tapping the PL and CE) partially mediated the relationship. Approximately 50% of the relationship was explained. Spatial working memory (tapping the VSSP) did not act as a mediator (*N* = 50).
Chapter Five	To assess the mediation hypothesis with anxiety and depression and by using verbal and spatial working memory tasks tapping CE processes. Mediation was hypothesised to be strongest when stress reactivity was high. Stress reactivity was measured by salivary cortisol.	Verbal working memory partially mediated the negative emotion-academic performance link. This was clearest when stress was high (i.e. a moderated mediation). Spatial working memory partially mediated the emotion-academic performance link independent of stress reactivity. CE processes were implicated (N = 31).
Chapter Six	1) To test the moderation mediation hypothesis in a larger sample. 2) to test the interaction hypothesis that predicts that children with high levels of emotion and low levels of working memory would score the lowest on academic tests.	The results showed support for the moderated mediation hypothesis with depression and test anxiety combined and for verbal working memory. Spatial working memory did not act as a mediator in the high stress reactivity group (*N* = 96).
Chapter Seven	A longitudinal analysis designed to specifically test the moderated mediation and interaction hypotheses.	There was evidence to support both hypotheses. Prior academic performance was controlled for in both models (*N* = 83). Over time, low working memory and high emotion in combination was associated with lower academic performance. Verbal working memory partially mediated the negative link between emotion and academic performance over time when stress reactivity was high.

In Chapters Six and Seven a negative association between emotion and academic performance was found only for those children who showed high stress reactivity. In contrast there was some evidence to suggest a positive relationship between emotion and academic performance when stress was low. A comparison of the associations between emotion and academic performance is shown in Table 8.2.

Previous research has also found that the average size of the association between anxiety and academic performance is approximately r = -.21 (e.g. Schwarzer, 1990). The associations between emotion and academic performance in this thesis were shown to be approximately equal to that size. For example, in the first empirical study in Chapter Three the average relationship between emotion and the academic performance tests was r = -.24 for trait anxiety, r = -.22 for test anxiety and r = -.29 for depression. In Chapters Three and Five, a latent variable combining all three types of emotion (trait anxiety, test anxiety and depression) produced slightly larger associations between emotion and academic performance in terms of attainment tests (β = -.37) and cognitive abilities tests (β = -.31) in Chapter Three and in terms of maths and science tests (β = -.30) in Chapter Five. This patter of results suggests that all three emotions are important in the association with academic performance and raises the possibility that there may be a common mechanism underlying this association (Aronen et al., 2005; Christopher & MacDonald, 2005). These two studies both suggest that a disruption of working memory processes may be common to both anxiety and depression. Indeed the trait emotion variables were highly interrelated which is consistent with previous research (Chorpita et al., 2000; Muris, Meesters, & Schouten, 2002; Muris et al., 2002).

The possible common mechanism through which trait anxiety, test anxiety and depression might all adversely affect academic performance is in the disruptive and or distractive influence on working memory. Although there are differences between the three constructs in terms of the type and quality of intrusive distracting thoughts, the quantity of thoughts and the cognitive resource-draining nature of task-irrelevant thinking in individuals high in these traits is the proposed common mechanism. For example, trait anxiety is characterised by worrisome thoughts, whereas the thoughts involved in test anxiety will be specific worries about test situations and outcomes. Depression on the other hand, is often characterised by ruminative negative self thinking. To reiterate, although the nature of thoughts will differ across different traits (anxiety, test anxiety, depression), the presence of distracting, resource-costly thoughts regardless of type may be the common mechanism that explains how working memory is disrupted in all these cases. Ultimately, this disruption can cause lowered academic performance.

The finding that negative emotion more broadly is linked to working memory and academic achievement suggests that inclusion of multiple measures of emotion in research assessing the relationship between emotion and academic performance is desirable in order to maximise the estimation of this link. It also suggests that the further investigation of the negative effects of depression, which has been largely under-researched to date, as well as anxiety on academic performance is warranted.

There were three main hypotheses in this thesis. First it was hypothesised that one mechanism that would partially explain the negative link between emotion and academic performance would be working memory. This is the partial mediation hypothesis. Second, the mediation effect of emotion on academic performance through working memory was thought to be strongest when stress reactivity was high. This was the moderated mediation hypothesis. Third, it was expected that children with high emotion and low working memory would have the lowest academic performance scores. This was the emotion x working memory interaction hypothesis. The mediation hypothesis will be discussed first.

Table 8.2. *A summary of the associations between emotion and academic performance found in this thesis*				
Chapter	Emotion	Academic performance	Direction of effect	Size of effect
Chapter Three	Trait anxiety	Average *r* with CAT & SAT	negative	$r = -.24$ [a]
	Depression	Average *r* with CAT & SAT	negative	$r = -.29$ [a]
	Test anxiety	Average *r* with CAT & SAT	negative	$r = -.22$ [a]
	latent variable including trait anxiety, depression and test anxiety	Latent variable including attainment tests (SATs)	negative	β = -.37**
	latent variable including trait anxiety, depression and test anxiety	Latent variable including cognitive ability tests (CAT)	negative	β = -.31*
Chapter Four	Trait anxiety	Latent variable including attainment tests (SATs)	negative	β = -.27†
	Trait anxiety	Latent variable including cognitive ability tests (CAT)	negative	β = -.30*
Chapter Five	latent variable including trait anxiety, depression and test anxiety	Latent variable including attainment tests of maths and science.	negative	β = -.30*

	Identical variables as above - high stress reactivity only		negative	$\beta = -.63^{**}$
	Identical variables as above - low stress reactivity only		negative	$\beta = -.09$
Chapter Six	latent variable including trait anxiety, depression and test anxiety	Latent variable including attainment tests of maths, spelling and IQ.	positive	$\beta = .24^{\dagger}$
	Trait anxiety excluded but high stress reactivity		negative	$\beta = -.41^{\dagger}$
	Trait anxiety excluded but low stress reactivity		positive	$\beta = .32^{\dagger}$
Chapter Seven	Summed standardised scores for depression and test anxiety at Time 1	Summed standardised scores for maths and Raven's SPM at Time 2		
	High stress reactivity		negative	$\beta = -.47^{**}$
	Low stress reactivity		positive	$\beta = .09$

Note.
[a] denotes a median correlation. See Table 3.1 in Chapter Three for individual *p*-values.
$^{\dagger}p < .06$
$^{*}p < .05$
$^{**}p < .01$.

8.2 Hypothesis One: Mediation.

The mediation hypothesis, that the negative link between emotion and academic performance would be partially mediated by working memory, was first tested in Chapter Four. The results of this study showed that trait anxiety was negatively related to academic performance and that verbal working memory (backwards digit span) accounted for approximately 50% of the initial relationship between trait anxiety and academic performance. The results showed that spatial working memory did not likewise act as a mediator. No significant mediation effects through spatial working memory were detected for any combination of trait anxiety and academic performance tests. It seemed therefore that verbal working memory was a significant factor in understanding the emotion-academic performance link, whereas spatial tasks were in this respect less important. More generally, the finding that working memory was positively related to academic outcomes in this thesis is consistent with prior research (Gathercole et al., 2004; Lehto, 1995). With the exception of some small correlations between working memory and spelling, the size of the correlations were equivalent to those found in other studies (Cain, Oakhill, & Bryant, 2004; Gathercole et al., 2004). However, in Chapter Four the spatial working memory task was not highly related to the academic performance tasks and so supported the assumption that spatial working memory is not as important as verbal in determining academic outcomes.

However, other research has found that spatial working memory positively correlates with maths (.44) English (.45) and science (.31) tests in a sample of 11 to 12 year old school children (St Clair-Thompson & Gathercole, 2006). These correlations are approximately double the size found in Chapter Four between spatial working memory and academic tests. This difference in findings was possibly due to the fact that the span measure used in the St Clair-Thompson and Gathercole study was more complex than the spatial span used in Chapter Four. The spatial span task in the St Clair-Thompson and Gathercole involved mental rotation of shapes, decision making as to whether the shape was the same as an original or a mirror image and recall of the spatial position of the top of each shape in a list. This task is arguably more demanding than the CANTAB forwards spatial span where the position of each coloured box in a spatial array must be recalled in the order in which they appeared.

Other studies have shown that both verbal and non-verbal components of working memory are important in predicting educational outcomes (Jarvis & Gathercole, 2003). Holmes and Adams (2006), for example, found that visuospatial working memory is a good predictor of maths ability with younger children.

The results of Chapter Four as they stood, then, left open the possibility that the finding of a partial mediation effect for verbal working memory was due to a confounding between domain (verbal/spatial) and complexity (simple/difficult). In other words, although the two working memory tasks used in this study differed in terms of domain, the verbal task was more complex, tapping CE processes whereas the spatial task was simpler tapping only the VSSP. The PET suggests that the component of working memory most adversely affected by anxiety is the CE. Therefore, this finding from Chapter Four may be interpreted as a negative effect of anxiety on academic performance via CE processes rather than on verbal processes tapping the PL per se.

Chapter Five was an exploratory study that built on Chapters Three and Four by using measures of anxiety and depression in the mediation analysis, as well as a range of working memory tasks that measured CE processes. Chapter Five, used spatial measures of working memory that were more demanding than the forward spatial span measure used in Chapter Four and therefore tapped more CE processes. The results showed that spatial working memory significantly mediated the negative link between emotion and academic performance. The extent of the mediation in this case was large, with the initial association (β = -.30) being reduced considerably towards zero (β = -.04). In the present study, the measures of spatial working memory that best predicted the mediation effect were backwards spatial span and two measures from the AWMA spatial span. All three measures are argued to make demands of the central executive as well as the visuospatial sketch pad (Alloway et al., 2006; Vandierendonck, Kemps, Fastame, & Szmalec, 2004). What these results suggest is that negative emotion can affect both verbal and spatial working memory given complex tasks that make sufficient demands on working memory resources. This conclusion is consistent with cognitive resource draining theories in anxiety (PET) and depression (RAM) and suggests that the CE is the most important component of working memory in understanding the potential negative effects of emotion on educational performance.

In support of this finding, recent research with schoolchildren found that test anxiety was negatively associated with a range of intelligence tests, with the exception of a simple spatial memory test (picture recall). This test was insensitive to worry, emotionality, lack of self-confidence, and a test anxiety factor score (Meijer & Oostdam, 2007). Research with adults has shown that anxiety can disrupt performance on a spatial working memory task, crucially when the secondary task involves the use of the central executive and not the phonological loop or visuospatial sketchpad (Eysenck et al., 2005). Eysenck et al. (2007) used this evidence to argue that the central executive is the component of working memory most adversely affected by anxiety.

Interestingly, although four dependent variables were used to represent verbal working memory in Chapter Five, the mediation of the emotion-academic performance association by verbal working memory was clearest when using the single indicator of backwards digit span; the same measure used in Chapter Four. There are at least two explanations for this. It is possible that the small sample size in this study reduced the ability to detect the small effect sizes usually expected between emotion and cognition. Alternatively, the backwards digit span may be more sensitive in detecting associations both between emotion and academic performance. Certainly there is historical precedent for associating digit span with anxiety (Moldawsky & Moldawsky, 1952) and the backwards digit span is a task that satisfies both elements described by the PET as most susceptible to the negative effects of anxiety on performance. That is, the PL (verbal processing) and CE (processing and storage). PET predicts that negative effects of anxiety on performance would be stronger on the PL rather than the VSSP due to worry associated with anxiety. A complication should be noted here, however, that concerns the non-purity of the backwards digit span task.

There is in fact evidence to show that spatial interference can selectively affect backwards digit span (Li & Lewandowsky, 1995). Similarly Hoshi et al. (2000) found that individuals who showed right hemisphere dorsolateral prefrontal cortex (DLPFC) activation could recall longer backward digit strings than those with left hemisphere activation. Although this study had a limited sample size *(N*=8), the results suggest that the backwards digit span task implicates visuospatial imagery, as well as verbal representation. As half of participants that showed predominately right hemisphere DLPFC activation performed better on the backwards digit span task (median score = 7) than those who showed predominately left hemisphere DLPFC activation (median score = 4), the authors of the study proposed that visual spatial imagery in the backwards digit span task may actually be more effective than a verbal strategy. Therefore, future research in this area should continue to examine both measures of verbal and spatial working memory with special reference to the complexity of measures that tap CE processes in working memory.

In addition to the issue of complexity, the backwards digit span task shares a numerical element with the maths academic performance tests. Throughout this thesis the negative mediation effects were often seen most clearly on maths academic performance tests. For example, the latent academic performance variable in Chapter Five was comprised of two maths tests and a science test. Both the backwards digit span task and mathematics require the use of the central executive and this association raises the possibility that this finding is likely to be the shared source of disruption.

The relationship between negative emotion and performance in maths tests is best understood in the context of the maths anxiety research (Ashcraft, 2002). For example, meta-analyses have found that the average common population correlation between anxiety and maths achievement is likely to be between $r = -.27$ (Ma, 1999) and $r = -.34$ (Hembree, 1990). In Chapter Three, the median correlation between emotion and maths was $r = -.24$, in Chapter Four the correlation between trait anxiety and maths was $r = -.28$ and the results of the emotion – academic performance association in Chapter Five also showed associations of a similar magnitude ($\beta = -.30$).

However, it should be noted that other research has found effects of emotion on a range of academic tests. For example, Gumora and Arsenio (2002) found inverse relationships between negative mood and a maths and English composite score and also verbal and quantitative achievement scores. Graziano, Reavis, Keane and Calkins (2007) found that emotion regulation was positively related equally to early literacy (r = .22) and maths (r = .22). Nevertheless, maths, anxiety and working memory have together been of particular interest to researchers.

Maths anxiety researchers have described the disruptive 'online effects' of anxiety on maths performance (Ashcraft & Krause, 2007). That is, an effect on the underlying cognitive processes when performing maths tasks. For example, Ashcraft and Kirk (2001) found that high maths anxiety individuals had small working memory spans, had increased reaction times when performing addition with a memory load task (making demands of the CE) and made more errors. This effect on working memory was not specific to maths, however, but also generalised to negatively affect a letter transformation task, showing that the modality-free CE may explain such effects.

The KS2 maths test used in this thesis has a mental subtest where individual questions are allotted a maximum time and the WRAT maths subtest, also used in this thesis, has a time limit of 15 minutes for completion. This timed section of the test is an additional factor likely to exacerbate the negative influence of emotion on performance (McDonald, 2001; Zeidner, 1998). For example, in a study of test anxiety in the Graduate Record Examinations, Powers (1986) found that the timing of the test was the most frequently mentioned factor of concern by both anxious and non-anxious test takers.

The associations between negative affect and performance in this study were also present for the science test in Chapters Three, Four and Five. The national curriculum Key stage two (KS2) science tests do involve some numerical skills such as working with measurement, interpreting numerical graphs and tally charts etc., and it is possible that working memory is necessary to successfully answer the questions on the test.

The results of this thesis suggested that English and spelling tests were less important in the mediated associations. Although previous research has shown that working memory is crucial for English skills such as reading comprehension (Cain et al., 2004), it can be argued that simple spelling involves little use of working memory. However, other research has found negative associations between emotion and a range of measures including vocabulary, mental arithmetic, progress in English and maths (Crozier & Hostettler, 2003). In addition, the results of Chapters Three and Four suggest that emotion can be linked to lower English test scores. This result may reflect the known link between working memory and reading (Daneman & Carpenter, 1980). Furthermore, it is likely that there are other factors not measured in this study that might explain some of the differences in mediation effects across test types. For example, as PET suggests, the relationship between emotion and performance may depend on motivation or effort. Therefore, it might be important to explore other individual difference variables to explain the negative effects of emotion on a range of test types. PET predicts that associations between anxiety and performance would be seen more often on 'difficult' tasks that make demands on the central executive. Maths and science are areas that are likely to draw more heavily on central executive resources (compared with spelling and English) for the reasons given above and this is the trend found in this thesis.

The results of this thesis also showed that a range of negative affect may be involved in the meditational paths. Trait anxiety, depression as well as test anxiety were used as indicators of emotion. The inclusion of depression supports RAM and is in keeping with other research which suggests that the negative automatic intrusive thoughts associated with depressed mood can adversely affect cognitive performance (Christopher & MacDonald, 2005; Ellis et al., 1997).

8.3 Hypothesis Two: Moderated mediation.

Stress reactivity was introduced as a variable in Chapter Five by measuring salivary cortisol levels at the time of working memory testing. In this Chapter, there was evidence to suggest that verbal working memory acted as a mediator between emotion and academic performance only when stress was high. In this sense the effect was a moderated mediation. In addition, spatial working memory also acted as a mediator independently of stress reactivity. The study was designed as an exploration into the associations between emotion, working memory and academic performance with special attention to stress reactivity. Care was taken to counteract any confounding effects of the diurnal rhythm in cortisol where the highest levels of cortisol are found in the early morning hours and lowest around midnight in the normal population (Kirschbaum & Hellhammer, 1989) by measuring each child at the same time points on testing days. The early part of the day, where cortisol levels are highest was excluded from the testing schedule. Chapter Six replicated the finding in Chapter Five that the mediation effect was moderated by stress reactivity on verbal working memory tasks. Given the research suggesting the relative importance of worry over emotionality or arousal (Eysenck & Calvo, 1992; Morris et al., 1981; Morris & Liebert, 1970), stress reactivity may best be thought of as a moderating factor that gives rise to cognitive worry and rumination. Put another way, the moderating effects of stress reactivity suggest that the trait measures of emotion (depression, trait anxiety and test anxiety) may measure a general proclivity towards emotional experience, including disruptive cognitions. A relatively high stress reaction may then trigger the potential to experience intrusive distracting thoughts. The finding in this thesis of no linear relationship between cortisol and the emotion measures has been reported elsewhere. For example, Vedhara et al. (2003) found no correlations between absolute cortisol levels and stress, anxiety or depression in a sample of 54 women. Similarly, no correlations were found between trait anxiety and cortisol, or indeed any endocrine or physiological response, in samples of patients with atopic dermatitis or healthy controls (Buske-Kirschbaum et al., 2004).

The indirect effects of emotion on academic performance via verbal working memory when stress is high, support the PET in terms of the PL and CE being implicated in this relationship.

However, a recent study by Shackman et al. (2006) provides an opposing position to this analysis, arguing that anxious arousal specifically disrupts circuitry in the right hemisphere that could lead to decrements on spatial and not verbal tasks. The results of Shackman et al. (2006) study did indeed find that threat induced anxiety in undergraduates selectively disrupted spatial as opposed to verbal working memory. Therefore it might have been expected that the mediation moderated by stress reactivity in this thesis would have involved spatial and not verbal working memory. However, this was not the case.

Shackman et al. (2006) proposed that this finding is due to the asymmetry in brain regions underlying anxious arousal. Some research shows, for example, that anxious states are primarily associated with the right prefrontal cortex (Dalton, Kalin, Grist, & Davidson, 2005; Fischer, Anderson, Furmark, Wik, & Fredrikson, 2002). However, a broader perspective on the literature suggests little convincing evidence for a single system, right hemisphere theory of emotion. Murphy, Nimmo-Smith, & Lawrence (2003) reviewed a total of 106 studies and concluded that this theory: "did not receive convincing support in the present analysis of all the studies targeting emotional processes, since approximately equivalent numbers of left and right sided maxima were observed" (p.223). Even when assessing a refinement of this hypothesis, namely that the right hemisphere is particularly involved when the perception of emotion rather than the experience or production of it per se is measured, the results: "failed to demonstrate a critical role for the RH [right hemisphere]…" (p.223). Only two versions of an n-back task were used in the Shackman et al. study and so it is possible that with a range of tasks that place heavier demands on working memory, anxious arousal would disrupt both verbal and spatial working memory. However there was no evidence that the moderated mediation effect would generalise to spatial working memory in the results of Chapters Five, Six or Seven. Interestingly Shackman et al. suggest that one of the mechanisms via which arousal might affect working memory could be cortisol.

Starkman et al. (2001) measured 38 patients with Cushing's syndrome (hypercortisolism) and controls on a range of verbal and spatial tests from the Wechsler Adult Intelligence Scale and the Wechsler Memory Scale. The findings of the study suggested that verbal learning and verbal functioning were more susceptible to negative effects of cortisol than spatial functioning. Although the moderating role of stress reactivity on cognitive performance, as measured by cortisol, is a relatively novel finding, it does add to a growing literature that highlights the negative effect of cortisol on working memory (Al'absi et al., 2002; Domes et al., 2005; Schoofs et al., 2008). There has, however, been a dearth of studies assessing the effects of cortisol on learning or memory in children and so more studies in this area are warranted. Studies measuring cortisol in children have shown that the typical diurnal rhythm of cortisol (highest levels in the morning, rapidly decreasing towards the evening) is present in most age ranges including 1-5 year-olds, 5-8 year-olds, 8-18 year-olds but excluding children <1 year-old (Kiess et al., 1995). Knutsson et al. (1997) also showed that there was no association between pubertal stage and diurnal rhythm of cortisol. Furthermore no age-related differences in mean serum cortisol levels were found in the sample (range = 2.2 to 18.5 years). Therefore, studies on the effect of cortisol on cognitive performance are viable even in very young children.

The propensity for negative relationships between emotion and performance in high stress reactivity, more generally, is consistent with previous research. For example, Deffenbacher (1978) found that a high anxious group solved less anagrams, only in a high stress condition. It has also been shown that cognitive interference due to task-irrelevant thoughts is higher for anxious individuals in the face of an evaluative stressor (e.g. Sarason, 1984). Because high stress reactivity individuals in this study were characterised by elevated levels of cortisol, an alternative, or perhaps complementary, biological explanation is worth noting. For example, it is known that higher cortisol levels are associated with decreases in working memory (Al'absi et al., 2002; Erickson et al., 2003). However, the identification of specific anatomical structures and neural mechanisms is difficult because cortisol receptors are distributed widely across the frontal cortex and not confined to particular areas (Lupien et al., 2005). If cortisol receptors were found predominately in the left or right frontal lobe, on the other hand, an explanation that involved cortisol disrupting cognitive processes in specific domains would be more convincing. However this is not the case. It is possible that some hitherto unknown action of cortisol can explain the relatively stronger associations between emotion and verbal working memory. In the Starkman et al. (2001) study assessing the cognitive performance of Cushing's, the authors also noted that cortisol receptors are widely distributed over the cortex.

The moderated mediation association between emotion, working memory and academic performance was assessed in cross-sectional studies as part of this thesis reported in Chapters Four, Five and Six. While these studies are obviously important they are necessarily limited in the evidence they provide concerning causality. To address this problem, Chapter Seven included longitudinal data from which some inference could be made concerning the causal status of variables in the study. In it, a complex moderated (high stress reactivity) mediation model was specified over two time points approximately nine months apart. The results showed a significant negative mediation effect of emotion on academic performance over time ($\beta = -.47$). Two of the major indirect (mediation) paths included working memory and two did not. The longitudinal nature of the study (i.e. emotion measurements temporally preceded academic performance measurements in time) allow for a tentative conclusion that emotion caused lower future academic performance, partially via working memory. The design of the structural model showed that the indirect effects were net of prior academic performance levels. Consistent with Chapters Five and Six, the variables used in the longitudinal analysis were depression and test anxiety and the academic tests most likely to be demanding of CE working memory processes (maths and Raven's SPM IQ test). To complement this longitudinal work, more experimental studies should be designed in order to have more certainty about how emotion causes lowered academic performance.

However there is some evidence to support the initial position that anxiety can cause lowered academic performance (Hembree, 1988). In this meta-analysis, 137 studies (28 with placebo treatments, 55 with waiting-list controls, 69 with minimal-contact controls and 15 with both a placebo and a second control group) were assessed to determine the effects of treating test anxiety on academic performance in terms of grade point average scores or IQ, aptitude and achievement scores. Treatments ranged from systematic desensitisation, relaxation training and cognitive-behavioural therapy. The favourable treatment outcomes were seen in terms of positive effect sizes (ES) in all instances. For example, cognitive-behavioural therapy for test anxiety had a significant positive effect on 'test performance' (ES = .52, p <.01), grade point average (ES = .72 p <.01) and in terms of pre-to-post change scores (ES = .55 p <.01).

In conclusion, studies on cortisol, learning/memory have been scarce to date. This is a novel study that has suggested, with the appropriate caveats noted, that stress reactivity may moderate the relationship between emotion and verbal working memory/academic performance.

8.4 Hypothesis Three: The emotion x working memory interaction.

The interactive effects of emotion and working memory in Chapter Six were associated with differential scores on the academic performance tests. That is, having both high emotion and low working memory capacity was associated with lower academic performance. This finding was derived from and is consistent with the work of Tobias (1985). A recent study that adds weight to this position (Johnson & Gronlund, 2009) showed that individuals low in working memory capacity were in fact more susceptible to the detrimental effects of anxiety on cognitive performance. On the criterion task, participants completed a demanding dual task paradigm which consisted of a short term memory task along with an auditory discrimination task. The results of this study showed a significant negative effect of trait anxiety on the dual task for those individuals with a low working memory capacity (β = -.63, p <.01). Those with a high working memory capacity were buffered against this negative effect (β = -.19, ns).

Conversely, those with high emotion but also high working memory in Chapter Six evinced higher academic performance scores. This suggests a facilitative effect of emotion on academic performance that may appear given good working memory ability. In support of this proposition, a recent study by Hayes, MacLeod and Hammond (in press) found that the negative anxiety-performance effect on category learning tasks was only apparent on working memory capacity dependent tasks and not working memory independent tasks. They also showed that anxiety effects were attenuated when an intentional learning element was introduced to the tasks that allowed for the exertion of effort. Although effort or facilitative anxiety were not explicitly measured in this thesis, it is possible that those with better working memory ability and higher emotional levels were motivated to put more effort into the tests to increase their performance and were able to do so given their working memory advantage. Under these conditions emotional levels may be facilitative to academic performance. Future research could test this hypothesis more explicitly.

The negative interaction associations between emotion, working memory and academic performance were all found on tests that made heavy demands on working memory. This relationship was true in Chapters Six and Seven. In contrast there were no significant interaction effects on the low working memory demand academic performance tests. This finding adds weight to the conclusion that negative effects of emotion are clearest when CE working memory processes are involved.

More broadly, this thesis has shown that negative effects of emotion on academic performance were not restricted to particular types of test. Some academic tests were nationally standardised and administered in schools, whilst others were experimenter-administered in small groups. The content of tests also varied. For example, the path coefficient for the simple association between emotion and academic performance in Chapter Three was similar for attainment and cognitive abilities tests. This result, in line with previous research (Crozier & Hostettler, 2003), suggests that the association between emotion and academic performance is not necessarily specific to particular tests and there were also negative effects of emotion on IQ (Hembree, 1988; Hopko et al., 2005; Mandler & Sarason, 1952). As McDonald (2001) points out, tests of ability are themselves given under test conditions and so can be contaminated by emotional factors along with other academic tests.

In the longitudinal analysis of Chapter Seven there was evidence to suggest that a combination of high emotion and low working memory significantly predicted lower academic performance levels over time. As with the moderated mediation longitudinal analysis, this interaction effect controlled for any influence of prior academic performance levels. Therefore one can conclude that having both high levels of emotion and low working memory ability can to some extent cause lowered academic performance.

An alternative hypothesis was also tested in Chapter Seven in line with the possibility that rather than anxiety causing academic problems, academic problems due to low ability cause anxiety. McDonald (2001) argues that the former is more likely as it has been shown that children with test anxiety improve their performance under more conducive conditions. For example, Hill & Eaton (1977) found that high anxious individuals showed inferior performance to low anxious individuals on an arithmetic task under a two thirds success/one third failure time-pressured condition, but comparable performance under a success only condition. In Chapter Seven, there was no significant path between T1 academic performance and T2 emotion, therefore suggesting that emotion is causing lowered academic performance rather than vice versa.

8.5 Other cognitive factors.

In Chapter Four an alternative explanation for the mediation finding by working memory was tested in the form of attentional processes. However, attention, as measured by a continuous performance task, did not act as a mediator between trait anxiety and academic performance. This result is particularly interesting as it might have been that anxiety would interfere with attention equally with working memory or there could even have been a facilitative effect of anxiety on attentional processes. The results of Chapter Four show that this is unlikely to be the case. Attention was beneficial for academic performance, but there was only a small non-significant negative indirect effect of trait anxiety on academic performance via attention ($\beta = -.05$). This suggests that attention is potentially important in predicting attainment but not important in explaining the relationship between trait anxiety and attainment. The attention task used in Chapter Four contained a small working memory component (Coull et al., 1996) and so it is likely that the small indirect effect is carried by both simple working memory and attention. The larger, significant indirect effects were carried by more intensive working memory (backwards digit span) in particular tapping CE processes. There is one study (Elliman, Green, Rogers, & Finch, 1997) that has found negative effects of anxiety on a sustained attention task, but only in terms of efficiency (time taken to complete the task) and not effectiveness (accuracy), which is the focus of this thesis. Collectively this evidence suggests that it is the complex elements of a task that are most susceptible to the negative effects of emotion.

The association between emotion, working memory and academic performance might have been expected to vary as a function of gender as previous research has shown that girls tend to report higher levels of emotion than boys (Mackinaw-Koons & Vasey, 2000). Muliti-group analyses in this thesis tested the hypothesis that the mediation effect would be different for boys and girls. This hypothesis was disconfirmed suggesting that the mediation can occur across gender. This is consistent with other work that has not found gender to be a moderating factor in the relationship between anxiety and academic performance (Seipp, 1991).

Although working memory is implicated in the emotion – academic performance relationship, there may be an alternative explanation for the results. In this thesis, backwards digit span was shown to be particularly prone to the disruptive effects of emotion. Backwards digit span is more obviously positively related to maths and science tests as both involve numerical skills, however, academic performance is also linked to general intelligence (Freberg, Vandiver, Watkins, & Canivez, 2008; Rohde & Thompson, 2007). This research raises the possibility that IQ could therefore be explaining the emotion – academic performance relationship. A further complicating factor in the emotion-performance relationship is that IQ is measured in testing conditions and so can be influenced by affective factors in the same way that other tests are (McDonald, 2001). Alternatively, a related but more general third factor could be involved. A recent study by Salthouse and Pink (2008) suggested that the known link between

IQ and working memory may actually reflect an ability to adapt quickly to new tasks and perform effectively.

Although not tested in this thesis the ACT has a similar yet different perspective on the relationship between anxiety and cognitive performance. The ACT aims to subsume PET but shares commonalities with it and is an extension of it. One commonality is that effects of anxiety on performance are assumed to operate primarily via the central executive. In this, the present results are consistent with either conceptualisation of the effects of anxiety on performance (PET or ACT). Where ACT differs is in the precise definition of the area of function that is expected to be affected by anxiety. PET refers to the central executive, whereas ACT considers the executive functions of inhibition and shifting to be prime areas of interest. The present study did not make a formal comparison between these functions. However, the fractionation of the CE into its component parts will be of future theoretical interest in determining precisely which aspects of cognition are involved in the emotion-academic performance link.

8.6 State anxiety and the emotion measures.

In this thesis anxiety was measured using self-report instruments. The CTAS measures test anxiety which is assumed to reflect a situation-specific personality trait (Wren & Benson, 2004) and the trait scale of the STAIC which is also assumed to measure anxiety as part of personality. In contrast, the state anxiety measure from the STAIC measures the current state of anxiety. In this thesis there was very little evidence that self-report state anxiety was related to academic performance. For example, in Chapters Four, Five and Six, state anxiety was not significantly related to the academic performance measures. In Chapter Six, state anxiety measured at the time of testing working memory was positively related to spelling MHV and Raven's SPM, which were tested on a separate day. These associations therefore may have been spurious. The null finding of state anxiety on academic performance in this thesis is contrary to a previous meta-analysis which has shown that state and trait anxiety are equally negatively related (both r = -.21) to academic performance (Seipp, 1991). It is also assumed within the theoretical framework of the PET that state anxiety is the ultimate mediator between trait anxiety and working memory performance. Hadwin et al. (2005), for example, showed that children in a high state anxiety group were less efficient in performing working memory tasks, although they were not less effective. The theoretical assumption that state anxiety would mediate the link between trait anxiety and performance was tested in Chapter Four where a mediation path was specified of the form: trait anxiety – state anxiety – working memory – academic performance. There was no evidence to suggest that state anxiety acted as a mediator in this chain; the indirect effect was close to zero ($\beta = -.001$). Furthermore, in Chapter Six, state anxiety was hypothesised to reduce the influence of an emotion x working memory interaction path to academic performance, given its putative role in lowering cognitive performance. However, adding state anxiety to the statistical model did not attenuate the coefficient in the interaction path. Although this finding is at odds with the theoretical assumptions of the PET, it is consistent with prior research. For example, a study by Eysenck et al. (2005) did not find that state anxiety mediated the effects of trait anxiety on working memory. The authors suggest that because trait anxious individuals are more sensitive to threat situations, any small amount of state anxiety may be sufficient to invoke an attentionally distracting situation.

Therefore what seems to be important is less the absolute level of state anxiety but more the personality-determined reaction to a stressful situation. It is possible that the state anxiety measure used in this thesis lacks validity at certain age ranges. However, null effects of state anxiety on performance were found for example in Chapter Four (11 – 12 year-olds) and Chapter Six (12 to 14 year-olds). Validity studies for the STAIC have shown only mild fluctuation in the mean state anxiety scores for different age groups. For example in a sample of 1554 schoolchildren, the mean state anxiety score for boys was 30.1, 31.0 and 31.8 for 9-10 year-olds, 10-11 year-olds and 12 -13 year-olds, respectively (Spielberger et al., 1973). For girls, there was a similar pattern with mean state anxiety scores taken as 30.3, 31.2 and 30.6 for the same respective age groups. An alternative to this explanation is that the self-report measure is not a true reflection of current anxiety. It may have been that participants may have given socially desirable answers or it may have been that when the measure was taken, towards the end of testing, the participants were not particularly anxious.

8.7 Limitations.

There are strengths to the present work. For example, the research has utilised several separate samples of children from several different secondary schools which helps with the generalisability of the findings. A mix of measures was used and while self-report measures were used, they were not relied upon exclusively. A physiological measure of stress was used, as well as academic performance tests and working memory tasks. The research also used two methodological designs; cross-sectional and longitudinal. The latter allows for some conclusion, albeit preliminary, about the causal status of emotion in the emotion-academic performance relationship.

There are however, several weaknesses. Firstly, although using a normal population sample is informative about general levels of emotion and working memory, it tells us little or nothing about clinical populations of children with, for example, severe anxiety/depression or very low cognitive abilities. It is likely that the direction of effects between emotion and academic performance in this thesis would be the same in clinical samples and it is possible that the effect sizes would be larger; however, this is as yet an untested empirical question.

While the majority of research assumes that negative emotion has a debilitative effect on performance there has been some research suggesting a facilitative effect of anxiety. Facilitative anxiety was not explicitly measured in this thesis, although facilitative effects of emotion on performance were found. Having good working memory and higher levels of emotion appeared to facilitate academic performance in Chapter Six and there was a suggestion in Chapter Five that displaying low stress reactivity allowed for a facilitative association between emotion and academic performance. This issue should be fully addressed in future work. The concept of facilitative anxiety can be traced at least as far back as Alpert and Haber (1960), however most research has focussed on the debilitative effects of emotion (McDonald, 2001) and it is not yet clear whether there are facilitative effects of emotion on academic performance (Putwain, 2007a). There is a recent conceptualisation of test anxiety that incorporates facilitative anxiety and a scale has been developed and validated (Lowe & Lee, 2008). Future work could use this framework to further investigate facilitative effects of emotion in academic performance.

The majority of statistical analyses were conducted within a structural equation modelling framework with an emphasis, or initial requirement, of acceptable goodness-of-fit. It should be remembered that a good-fitting model is not proof that the model is in any sense true. Kline (2005) gave several possibilities. First, the model may accurately reflect reality. Second, the model might be an equivalent version of one that corresponds to reality, but is itself incorrect. Third, the model fits the data from a non-representative sample, but has poor fit in the population. Lastly, the model may have so many parameters that it cannot have poor fit even if it is severely wrong. Most pertinently, statistical models can only ever be disconfirmed. Therefore, one should be cautious with the interpretation of model fit. In addition, the Chi square goodness-of-fit index, which has an associated p-value is particularly sensitive to sample size. Therefore very small sample sizes with estimates that are not very close to the data collected may still be declared a good-fitting model. Conversely, with larger samples, models that only deviate slightly from a specified model may be declared a poor fit. However, in this thesis a range of goodness-of-fit indices was used along with several different statistical techniques in an attempt to answer the hypotheses. A final caution that needs to be made concerning structural equation modelling is consistent with Kline's notion of the so-called 'garden path' fallacy. Researchers can sometimes be lead to misinterpret output from structural equation models and diagrams. Such errors include only evaluating overall model fit and ignoring other information, interpreting good fit as meaning the model is 'proved' and failing to consider alternative models. Another fallacy relates to the causal appearance of path diagrams. Even though the path diagrams in the present study are in a sense hypothesising causal paths, no path represented in a diagram is necessarily causal.

There is a temptation to the researcher to overly interpret a structural equation model when, on inspection of a path between two variables in a diagram, one is persuaded that variable A is causing variable B. One should remember that only in the case of a longitudinal analysis should causal factors be seriously contemplated. Even in this situation, putative causes may be correlational only, as other causal factors may not be included in the model.

From the cross-sectional studies in this thesis it is not possible to draw any conclusions regarding causal relationships. Experiments, such as Ellis et al.'s (1997) mood induction experiment that resulted in poor memory recall or the meta-analysis of Hembree (1988) that showed that experiments reducing test anxiety produced gains in achievement, do qualify as causal evidence for the interference of emotion on academic performance. Ultimately, as others have suggested (Hopko et al., 2005; Musch & Bröder, 1999; Schwarzer, 1990), more longitudinal studies are needed to fully understand the relationship between emotion and academic performance.

The sample sizes were relatively small in some analysis, particularly in Chapter Five (*N* = 31) where high and low stress reactivity analyses essentially reduced the sample size by half. There are two main problems with using a small sample size. One, the parameter estimates in the models may be biased. Two, there is a reduction in the power to significantly detect given effects, should they actually exist. For example, to have reasonable power (80%) to detect a correlation of $r = -.30$ at the .05 level of significance, would require a sample size of approximately 85. The effect of sample size is illustrated in Chapter Three where a sample size of 84 was able to significantly detect several correlations of this magnitude and lower. Further studies are needed for purposes of replication and extension, preferably with a much larger sample size.

Relatedly, some models did not fit well or failed to converge. Some argue for structural equation models to have large samples, 200 cases or more as a minimum (Barrett, 2007). Others disagree and suggest that in certain circumstances, where the science is good and a small sample is not due to want of effort small *N* models are acceptable (Bentler, 2007).

Structural equation modelling encompasses factor analysis and linear regression techniques. In the same way that factor analysis is an iterative process that requires many decisions to be made as to which elements to include and which to discard, structural equation modelling also demands such a decision making process. There is flexibility to specify multiple models and without sound theoretical background, the amount of models tested could become voluminous. The researcher needs to be aware of the possibility of capitalising on chance when testing many models. In conclusion, the benefits of using a structural equation modelling framework that allow for latent variables with structural paths, indirect effects and bootstrapped *p*-values outweighs the costs involved, for example the requirement of larger sample sizes. For example, latent variables in structural equation models allow for the identification of factors influential in accounting for reliable variance as opposed to variance due to measurement error.

A main strength of these studies is that it they have high levels of ecological validity. Typically developing children participated who were attending mainstream schools. Their scores on emotional measures, cortisol responses and academic performance scores were all within the normal range. In addition the protocol used was not designed to induce perhaps artificially high levels of stress such as performance in the Trier Social Stress Test. A recent example of a study employing this paradigm is reported by van West, Claes, Sulon and Deboutte (2008). In this study 25 children with social phobia and 25 controls. Participants were asked to prepare and give a five-minute speech on a topic of their choice to a committee of two or three judges. Seven cortisol measurements were taken over the course of the total testing period (135 minutes). The results showed a highly significant group x time interaction where children in the social phobia group showed a marked increase in cortisol over time. Also of note in this study, trait but not state anxiety was positively related to cortisol levels. It would be expected that effect sizes would be larger in children with clinical anxiety or depression or children with working memory and other cognitive deficits.

8.8 Implications for theory and practice - Future directions.

A major educational implication of the present research is that an improvement in working memory and a reduction in emotional levels may result in an improvement in academic performance for some children. There is evidence to suggest that reducing emotional levels can improve academic test scores (Keogh et al., 2006). In this study, schoolchildren were given a 10-week stress reduction intervention programme at the run-up to GCSE examinations. The intervention group performed significantly better than the education-as-usual group who received no stress reduction intervention.

There is also evidence to show that working memory can be improved through training (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). This study used a dual *n*-back working memory task in several training conditions using spatial and verbal working memory. For the spatial *n*-back component, squares were presented sequentially at eight different locations on a computer screen. Simultaneously to this spatial task, eight consonants were auditorily presented to participants through headphones. A response was required whenever one of the presented stimuli matched the one presented *n* positions back in the sequence. The value of *n* was increased by 1 if few mistakes were made on a given block of trials. The results of this study showed that participants made significant gains in working memory performance which were dependent on the number of days of training received. Significant differences between training and control groups appeared at 17 days of training. Furthermore, gains in working memory over time were accompanied by improvements in IQ. Therefore training in working memory can lead to transference onto other cognitive abilities equally likely to benefit academic performance. Both anxiety reduction and working memory training have been shown to independently benefit academic performance. However, the findings of this thesis suggest that both approaches could be used in combination.

In the results of this thesis there was a complex interaction between emotion and working memory. Chapter Six showed clearly that children with high emotion and low working memory performed worst of all combination groups on academic tests that made a heavy demand on working memory. However, those with good working memory and high emotion often performed the best of all groups on the same academic performance tests. In relation to a future working memory training/anxiety reduction study, there will be differential expectations for academic performance outcome depending on the initial levels of emotion and working memory. In such a trial, a short longitudinal study could be used to include several groups for training and intervention. Condition A could include working memory training over four weeks. Group B could be given an anxiety reduction intervention for the same amount of time. A further condition C, could include both working memory training and emotion intervention. It would be expected that only those who initially showed poor working memory and high emotion would benefit from condition C. All other children would be expected to achieve the highest academic performance gains in condition A only.

A major theoretical implication for the emotion-academic performance relationship that stems from the findings presented in this thesis is that a model positing a simple linear relationship is insufficient. A model summarising the key paths to academic underachievement in this thesis is illustrated in Figure 8.1. This model is not a complete account of the emotion-academic performance relationship, but attempts to model some of the complexities that are involved. A key pathway to lowered academic performance is through a disruption of working memory. In this thesis, this mediation was ultimately found to be moderated by high stress reactivity. In addition, this moderated mediation was specific to verbal working memory. Spatial working memory also mediated the relationship between emotion and academic performance regardless of stress reactivity. In these pathways the working memory measures used were to some extent drawing on CE processes. This finding is consistent with previous theoretical views (PET and RAM). In addition the academic performance measures also made heavy demands on working memory. There is also an interaction between emotion and working memory pathway that leads to lowered academic performance in the model. The final pathway in the model essentially represents all that has remained untested in this thesis.

While this thesis focuses on understanding the relationship between negative emotion and academic achievement in the context of working memory, there is evidence to suggest other factors that could be potentially involved in a model of emotion-academic performance. One potential candidate, i.e. avoidance will be discussed. The central and defining behavioural aspect of anxiety is a behaviourally inhibited temperament in childhood and subsequent avoidance behaviour (Rapee, 2002).

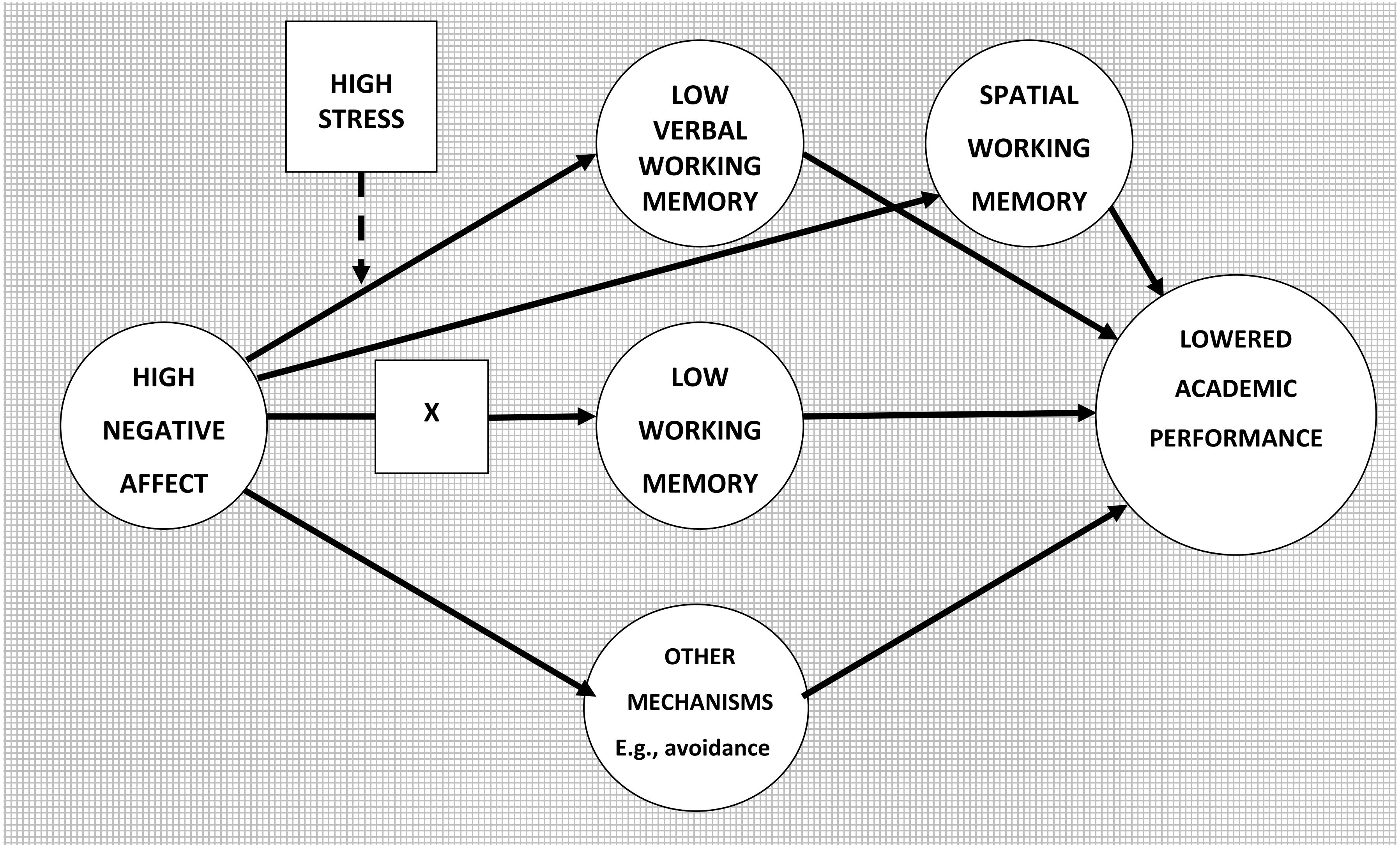


Figure 8.1. A schematic model of a multiple moderation and mediation model of emotion in academic performance. The X in the diagram represents the interaction between high emotion and low working memory as a path to lowered academic performance.

Avoidance of situations that are believed by the individual to increase emotional symptoms is also associated with both anxiety and depression (Ottenbreit & Dobson, 2004). In this study, a Cognitive-Behavioral Avoidance Scale was developed with a group of undergraduate students. The scale was significantly correlated with depression (r = .48) as well as anxiety (r = .58). Of particular interest to this discussion were the behavioural non-social and cognitive non-social subscales. Examples of the items included in the behavioural non-social subscale were: “I avoid trying new activities that hold the potential for failure” and: “I quit activities that challenge me too much”. Examples for the cognitive non-social subscale were: “While I know that I have to make some important decisions about school/work, I just do not get down to it” and: “I distract myself when I start to think about my work/school performance”. Although not measured in this study, avoidance has been shown to negatively predict academic achievement in a longitudinal study involving undergraduate students (Nurmi, Aunola, Salmela-Aro, & Lindroos, 2003). Similarly Turner (2002) has shown that the avoidance strategies of self-handicapping (e.g. “Some students purposely don’t try hard in math. Then if they don’t do well, they can say it’s because they didn’t try. How true is this of you?”) avoiding help-seeking (“I don’t ask questions during math, even if I don’t understand the Lesson”) and avoiding novelty (“I would choose math problems I knew I could do, rather than those I haven’t done before”) are used by children in mathematics and are negatively correlated to achievement scores.

The role of avoidance could be tested in a longitudinal model alongside the moderated mediation hypothesis tested in Chapter seven of this thesis. It would be expected that those displaying high stress reactivity will show stronger negative associations between emotion and working memory and academic performance and in addition a second pathway of avoidance would be hypothesised to exist. Those with high stress reactivity could show strong positive associations with avoidance strategies and in turn strong negative associations between avoidance and academic performance.

In conclusion this thesis ultimately emphasises the importance of integrating cognition and emotion in developmental research, and specifically in relation to understanding academic underperformance in children (e.g. Blair, 2002; Lemerise & Arsenio, 2000). This study extends previous research to highlight some complex ways in which emotion and working memory operate to contribute to lowered academic performance.

APPENDIX A: SELF-REPORT MEASURES

A1. The children's test anxiety scale

Test Attitude Survey

Example - Please read the following statement and decide if it describes the way you are while you are taking tests.

If the statement is **almost never** or **never** like you, you should circle **1**.
If the statement describes the way you are **some of the time**, circle **2**.
If the statement describes the way you are **most of the time**, circle **3**.
If the statement is **almost always** or **always** like you, circle **4**.

While I am taking tests . . .

I think about doing other things.

Almost never	Some of the time	Most of the time	Almost always
1	2	3	4

The items below describe how some students may think, feel, or act while they are taking tests. Please read each statement carefully and decide if the statement describes how you think, feel, or act during a test. Then circle the answer that best describes the way you are while you are taking a test. If you are not sure which answer to circle, read the statement again before circling your answer. Remember that there are no "right" or "wrong" answers on this survey. Please give truthful answers.

While I am taking tests…

1. I wonder if I will pass.

Almost never	Some of the time	Most of the time	Almost always
1	2	3	4

2. My heart beats fast.

1	2	3	4

3. I look around the room.

1	2	3	4

4. I feel nervous.

1	2	3	4

5. I think I am going to get a bad mark.

1	2	3	4

While I am taking tests…

6. It is hard for me to remember the answers.

Almost never	Some of the time	Most of the time	Almost always
1	2	3	4

7. I play with my pencil.

1	2	3	4

8. My face feels hot.

1	2	3	4

9. I worry about failing.

1	2	3	4

10. My tummy feels funny.

1	2	3	4

While I am taking tests…

11. I worry about doing something wrong.

Almost never	Some of the time	Most of the time	Almost always
1	2	3	4

12. I check the time.

1	2	3	4

13. I think about what my mark will be.

1	2	3	4

14. I find it hard to sit still.

1	2	3	4

15. I wonder if my answers are right.

1	2	3	4

While I am taking tests…

16. I think that I should have studied more.

Almost never	Some of the time	Most of the time	Almost always
1	2	3	4

17. My head hurts.

1	2	3	4

18. I look at other people.

1	2	3	4

19. I think most of my answers are wrong.

1	2	3	4

20. I feel warm.

1	**2**	**3**	**4**

While I am taking tests…

21. I worry about how hard the test is.

Almost never	Some of the time	Most of the time	Almost always
1	**2**	**3**	**4**

22. I try to finish quickly.

1	**2**	**3**	**4**

23. My hand shakes.

1	**2**	**3**	**4**

24. I think about what will happen if I fail.

1	**2**	**3**	**4**

25. I need to go to the toilet.

1	**2**	**3**	**4**

While I am taking tests…

26. I tap my feet.

Almost never	Some of the time	Most of the time	Almost always
1	**2**	**3**	**4**

27. I think about how poorly I am doing.

1	**2**	**3**	**4**

28. I feel scared.

1	**2**	**3**	**4**

29. I worry about what my parents will say.

1	**2**	**3**	**4**

30. I stare.

1	**2**	**3**	**4**

A2. The Revised Children's Anxiety and Depression Scales – Major Depressive Disorder scale

RCADS-MDD

Please put a circle around the word that shows how often each of these things happen to you. There are no right or wrong answers.

1.	I feel sad or empty……….	Never	Sometimes	Often	Always
2.	Nothing is much fun anymore……….	Never	Sometimes	Often	Always
3.	I have trouble sleeping……….	Never	Sometimes	Often	Always
4.	I have problems with my	Never	Sometimes	Often	Always
5.	I have no energy for things……….	Never	Sometimes	Often	Always
6.	I am tired a lot……….	Never	Sometimes	Often	Always
7.	I cannot think clearly……….	Never	Sometimes	Often	Always
8.	I feel worthless……….	Never	Sometimes	Often	Always
9.	I feel like I don't want to move……….	Never	Sometimes	Often	Always
10.	I feel restless……….	Never	Sometimes	Often	Always

A3. The State trait Anxiety Inventory for Children Trait Form.

1	I worry about making mistakes	hardly	sometimes	often
2	I feel like crying	hardly	sometimes	often
3	I feel unhappy	hardly	sometimes	often
4	I have trouble making up my mind	hardly	sometimes	often
5	It is difficult for me to face problems	hardly	sometimes	often
6	I worry too much	hardly	sometimes	often
7	I get upset at home	hardly	sometimes	often
8	I am shy	hardly	sometimes	often
9	I feel troubled	hardly	sometimes	often
10	Unimportant thoughts run through my mind and bother me	hardly	sometimes	often
11	I worry about school	hardly	sometimes	often
12	I have trouble deciding what to do	hardly	sometimes	often
13	I notice my heart beats faster	hardly	sometimes	often
14	I am secretly afraid	hardly	sometimes	often
15	I worry about my parents	hardly	sometimes	often
16	My hands get sweaty	hardly	sometimes	often
17	I worry about things that may happen	hardly	sometimes	often
18	It is hard for me to fall asleep at night	hardly	sometimes	often
19	I get a funny feeling in my stomach	hardly	sometimes	often
20	I worry about what others think of me	hardly	sometimes	often

A4. The State trait Anxiety Inventory for Children State Form.

1	I feel	very	calm	calm	not	calm
2	I feel	very	upset	upset	not	upset
3	I feel	very	pleasant	pleasant	not	pleasant
4	I feel	very	Nervous	Nervous	not	Nervous
5	I feel	very	Jittery	Jittery	not	Jittery
6	I feel	very	Rested	Rested	not	Rested
7	I feel	very	Scared	Scared	not	Scared
8	I feel	very	Relaxed	Relaxed	not	Relaxed
9	I feel	very	Worried	Worried	not	Worried
10	I feel	very	Satisfied	Satisfied	not	Satisfied
11	I feel	very	Frightened	Frightened	not	Frightened
12	I feel	very	Happy	Happy	not	Happy
13	I feel	very	Sure	Sure	not	Sure
14	I feel	very	Good	Good	not	Good
15	I feel	very	Troubled	Troubled	not	Troubled
16	I feel	very	Bothered	Bothered	not	Bothered
17	I feel	very	Nice	Nice	not	Nice
18	I feel	very	Terrified	Terrified	not	Terrified
19	I feel	very	Mixed-up	Mixed-up	not	Mixed-up
20	I feel	very	Cheerful	Cheerful	not	Cheerful

APPENDIX B: LETTERS TO SCHOOLS/PARENTS AND CONSENT FORMS

B1. Parental information letter and 'opt-out' consent form for questionnaire data collection described in Chapter Three.

September 2006

Parent or Guardian

Dear Parent/Guardian,

My name is Matthew Owens and I am a postgraduate student training at the University of Southampton. I am carrying out a study at The Arnewood School under the supervision of Dr. Julie Hadwin, a lecturer in child development. We are working with your Head teacher and Sabine Stroud on a research project about understanding the link between emotions and school tests. We would like to ask your permission to work with your child in this project. This will involve pupils completing some 'tick box' questionnaires at the school. We are writing to all parents in the school whose children are in Year 8. You only need to return the slip below ***if you do not*** want your child to participate.

Your child's participation in the project

In a convenient time such as registration, pupils will be asked to complete some tick box questionnaires about emotions. We will use the attainment scores (CAT and SATs) for the children that have already been collected by the school.

The Project has been reviewed by the University ethics committee, and all of the information gathered will be strictly confidential.

If you **DO NOT** want your child to participate in the study, please fill out the slip below and

return it to the school by the 15th of September.

We greatly appreciate your help in this project, which will give us a better understanding of emotions and school tests. We will be pleased to answer any questions regarding this study before or after it has taken place.

Thank you kindly for taking the time to read this.

Yours sincerely,

Matthew Owens (m.owens@soton.ac.uk) 023 80594586

Parental Consent form

Children’s anxiety and achievement

I _____________________________________have read the attached information letter.

I *do not* want my child to participate in this project.

Child’s Name_______________________________

Child’s Date of Birth: _________________Today’s Date:_____________

Your Name:_______________________________ Parent/ Guardian

Your Signature:____

I understand that if I have questions about my child’s rights as a participant in this research, or if I feel that they have been placed at risk, I can contact the Chair of the Ethics Committee, Department of Psychology, University of Southampton, Southampton, SO17 1BJ.

B2. Pupil consent form for the questionnaire data collection described in Chapter Three.

Participant ID……………………………………………

Feelings, memory and learning Project

Consent Form

My name is Matthew Owens and I am from the University of Southampton. I am looking at the different ways young people feel and how the way they feel affects their work.

I need your help to do this project.

I would like you to fill out the questionnaires in this pack.

I will not use any names in the project.

If you agree to help by filling in these questionnaire please complete the section below.

Thank you very much for helping with this project!

Please complete:

Name ………………………………………………

Male/female ………………………………………………

Date of birth ………………………………………………

Signature ………………………………………………

Today's date ………………………………………………

B3. Parental information letter and 'opt-in' consent form for the study described in Chapter Four.

Email: mo104@soton.ac.uk
Telephone: 02380 594586
November 2005

Dear Parent/Guardian,

My name is Matthew Owens and I am a postgraduate student at the University of Southampton. I am carrying out a study under the supervision of Dr. Julie Hadwin, a lecturer in child development. Your Head teacher has kindly agreed to let us approach you, to ask if you would give us permission to work with your child as part of our research project. This project involves working with children in Year 7, in school, for a brief period of time. We are writing to all parents in the school, whose children are in this year group, in order to obtain written permission for us to work with the children.

Your child's participation in the project
The aim of this project is to understand how anxiety can affect children's performance. We will carry out two main tasks, to assess this.

We will measure how children feel, using a questionnaire. There are copies of this questionnaire available at the school, if you would like to see it.

The questionnaire assesses the extent to which children are anxious. Children have to indicate how much each statement describes them by choosing the most appropriate response. An example of the items included is, "I have trouble making up my mind".

The computer tasks will involve looking at numbers and shapes and following patterns and sequences. Children will be asked to press a button to indicate their response.

In addition I would like to use attainment scores for the children that have already been collected by the school.

The Project has been reviewed and approved by the University ethics committee, and all of the information gathered will be strictly confidential. Children will be told that they may leave at any time, if they do not want to carry on with the tasks.

If you are willing to let your child take part in this project, then please return the consent slip to the School Office as close to the **28th November** as possible.

We hope that this Project will give some understanding of anxiety and educational achievement. The children will be debriefed and all their questions answered on the day. We will be pleased to answer any questions regarding this study before or after it has taken place.

Thank you kindly for taking the time to read this letter.

Yours sincerely,
Matthew Owens

Parental Consent form

Children's anxiety and achievement

I ______________________________________have read the attached information letter.

I understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. I understand that data collected as part of this research project will be treated confidentially, and that published results of this research project will maintain my child's confidentiality.

I give my consent for my child to participate in this study.

Child's Name________________________________

Child's Date of Birth: _________________Today's Date:_____________

Your Name:________________________________ Parent/ Guardian

Your Signature:____

I understand that if I have questions about my child's rights as a participant in this research, or if I feel that they have been placed at risk, I can contact the Chair of the Ethics Committee, Department of Psychology, University of Southampton, Southampton, SO17 1BJ.

B4. Pupil consent form for the questionnaire data collection described in Chapter Four

Participant ID……………………………………………

Feelings, memory and educational achievement

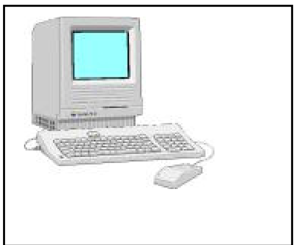
Consent Form

I am looking at the different ways young people feel and how the way they feel affects their work.

I need your help to do this project.

In the first task, there is a questionnaire to complete.

There are no right or wrong answers to the questions.



In the second task, I will ask you to complete some tasks on the computer.

No-body else, except me, will see any of the answers that you give.

It is up to you whether you want to take part or not. I will understand if you decide not to. If you decide that you want to stop the task at any time, you can do so.

Thank you very much!

If you agree to help me, then please sign your name below:

Name ……………………………………………

Male/female ……………………………………………

Date of birth ……………………………………………

Signature ……………………………………………

Today's date ……………………………………………

B5. Parental information letter and 'opt-in' consent form for the study described in Chapter Five.

Matthew Owens,
School of Psychology,
University of Southampton,
Highfield, Southampton
SO17 1BJ.

Emotion & Learning

July 2006

Dear […………………………],

My name is Matthew Owens and I am a postgraduate researcher at the University of Southampton. I am carrying out a study at Bitterne Park School with permission from your head teacher. This study is supervised by Professor Jim Stevenson and Dr. Julie Hadwin at the University of Southampton. Your child, […………………………], has been chosen by the school to participate in our new research project. We are interested in finding out how emotions and hormones affect learning in children, and would like to ask your permission to include your child in this project. This will involve working with your child at the school, for a brief period of time.

Your child's involvement.

We will go through some memory games on a laptop, complete some 'tick box' questionnaires, and do a quick test of spelling, maths and reading. As we are doing the tasks we will ask your child to chew on some cotton rolls so we can collect saliva samples. This allows us to measure hormones in the body.

We will use the attainment scores for the children that have already been collected by the school.

The Project has been reviewed by the University ethics committee, and all of the information gathered will be kept strictly confidential. I, Matthew Owens, will be the researcher involved with the testing and I have had an enhanced disclosure check from the criminal records bureau. A copy of which has been seen by …………………………at the school.

If you are happy for your child to participate in this project, please fill out the slip overleaf and return it to…………………………, at the school as soon as possible.

We greatly appreciate your help in this project, which will give us a better understanding of the role that emotions and hormones play in learning at school. We will be pleased to answer any questions regarding this study before or after it has taken place. Please direct these questions to Matthew Owens at the University of Southampton 023 80594586 m.owens@soton.ac.uk

Thank you kindly for taking the time to read this letter.

Yours sincerely,

Matthew Owens and …………………………

PLEASE RETURN TO………………………… **AS SOON AS POSSIBLE**

Parental Consent form

I _______________________________________have read the attached information letter.

I agree to my child participating in this project.

Child's Name_________________________________

Child's Date of Birth:_________________Today's Date:_____________

Your Signature:____

I understand that if I have questions about my child's rights as a participant in this research, or if I feel that they have been placed at risk, I can contact the Chair of the Ethics Committee, Department of Psychology, University of Southampton, Southampton, SO17 1BJ.

B6. Pupil consent form for the data collection described in Chapter Five.

Participant ID……………………………………………

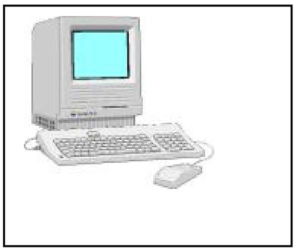
Feelings, memory and learning

Consent Form

I am looking at the different ways young people feel and how the way they feel affects their work.

I need your help to do this project.

First we are going to do a maths and spelling test in a group and fill in some questionnaires.



On another day, I will see you individually and ask you to complete some memory tasks on the computer.

I will also ask you to chew on some cotton pads to collect saliva. This helps us to measure chemicals (hormones) in your body.

No-body else, except me, will see any of the answers that you give.

It is up to you whether you want to take part or not. I will understand if you decide not to. If you decide that you want to stop the task at any time, or you want a break you can do so.

Thank you very much!

If you agree to help me, then please fill out **ALL** the sections below:

Name ……………………………………………

Male/female ……………………………………………

Date of birth (day, month, year) …………/……………………/……………

Signature ……………………………………………

Today's date ……………………………………………

B7. Parental information letter and consent form for the longitudinal study described in Chapters Six and Seven.

Matthew Owens,
School of Psychology,
University of Southampton,
Highfield, Southampton
SO17 1BJ.

Emotion & Learning

March 2007

Dear […………………………],

My name is Matthew Owens and I am a postgraduate researcher at the University of Southampton. I am carrying out a study at Purbrook School with permission from your head teacher. This study is supervised by Professor Jim Stevenson and Dr. Julie Hadwin at the University of Southampton, and Sue Kelly at Purbrook. We are writing to parents/guardians of all children in the same year. We are interested in finding out how emotions and hormones affect learning in children over time, and would like to ask your permission to include your child in this project. This will involve working with your child at the school, for a brief period of time.

Your child's involvement.

We will go through some memory games on a laptop, complete some 'tick box' questionnaires, and do some ability/achievement tests. As we are doing the tasks we will ask your child to chew on some cotton rolls so we can collect saliva samples. This allows us to measure hormones in the body. I will come back to the school at a later date and follow-up the progress of all children.

We will use the attainment scores for the children that have already been collected by the school.

The Project has been reviewed by the University ethics committee, and all of the information gathered will be kept strictly confidential. I will be the researcher involved with the testing and I have had a 'police check' from the criminal records bureau. A copy of which has been seen by Sue Kelly at the school.

If you are happy for your child to participate in this project, please fill out the slip overleaf and return it to Sue Kelly at the school as soon as possible.

We greatly appreciate your help in this project, which will give us a better understanding of the role that emotions and hormones play in learning at school. Your child will receive a certificate of participation at the end of the study to add to their record of achievement.

We will be pleased to answer any questions regarding this study before or after it has taken place. Please direct these questions to Matthew Owens at the University of Southampton 023 80594586 m.owens@soton.ac.uk

Thank you kindly for taking the time to read this letter.

Yours sincerely,

Matthew Owens

PLEASE RETURN TO SUE KELLY AS SOON AS POSSIBLE

Parental Consent form

I ______________________________________have read the attached information letter.

I agree to my child participating in this project.

Child's Name________________________________

Child's Date of Birth: _________________Today's Date:_____________

Your

Signature:____

I understand that if I have questions about my child's rights as a participant in this research, or if I feel that they have been placed at risk, I can contact the Chair of the Ethics Committee, Department of Psychology, University of Southampton, Southampton, SO17 1BJ.

B8. Pupil consent form for the data collected and presented in Chapter Six and Seven.

Participant ID………………………………………………

Feelings, memory and learning

Consent Form

I am looking at the different ways young people feel and how the way they feel affects their work.

I need your help to do this project.

First we are going to do some tests in a group and fill in some questionnaires.

On another day, I will see you individually and ask you to complete some memory tasks on the laptop.

I will also ask you to chew on some cotton pads to collect saliva. This helps us to measure chemicals (hormones) in your body.

No-body else, except me, will see any of the answers that you give.

It is up to you whether you want to take part or not. I will understand if you decide not to. If you decide that you want to stop the task at any time, or you want a break you can do so.

Thank you very much!

If you agree to help me, then please fill out **ALL** the sections below:

Name ………………………………………………

Male/female ………………………………………………

Date of birth (day, month, year) ……………/……………………………/………………

Signature ………………………………………………

Today's date ………………………………………………

APPENDIX C: NONSIGNIFICANT EMOTION X WORKING MEMORY INTERACTION TABLES FROM CHAPTER SIX.

Table C.1. *The interaction between trait anxiety and working memory on low working memory demand academic performance tests.*

	High Trait Anxiety/High Working Memory	*Low Trait Anxiety/Low Working Memory*	*Low Trait Anxiety/High Working Memory*	*High Trait Anxiety/Low Working Memory*	F ratio (df)	P value
Spelling						
AWMA Forward digit span	42.86 (5.84)	35.79 (3.20)	40.86 (4.43)	38.28 (5.30)	0.07 (1,92)	.79
AWMA Backward digit span	41.59 (6.27)	36.44 (3.89)	39.87 (4.62)	38.63 (4.81)	0.05 (1,92)	.82
AWMA Listening recall	42.26 (6.36)	36.30 (3.67)	39.48 (4.74)	39.04 (5.16)	0.00 (1,92)	.98
AWMA Spatial span	41.52 (6.11)	37.42 (4.05)	38.05 (4.33)	40.06 (5.54)	0.14 (1,92)	.71
CANTAB Forward Spatial span	41.24 (6.23)	38.24 (4.62)	37.80 (4.53)	39.64 (5.52)	0.91 (1,92)	.34
CANTAB Backward Spatial span	41.07 (6.26)	38.20 (4.70)	37.84 (4.45)	39.06 (4.89)	1.17 (1,92)	.28
MHV						
AWMA Forward digit span	23.71 (3.76)	19.18 (3.78)	22.05 (3.21)	19.32 (4.00)	1.00 (1,92)	.32
AWMA Backward digit span	22.96 (3.93)	19.70 (3.98)	21.30 (3.44	19.00 (4.15)	2.18 (1,92)	.14
AWMA Listening recall	23.63 (3.67)	19.00 (3.73)	21.67 (3.45)	19.70 (4.26)	0.65 (1,92)	.42
AWMA Spatial span	22.61 (4.72)	19.04 (3.65)	21.70 (3.33)	19.71 (3.87)	0.02 (1,82)	.89
CANTAB Forward Spatial span	22.05 (4.04)	20.12 (3.84)	20.76 (3.79)	20.72 (4.74)	0.17 (1,92)	.69
CANTAB Backward Spatial span	22.30 (4.04)	20.44 (3.64)	20.44 (4.01)	19.50 (4.70)	2.72 (1,92)	.10

Table C.2. *The interaction between test anxiety and working memory on low working memory demand academic performance tests.*

	High Test Anxiety/High Working Memory	*Low Test Anxiety/Low Working Memory*	*Low Test Anxiety/High Working Memory*	*High Test Anxiety/Low Working Memory*	F ratio (df)	P value
Spelling						
AWMA Forward digit span	41.05 (5.49)	36.50 (3.65)	42.46 (4.74)	37.34 (5.06)	1.31	.26
AWMA Backward digit span	39.52 (5.96)	36.88(4.02)	42.30 (4.80)	37.90 (4.81)	3.48	.07
AWMA Listening recall	39.81 (5.78)	37.48 (4.08)	41.32 (5.42)	38.04 (5.24)	0.96	.33
AWMA Spatial span	39.57 (6.31)	38.32 (4.90)	40.23 (4.91)	38.62 (4.83)	0.18	.68
CANTAB Forward Spatial span	39.42 (6.01)	39.62 (5.20)	39.32 (5.21)	38.21 (4.97)	0.47	.49
CANTAB Backward Spatial span	39.10 (6.14)	38.68 (5.07)	40.15 (5.22)	38.37 (4.44)	0.11	.74
MHV						
AWMA Forward digit span	22.42 (4.34)	19.92 (3.65)	23.21 (2.83)	18.69 (3.98)	0.08	.78
AWMA Backward digit span	21.67 (4.46)	20.40 (4.02)	22.83 (2.71)	18.24 (3.78)	0.41	.53
AWMA Listening recall	21.81 (4.29)	19.96 (3.66)	23.04 (2.96)	18.89 (4.27)	0.01	.92
AWMA Spatial span	21.57 (5.24)	20.05 (3.99)	22.77 (2.62)	18.52 (3.30)	0.04	.85
CANTAB Forward Spatial span	20.67 (4.43)	21.12 (3.96)	22.09 (3.21)	19.67 (4.57)	0.00	.99
CANTAB Backward Spatial span	20.69 (4.76)	20.68 (4.10)	22.31 (3.07)	19.37 (4.00)	0.03	.86

APPENDIX D: LOW DEMAND WORKING MEMORY MODELS REPORTED IN CHAPTER SEVEN.

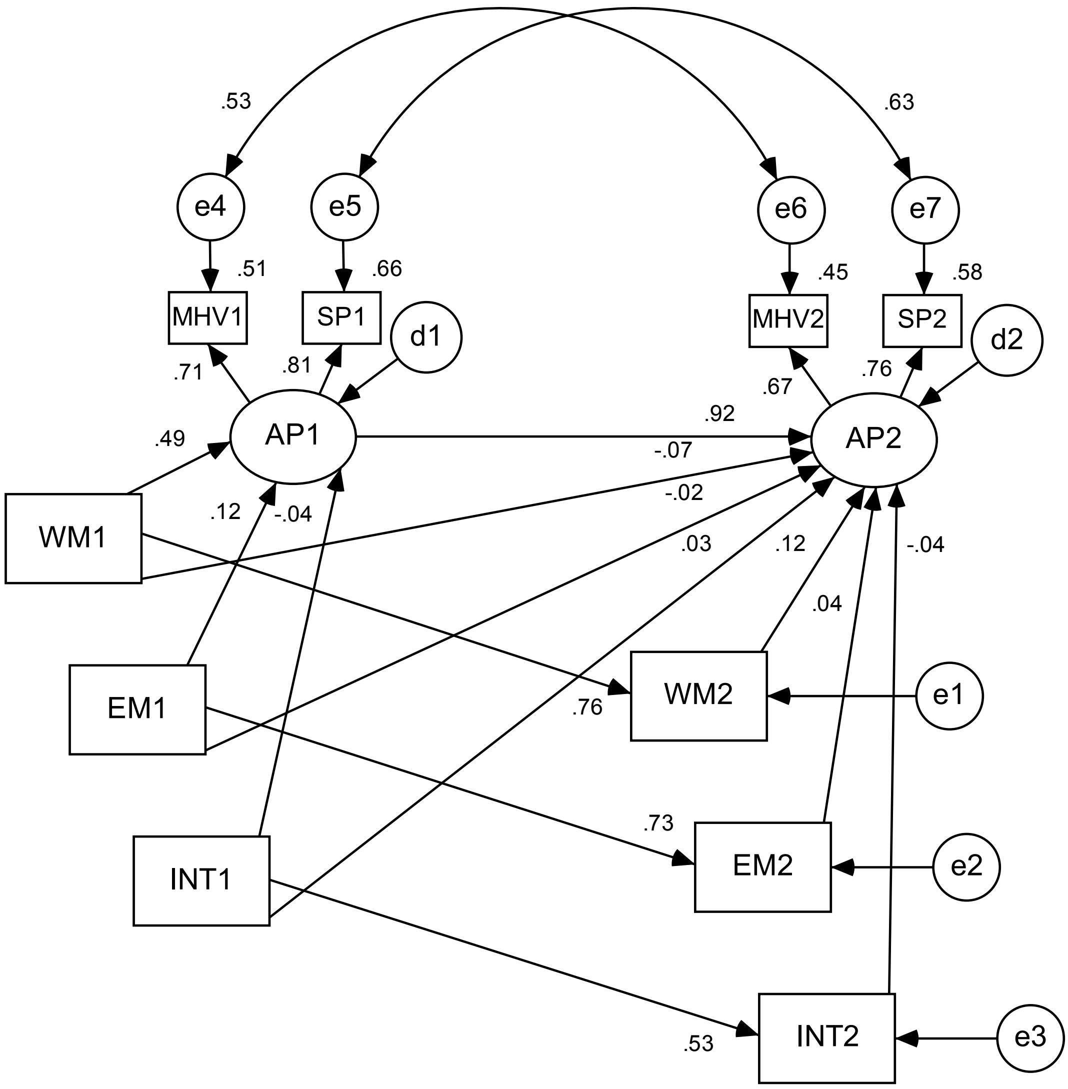


FIGURE D.1. The low demand working memory interaction model. WM1 = T1 working memory; EM1 = T1 emotion; INT1 = T1 interaction between emotion and working memory; AP1 = T1 academic performance. Academic performance is comprised of spelling and MHV test in this low demand model. Variables to the right of the diagram labelled with 2 are the T2 equivalents of T1 variables.

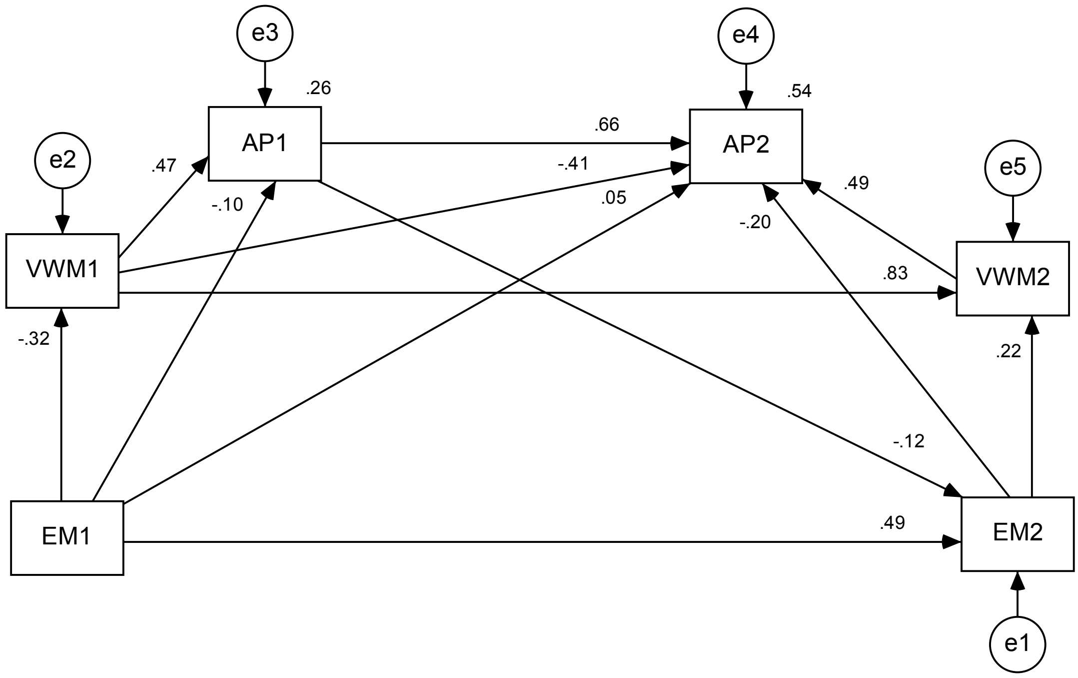


FIGURE D.2. The low demand working memory mediation model – high stress reactivity group. VWM1 = T1 verbal working memory; EM1 = T1 emotion comprised of depression and test anxiety; AP1 = T1 academic performance. Variables to the right of the diagram labelled with 2 are the T2 equivalents of T1 variables.

LIST OF REFERENCES

Al'absi, M., Hugdahl, K., & Lovallo, W. R. (2002). Adrenocortical stress responses and altered working memory performance. *Psychophysiology, 39,* 95-99.

Alloway, T. P. (2007). The Automated Working Memory Assessment. London: The Psychological Corporation.

Alloway, T. P., Gathercole, S. E., & Pickering, S. J. (2006). Verbal and visuospatial short-term and working memory in children: Are they separable? *Child Development, 77,* 1698-1716.

Alpert, R. & Haber, R. N. (1960). Anxiety in academic achievement situations. *The Journal of Abnormal and Social Psychology, 61,* 207-215.

American Psychiatric Association (2000). *Diagnostic and Statistical Manual of Mental Disorders*. (Fourth Edition, Text Revision). Washington DC: American Psychiatric Association.

Ameringen, M. V., Mancini, C., & Farvolden, P. (2003). The impact of anxiety disorders on educational achievement. *Journal of Anxiety Disorders, 17,* 561-571.

Andrade, J. (2001). An Introduction to Working Memory. In J.Andrade (Ed.), *Working Memory in Perspective* (pp. 3-30). Hove, UK: Psychology Press.

Andres, P. (2003). Frontal cortex as the central executive of working memory: Time to revise our view. *Cortex, 39,* 871-895.

Andrews, B. & Wilding, J. M. (2004). The relation of depression and anxiety to life-stress and achievement in students. *British Journal of Psychology, 95,* 509-521.

Angold, A., Costello, E. J., & Erkanli, A. (1999). Comorbidity. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 40,* 57-87.

Arbuckle, J. L. (2006). AMOS 7.0 User's Guide. Bethlehem Pike, Pennsylvania, Amos Development Corporation.

Aronen, E. T., Vuontela, V., Steenari, M. R., Salmi, J., & Carlson, S. (2005). Working memory, psychiatric symptoms, and academic performance at school. *Neurobiology of Learning & Memory, 83,* 33-42.

Asbahr, F. R. (2004). Anxiety disorders in childhood and adolescence: clinical and neurobiological aspects. *Jornal de Pediatria, 80,* S28-S34.

Ashcraft, M. H. & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review, 14,* 243-248.

Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions in Psychological Science, 11,* 181-185.

Ashcraft, M. H. & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General, 130,* 224-237.

Baddeley, A. (2003). Working memory: Looking back and looking forward. *Nature Reviews Neuroscience, 4,* 829-839.

Baddeley, A., Della Sala, S., Papagno, C., & Spinnler, H. (1997). Dual-task performance in dysexecutive and nondysexecutive patients with a frontal lesion. *Neuropsychology, 11,* 187-194.

Baddeley, A. D. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences, 4,* 417-423.

Baddeley, A. D. & Hitch, G. J. (1974). Working memory. In G.Bower (Ed.), *Recent advances in learning and motivation* (pp. 47-90). New York: Academic Press.

Baddeley, A. (1986). *Working memory*. New York, NY: Clarendon Press/Oxford University Press.

Baddeley, A. (1996a). Exploring the central executive. *The Quarterly Journal of Experimental Psychology, 49A,* 5-28.

Baddeley, A. (1996b). The fractionation of working memory. *Proceedings of the National Academy of Sciences, 93,* 13468-13472.

Baddeley, A. (1998). The central executive: A concept and some misconceptions. *Journal of the International Neuropsychological Society, 4,* 523-526.

Baker, S. C. et al. (1996). Neural systems engaged by planning: A PET study of the Tower of London task. *Neuropsychologia, 34,* 515-526.

Barlow, D. H. (2000). Unraveling the mysteries of anxiety and its disorders from the perspective of emotion theory. *American Psychologist, 55,* 1247-1263.

Baron, R. M. & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality & Social Psychology, 51,* 1173-1182.

Barrett, P. (2007). Structural equation modelling: Adjudging model fit. *Personality and Individual Differences, 42,* 815-824.

Beck, A. T. (1976). *Cognitive therapy and the emotional disorders*. Oxford: International Universities Press.

Beck, A. T., Emery, G., & Greenberg, R. L. (1985). *Anxiety disorders and phobias: A cognitive perspective*. New York: Basic Books.

Bell, M. A. & Wolfe, C. D. (2004). Emotion and cognition: An intricately bound developmental process. *Child Development, 75,* 366-370.

Bentler, P. M. (2007). On tests and indices for evaluating structural models. *Personality and Individual Differences, 42,* 825-829.

Berrios, G. (1999). Anxiety disorders: a conceptual history. *Journal of Affective Disorders, 56,* 83-94.

Berrios, G. E. (1988). Melancholia and Depression During the 19th-Century - A Conceptual History. *British Journal of Psychiatry, 153,* 298-304.

Blair, C. (2002). School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist, 57,* 111-127.

Blair, C., Granger, D., & Razza, R. P. (2005). Cortisol Reactivity is Positively Related to Executive Function in Preschool Children Attending Head Start. *Child Development, 76,* 554-567.

Bollen, K. A. & Curran, P. J. (2006). *Latent Curve Models: A Structural Equation Modelling Perspective*. Hoboken, NJ: John Wiley & Sons.

Bolton, D. et al. (2006). Prevalence and genetic and environmental influences on anxiety disorders in 6-year-old twins. *Psychological Medicine, 36,* 335-344.

Bonne, O. et al. (2003). Prospective evaluation of plasma cortisol in recent trauma survivors with posttraumatic stress disorder. *Psychiatry Research, 119,* 171-175.

Breslau, J., Michael, L., Nancy, S. B., & Kessler, R. C. (2008). Mental disorders and subsequent educational attainment in a US national sample. *Journal of Psychiatric Research, 42,* 708-716.

Bruyer, R. & Scailquin, J. C. (1998). The visuospatial sketchpad for mental images: Testing the multicomponent model of working memory. *Acta Psychologica, 98,* 17-36.

Burnham, K. P. & Anderson, D. R. (2002). *Model selection and multimodel inference: a practical information-theoretic approach*. New York: Springer.

Buske-Kirschbaum, A. et al. (2004). Persaonality characteristics and their association with biological stress responses in patients with Atopic dermatitis. *Dermatology and Psychosomatics,* 12-16.

Cabeza, R. & Nyberg, L. (2001). Imaging Cognition II: An empirical review of 257 PET and fMRI studies. *Journal of Cognitive Neuroscience, 12,* 1-47.

Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology, 96,* 31-42.

Calvo, M. G. & Eysenck, M. W. (1996). Phonological Working Memory and Reading in Test Anxiety. *Memory, 4,* 289-305.

Cambridge Neuropsychological Test Automated Battery. (2004). (Version CANTABeclipse) [Computer software]. Cambridge: Cambridge Cognition.

Cameron, H. A. & McKay, R. D. (1999). Restoring production of hippocampal neurons in old age. *Nature Neuroscience, 2,* 894-897.

Chavira, D. A., Stein, M. B., Bailey, K., & Stein, M. T. (2004). Comorbidity of generalized social anxiety disorder and depression in a pediatric primary care sample. *Journal of Affective Disorders, 80,* 163-171.

Chorpita, B. F., Moffitt, C. E., & Gray, J. (2005). Psychometric properties of the Revised Child Anxiety and Depression Scale in a clinical sample. *Behaviour Research and Therapy, 43,* 309-322.

Chorpita, B. F., Yim, L., Moffitt, C., Umemoto, L. A., & Francis, S. E. (2000). Assessment of symptoms of DSM-IV anxiety and depression in children: A revised child anxiety and depression scale. *Behaviour Research and Therapy, 38,* 835-855.

Christopher, G. & MacDonald, J. (2005). The impact of clinical depression on working memory. *Cognitive Neuropsychiatry, 10,* 379-399.

Clark, D. M. (1986). A cognitive approach to panic. *Behaviour Research and Therapy, 24,* 461-470.

Collette, F. & Van der Linden, M. (2002). Brain imaging of the central executive component of working memory. *Neuroscience & Biobehavioral Reviews, 26,* 105-125.

Conway, A. R. A., Cowan, N., Bunting, M. F., Therriault, D. J., & Minkoff, S. R. B. (2002). A latent variable analysis of working memory capacity, short-term memory capacity, processing speed, and general fluid intelligence. *Intelligence, 30,* 163-183.

Coplan, J. D. et al. (2002). Salivary cortisol concentrations before and after carbon-dioxide inhalations in children. *Biological Psychiatry, 51,* 326-333.

Costello, E. J. P., Mustillo, S. P., Erkanli, A. P., Keeler, G. M., & Angold, A. M. (2003). Prevalence and Development of Psychiatric Disorders in Childhood and Adolescence. *Archives of General Psychiatry, 60,* 837-844.

Coull, J. T., Frith, C. D., Frackowiak, R. S. J., & Grasby, P. M. (1996). A fronto-parietal network for rapid visual information processing: A PET study of sustained attention and working memory. *Neuropsychologia, 34,* 1085-1095.

Cowan, N. (1999). An Embedded Processes of Working Memory. In A.Miyake & P. Shah (Eds.), *Models of Working Memory* (pp. 62-101). Cambridge.

Crozier, W. R. & Hostettler, K. (2003). The influence of shyness on children's test performance. *British Journal of Educational Psychology, 73,* 317-328.

D'Esposito, M. et al. (1995). The Neural Basis of the Central Executive System of Working-Memory. *Nature, 378,* 279-281.

Dalton, K. M., Kalin, N. H., Grist, T. M., & Davidson, R. J. (2005). Neural-Cardiac Coupling in Threat-Evoked Anxiety. *Journal of Cognitive Neuroscience, 17,* 969-980.

Daneman, M. & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning & Verbal Behavior, 19,* 450-466.

Darke, S. (1988). Anxiety and working memory capacity. *Cognition & Emotion, 2,* 145-154.

de Kloet, E. R., Oitzl, M. S., & Joels, M. (1999). Stress and cognition: are corticosteroids good or bad guys? *Trends in Neurosciences, 22,* 422-426.

Dearing, E. & Hamilton, L. C. (2006). Contemporary advances and classic advice for analyzing mediating and moderating variables. *Monographs of the Society for Research in Child Development, 71,* 88-104.

Deffenbacher, J. L. (1978). Worry, Emotionality, and Task-Generated Interference in Test Anxiety - Empirical-Test of Attentional Theory. *Journal of Educational Psychology, 70,* 248-254.

Della Sala, S., Gray, C., Baddeley, A., Allamano, N., & Wilson, L. (1999). Pattern span: A tool for unwelding visuo-spatial memory. *Neuropsychologia, 37,* 1189-1199.

Derakshan, N. & Eysenck, M. W. (1998). Working memory capacity in high trait-anxious and repressor groups. *Cognition & Emotion, 12,* 697-713.

Dickerson, S. S. & Kemeny, M. E. (2004). Acute Stressors and Cortisol Responses: A Theoretical Integration and Synthesis of Laboratory Research. *Psychological Bulletin, 130,* 355-391.

Dineen, K. A. & Hadwin, J. A. (2004). Anxious and depressive symptoms and children's judgements of their own and others' interpretation of ambiguous social scenarios. *Journal of Anxiety Disorders, 18,* 499-513.

Domes, G., Rothfischer, J., Reichwald, U., & Hautzinger, M. (2005). Inverted-U Function Between Salivary Cortisol and Retrieval of Verbal Memory After Hydrocortisone Treatment. *Behavioral Neuroscience, 119,* 512-517.

Donald, M. (1991). *Origins of the modern mind*. Cambridge: Harvard University Press.

Eley, T. C. et al. (2003). A twin study of anxiety-related behaviours in pre-school children. *Journal of Child Psychology and Psychiatry, 44,* 945-960.

Elliman, N. A., Green, M. W., Rogers, P. J., & Finch, G. M. (1997). Processing-efficiency theory and the working-memory system: Impairments associated with sub-clinical anxiety. *Personality and Individual Differences, 23,* 31-35.

Ellis, H. C. (1985). On the Importance of Mood Intensity and Encoding Demands in Memory - Commentary. *Journal of Experimental Psychology-General, 114,* 392-395.

Ellis, H. C. (1990). Depressive Deficits in Memory - Processing Initiative and Resource-Allocation. *Journal of Experimental Psychology-General, 119,* 60-62.

Ellis, H. C. (1991). Focused Attention and Depressive Deficits in Memory. *Journal of Experimental Psychology-General, 120,* 310-312.

Ellis, H. C. & Ashbrook, P. W. (1988). Resource allocation model of the effects of depressed mood states on memory. In K.Fiedler & J.F.Forgas (Eds.), *Affect, cognition, and social behaviour* (pp. 25-43). Toronto: Hogrefe.

Ellis, H. C., Moore, B. A., Varner, L. J., Ottaway, S. A., & Becker, A. S. (1997). Depressed mood, task organization, cognitive interference, and memory: Irrelevant thoughts predict recall performance. *Journal of Social Behavior and Personality, 12,* 453-470.

Ellis, H. C. & Moore, B. A. (1999). Mood and Memory. In T.Dalgleish & M. J. Power (Eds.), *Handbook of cognition and emotion* (pp. 193-210). New York, NY, US: John Wiley & Sons Ltd.

Ellis, H. C., Thomas, R. L., & Rodriguez, I. A. (1984). Emotional mood states and memory: Elaborative encoding, semantics processing, and cognitive effort. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10,* 470-482.

Emerson, C. S., Mollet, G. A., & Harrison, D. W. (2005). Anxious-depression in boys: An evaluation of executive functioning. *Archives of Clinical Neuropsychology, 20,* 539-546.

Erickson, K., Drevets, W., & Schulkin, J. (2003). Glucocorticoid regulation of diverse cognitive functions in normal and pathological emotional states. *Neuroscience & Biobehavioral Reviews, 27,* 233-246.

Eysenck, M. W. & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition & Emotion, 6,* 409-434.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7,* 336-353.

Eysenck, M. W., Payne, S., & Derakshan, N. (2005). Trait anxiety, visuospatial processing, and working memory. *Cognition & Emotion, 19,* 1214-1228.

Fehm, L., Pelissolo, A., Furmark, T., & Wittchen, H. U. (2005). Size and burden of social phobia in Europe. *European Neuropsychopharmacology, 15,* 453-462.

Fischer, H., Anderson, J. L. R., Furmark, T., Wik, G., & Fredrikson, M. (2002). Right-sided human prefrontal brain activation during acquisition of conditioned fear. *Emotion, 2,* 233-241.

Foreman, D. M. & Goodyer, I. M. (1988). Salivary Cortisol Hypersecretion in Juvenile Depression. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 29,* 311-320.

Freberg, M. E., Vandiver, B. J., Watkins, M. W., & Canivez, G. L. (2008). Significant factor score variability and the validity of the WISC-III Full Scale IQ in predicting later academic achievement. *Applied Neuropsychology, 15,* 131-139.

Fröjd, S. A. et al. (2008). Depression and school performance in middle adolescent boys and girls. *Journal of Adolescence, 31,* 485-498.

Furmark, T. (2002). Social phobia: overview of community surveys. *Acta Psychiatrica Scandinavica, 105,* 84-93.

Gathercole, S. E. & Pickering, S. J. (2000a). Assessment of working memory in six- and seven-year-old children. *Journal of Educational Psychology, 92,* 377-390.

Gathercole, S. E. & Pickering, S. J. (2000b). Working memory deficits in children with low achievements in the national curriculum at 7 years of age. *British Journal of Educational Psychology, 70,* 177-194.

Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from National curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology, 18,* 1-16.

Gaudry, E., Vagg, P., & Spielberger, C. D. (1975). Validation of State-Trait Distinction in Anxiety Research. *Multivariate Behavioral Research, 10,* 331-341.

Glied, S. & Pine, D. S. (2002). Consequences and correlates of adolescent depression. *Archives of Pediatrics & Adolescent Medicine, 156,* 1009-1014.

Granger, D. A., Weisz, J. R., & Kauneckis, D. (1994). Neuroendocrine reactivity, internalizing behavior problems, and control-related cognitions in clinic-referred children and adolescents. *Journal of Abnormal Psychology, 103,* 267-276.

Graziano, P. A., Reavis, R. D., Keane, S. P., & Calkins, S. D. (2007). The role of emotion regulation in children's early academic success. *Journal of School Psychology, 45,* 3-19.

Greaves-Lord, K. et al. (2007). Higher cortisol awakening response in young adolescents with persistent anxiety problems. *Acta Psychiatrica Scandinavica, 116,* 137-144.

Greenberg, P. E. et al. (2003). The economic burden of depression in the United States: How did it change between 1990 and 2000? *Journal of Clinical Psychiatry, 64,* 1465-1475.

Grover, R. L., Ginsburg, G. S., & Ialongo, N. (2007). Psychosocial outcomes of anxious first graders: A seven-year follow-up. *Depression and Anxiety, 24,* 410-420.

Gullone, E. (2000). The development of normal fear: A century of research. *Clinical Psychology Review, 20,* 429-451.

Gumora, G. & Arsenio, W. F. (2002). Emotionality, emotion regulation, and school performance in middle school children. *Journal of School Psychology, 40,* 395-413.

Gunther, T., Holtkamp, K., Jolles, J., Herpertz-Dahlmann, B., & Konrad, K. (2004). Verbal memory and aspects of attentional control in children and adolescents with anxiety disorders or depressive disorders. *Journal of Affective Disorders, 82,* 265-269.

Hadwin, J., Frost, S., French, C. C., & Richards, A. (1997). Cognitive processing and trait anxiety in typically developing children: Evidence for an interpretation bias. *Journal of Abnormal Psychology, 106,* 486-490.

Hadwin, J. A., Brogan, J., & Stevenson, J. (2005). State anxiety and working memory in children: A test of processing efficiency theory. *Educational Psychology, 25,* 379-393.

Hadwin, J. A., Garner, M., & Perez-Olivas, G. (2006). The development of information processing biases in childhood anxiety: A review and exploration of its origins in parenting. *Clinical Psychology Review, 26,* 876-894.

Hayes, S., MacLeod, C., & Hammond, G. Anxiety-linked task performance: Dissociating the influence of restricted working memory capacity and increased investment of effort. *Cognition & Emotion,* (in press).

Hembree, R. (1990). The Nature, Effects, and Relief of Mathematics Anxiety. *Journal for Research in Mathematics Education, 21,* 33-46.

Hembree, R. (1988). Correlates, causes, effects, and treatment of test anxiety. *Review of Educational Research, 58,* 47-77.

Het, S., Ramlow, G., & Wolf, O. T. (2005). A meta-analytic review of the effects of acute cortisol administration on human memory. *Psychoneuroendocrinology, 30,* 771-784.

Hettema, J. M., Neale, M. C., & Kendler, K. S. (2001). A Review and Meta-Analysis of the Genetic Epidemiology of Anxiety Disorders. *American Journal of Psychiatry, 158,* 1568-1578.

Hill, K. T. & Eaton, W. O. (1977). The interaction of test anxiety and success-failure experiences in determining children's arithmetic performance. *Developmental Psychology, 13,* 205-211.

Hill, K. T. & Wigfield, A. (1984). Test anxiety: A major educational problem and what can be done about it. *Elementary School Journal, 85,* 105-126.

Holmes, J. & Adams, J. W. (2006). Working memory and children's mathematical skills: Implications for mathematical development and mathematics curricula. *Educational Psychology, 26,* 339-366.

Holroyd, K. A., Westbrook, T., Wolf, M., & Badhorn, E. (1978). Performance, Cognition, and Physiological Responding in Test Anxiety. *Journal of Abnormal Psychology, 87,* 442-451.

Holsboer, F. (2000). The corticosteroid receptor hypothesis of depression. *Neuropsychopharmacology, 23,* 477-501.

Hopko, D. R., Ashcraft, M. H., Gute, J., Ruggiero, K. J., & Lewis, C. (1998). Mathematics Anxiety and Working Memory: Support for the Existence of a Deficient Inhibition Mechanism. *Journal of Anxiety Disorders, 12,* 343-355.

Hopko, D. R., Crittendon, J. A., Grant, E., & Wilson, S. A. (2005). The impact of anxiety on performance IQ. *Anxiety, Stress & Coping: An International Journal, 18,* 17-35.

Hoshi, Y. et al. (2000). Visuospatial imagery is a fruitful strategy for the digit span backward task: a study with near-infrared optical tomography. *Cognitive Brain Research, 9,* 339-342.

Hu, L. & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis:conventional criteria versus new alternatives. *Structural Equation Modeling, 6,* 1-55.

Hudziak, J. J. et al. (2004). Genetic and environmental contributions to the child behavior checklist Obsessive-Compulsive Scale - A cross-cultural twin study. *Archives of General Psychiatry, 61,* 608-616.

Hume, D. (2003). *A Treatise of Human Nature*. Project Gutenberg, http://www.gutenberg.org/etext/4705.

Ikeda, M., Iwanaga, M., & Seiwa, H. (1996). Test anxiety and working memory system. *Perceptual and Motor Skills, 82,* 1223-1231.

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences of the United States of America, 105,* 6829-6833.

Jarvis, H. L. & Gathercole, S. E. (2003). Verbal and non-verbal working memory and achievements on National Curriculum tests at 11 and 14 years of age. *Educational and Child Psychology, 20,* 123-140.

Johnson, D. R. & Gronlund, S. D. (2009). Individuals lower in working memory capacity are particularly vulnerable to anxiety's disruptive effect on performance. *Anxiety, Stress & Coping, 22,* 201-213.

Judd, C. M. & Kenny, D. A. (1981). Process analysis: Estimating mediation in treatment evaluations. *Evaluation Review, 5,* 602-619.

Kallen, V. L. et al. (2008). Associations between HPA axis functioning and level of anxiety in children and adolescents with an anxiety disorder. *Depression and Anxiety, 25,* 131-141.

Kaye, D., Kirschner, P., & Mandler, G. (1953). The effect of test anxiety on memory span in a group test situation. *Journal of Consulting Psychology, 17,* 265-266.

Kendler, K. S., Gardner, C. O., Gatz, M., & Pedersen, N. L. (2007). The sources of co-morbidity between major depression and generalized anxiety disorder in a Swedish national twin sample. *Psychological Medicine, 37,* 453-462.

Kendler, K. S., Davis, C. G., & Kessler, R. C. (1997). The familial aggregation of common psychiatric and substance use disorders in the National Comorbidity Survey: A family history study. *British Journal of Psychiatry, 170,* 541-548.

Keogh, E., Bond, F. W., French, C. C., Richards, A., & Davis, R. E. (2004). Test anxiety, susceptibility to distraction and examination performance. *Anxiety Stress and Coping, 17,* 241-252.

Keogh, E., Bond, F. W., & Flaxman, P. E. (2006). Improving academic performance and mental health through a stress management intervention: Outcomes and mediators of change. *Behaviour Research and Therapy, 44,* 339-357.

Kessler, R. C., Berglund, P., Demler, O., Jin, R., & Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions' of DSM-IV disorders in the national comorbidity survey replication. *Archives of General Psychiatry, 62,* 593-602.

Kessler, R. C. et al. (2008). Co-morbid major depression and generalized anxiety disorders in the National Comorbidity Survey follow-up. *Psychological Medicine, 38,* 365-374.

Kessler, R. C. et al. (1996). Comorbidity of DSM-III-R major depressive disorder in the general population: Results from the US National Comorbidity Survey. *British Journal of Psychiatry, 168,* 17-30.

Kessler, R. C., Foster, C. L., Saunders, W. B., & Stang, P. E. (1995). Social consequences of psychiatric disorders I: Educational attainment. *American Journal of Psychiatry, 152,* 1026-1032.

Kiess, W. et al. (1995). Salivary Cortisol-Levels Throughout Childhood and Adolescence - Relation with Age, Pubertal Stage, and Weight. *Pediatric Research, 37,* 502-506.

Kirschbaum, C. & Hellhammer, D. H. (1989). Salivary cortisol in psychobiological research: an overview. *Neuropsychobiology, 22,* 15-169.

Kline, R. B. (2005). *Principle and Practice of Structural Equation Modeling*. New York: The Guilford Press.

Knutsson, U. et al. (1997). Circadian cortisol rhythms in healthy boys and girls: Relationship with age, growth, body composition, and pubertal development. *Journal of Clinical Endocrinology and Metabolism, 82,* 536-540.

Kovacs, M. (1992). *Children's Depression Inventory manual.* North Tonawanda, NY: Multi-Health Systems.

Lane, R. D., Nadel, L., Allen, J. J. B., & Kaszniak, A. W. (2000). The Study of Emotion from the Perspective of Cognitive Neuroscience. In R.D.Lane & L. Nadel (Eds.), *Cognitive Neuroscience of Emotion* (pp. 3-11). Oxford: Oxford University Press.

Lazarus, R. S. (1982). Thoughts on the Relations Between Emotion and Cognition. *American Psychologist, 37,* 1019-1024.

Lazarus, R. S. (1984). On the Primacy of Cognition. *American Psychologist, 39,* 124-129.

Lehto, J. (1995). Working memory and school achievement in the Ninth Form. *Educational Psychology, 15,* 271-281.

Lemerise, E. A. & Arsenio, W. F. (2000). An integrated model of emotion processes and cognition in social information processing. *Child Development, 71,* 107-118.

Li, S. C. & Lewandowsky, S. (1995). Forward and backward recall: Different retrieval processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 837-847.

Liebert, R. M. & Morris, L. W. (1967). Cognitive and emotional components of test anxiety: a distinction and some initial data. *Psychological Reports, 20,* 975-978.

Little, T. D., Card, N. A., Bovaird, J. A., Preacher, K., & Crandall, C. S. (2007). Structural equation modeling of mediation and moderation with contextual factors. In T.D.Little, J.A.Bovaird, & N.A.Card (Eds.), *Modeling contextual effects in longitudinal studies.* (pp. 207-230). Mahwah, NJ: Erlbaum.

Locke, J. (1877). *An Essay Concerning Human Understanding*. (Thirtieth). London: George Bell & Sons.

Lohman, D. F., Hagen, E. P., & Thorndike, D. L. (2003). *Cognitive Abilities Test: Third Edition*. Windsor, UK: NFER Nelson.

Lowe, P. A. & Lee, S. W. (2008). Factor structure of the Test Anxiety Inventory for Children and Adolescents (TAICA) scores across gender among students in elementary and secondary school settings. *Journal of Psychoeducational Assessment, 26,* 231-246.

Luciana, M. (2003). Practitioner review: Computerized assessment of neuropsychological function in children: Clinical and research applications of the Cambridge Neuropsychological Testing Automated Battery (CANTAB). *Journal of Child Psychology & Psychiatry, 44,* 649-663.

Lupien, S. J. et al. (1998). Cortisol levels during human aging predict hippocampal atrophy and memory deficits. *Nature Neuroscience, 1,* 69-73.

Lupien, S. J., King, S., Meaney, M. J., & McEwen, B. S. (2001). Can poverty get under your skin? Basal cortisol levels and cognitive function in children from low and high socioeconomic status. *Development and Psychopathology, 13,* 653-676.

Lupien, S., Lecours, A. R., Lussier, I., & Schwartz, G. (1994). Basal cortisol levels and cognitive deficits in human aging. *Journal of Neuroscience, 14,* 2893-2903.

Lupien, S. J. et al. (2005). Stress hormones and human memory function across the lifespan. *Psychoneuroendocrinology, 30,* 225-242.

Lupien, S. J., Gillin, C. J., & Hauger, R. L. (1999). Working Memory Is More Sensitive Than Declarative Memory to the Acute Effects of Corticosteroids: A Dose-Response Study in Humans. *Behavioral Neuroscience, 113,* 420-430.

Ma, X. (1999). A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics. *Journal for Research in Mathematics Education, 30,* 520-540.

Mackinaw-Koons, B. & Vasey, M. W. (2000). Considering sex differences in anxiety and its disorders across the life span: A construct-validation approach. *Applied & Preventive Psychology, 9,* 191-209.

MacKinnon, D. P., Lockwood, C. M., Hoffman, J. M., West, S. G., & Sheets, V. (2002). A comparison of methods to test mediation and other intervening variable effects. *Psychological Methods, 7,* 83-104.

MacKinnon, D. P., Lockwood, C. M., & Williams, J. (2004). Confidence limits for the indirect effect: Distribution of the product and resampling methods. *Multivariate Behavioral Research, 39,* 99-128.

MacKinnon, D. P., Warsi, G., & Dwyer, J. H. (1995). A simulation study of mediated effect measures. *Multivariate Behavioral Research, 30,* 41-62.

MacLeod, C. & Donnellan, A. M. (1993). Individual differences in anxiety and the restriction of working memory capacity. *Personality & Individual Differences, 15,* 163-173.

Mandler, G. & Sarason, S. B. (1952). A study of anxiety and learning. *Journal of Abnormal & Social Psychology, 47,* 166-173.

Mannie, Z. N., Harmer, C. J., & Cowen, P. J. (2007). Increased waking salivary cortisol levels in young people at familial risk of depression. *American Journal of Psychiatry, 164,* 617-621.

Marlett, N. J. & Watson, D. (1968). Test anxiety and immediate or delayed feedback in a test-like avoidance task. *Journal of Personality and Social Psychology, 8,* 200-203.

Mathews, A. & MacLeod, C. (1994). Cognitive approaches to emotion and emotional disorders. *Annual Review of Psychology, 45,* 25-50.

McDonald, A. S. (2001). The prevalence and effects of test anxiety in school children. *Educational Psychology, 21,* 89-101.

McEwen, B. S. & Sapolsky, R. M. (1995). Stress and cognitive function. *Current Opinion in Neurobiology, 5,* 205-216.

McNally, R. J. (2001). On the scientific status of cognitive appraisal models of anxiety disorder. *Behaviour Research and Therapy, 39,* 513-521.

Meijer, J. & Oostdam, R. (2007). Test anxiety and intelligence testing: A closer examination of the stage-fright hypothesis and the influence of stressful instruction. *Anxiety, Stress & Coping: An International Journal, 20,* 77-91.

Meinhardt, J. & Pekrun, R. (2003). Attentional resource allocation to emotional events: An ERP study. *Cognition & Emotion, 17,* 477-500.

Merikangas, K. R. et al. (1998). Co-morbidity and familial aggregation of alcoholism and anxiety disorders. *Psychological Medicine, 28,* 773-788.

Milner, B. (1971). Interhemispheric Differences in Localization of Psychological Processes in Man. *British Medical Bulletin, 27,* 272-277.

Miyake, A. & Shah, P. (1999). *Models of working memory: Mechanisms of active maintenance and executive control*. New York, NY: Cambridge University Press.

Moffitt, T. E. et al. (2007). Depression and generalized anxiety disorder: cumulative and sequential comorbidity in a birth cohort followed prospectively to age 32 years. *Archives of General Psychiatry, 64,* 651-660.

Mogg, K., Bradbury, K. E., & Bradley, B. P. (2006). Interpretation of ambiguous information in clinical depression. *Behaviour Research and Therapy, 44,* 1411-1419.

Moldawsky, S. & Moldawsky, P. C. (1952). Digit span as an anxiety indicator. *Journal of Consulting Psychology, 16,* 115-118.

Morris, L. W., Davis, M. A., & Hutchings, C. H. (1981). Cognitive and Emotional Components of Anxiety - Literature-Review and A Revised Worry-Emotionality Scale. *Journal of Educational Psychology, 73,* 541-555.

Morris, L. W. & Liebert, R. M. (1970). Relationship of Cognitive and Emotional Components of Test Anxiety to Physiological Arousal and Academic Performance. *Journal of Consulting and Clinical Psychology, 35,* 332-337.

Morris, L. W. & Liebert, R. M. (1969). Effects of anxiety on timed and untimed intelligence tests: Another look. *Journal of Consulting and Clinical Psychology, 33,* 240-244.

Muris, P. & Field, A. P. (2008). Distorted cognition and pathological anxiety in children and adolescents. *Cognition & Emotion, 22,* 395-421.

Muris, P., Meesters, C., & Schouten, E. (2002). A brief questionnaire of DSM-IV-defined anxiety and depression symptoms among children. *Clinical Psychology & Psychotherapy, 9,* 430-442.

Muris, P., Merckelbach, H., Ollendick, T., King, N., & Bogie, N. (2002). Three traditional and three new childhood anxiety questionnaires: their reliability and validity in a normal adolescent sample. *Behaviour Research and Therapy, 40,* 753-772.

Muris, P., Merckelbach, H., Schmidt, H., Gadet, B., & Bogie, N. (2001). Anxiety and depression as correlates of self-reported behavioural inhibition in normal adolescents. *Behaviour Research and Therapy, 39,* 1051-1061.

Murphy, F. C., Nimmo-Smith, I., & Lawrence, A. D. (2003). Functional neuroanatomy of emotions: A meta-analysis. *Cognitive, Affective & Behavioral Neuroscience, 3,* 207-233.

Musch, J. & Bröder, A. (1999). Test anxiety versus academic skills: A comparison of two alternative models for predicting performance in a statistics exam. *British Journal of Educational Psychology, 69,* 105-116.

Mykletun, A., Stordal, E., & Dahl, A. A. (2001). Hospital Anxiety and Depression (HAD) scale: factor structure, item analyses and internal consistency in a large population. *British Journal of Psychiatry, 179,* 540-544.

National Comorbidity Survey (2007). Lifetime prevalence of DSM-IV/WMH-CIDI disorders by sex and cohort (n=9282). National Comorbidity Survey website [On-line]. Available: www.hcp.med.harvard.edu/ncs/ftpdir/table_ncsr_LTprevgenderxage.pdf

Nesse, R. (1998). Emotional disorders in evolutionary perspective. *British Journal of Medical Psychology, 71,* 397-415.

NFER Nelson (2004). *Cognitive Abilities Test (CAT) and GCSE grades: Autumn 2004.* Windsor, UK: NFER Nelson.

NFER Nelson (2005a). *Cognitive Abilities Test (CAT) and end of key stage 2 levels: Autumn 2005.* Windsor, UK: NFER Nelson.

NFER Nelson (2005b). *Cognitive Abilities Test (CAT) and end of key stage 3 levels: Autumn 2005.* Windsor, UK: NFER Nelson.

Nisbett, R. E. & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review, 84,* 231-259.

Nolen-Hoeksema, S. (2000). The role of rumination in depressive disorders and mixed anxiety/depressive symptoms. *Journal of Abnormal Psychology, 109,* 504-511.

Norman, D. A. & Shallice, T. (1986). Attention to action:willed and automatic control of behaviour. In R.J.Davidson, G.E.Schwarts, & D.Shapiro (Eds.), *Consciousness and Self-regulation. Advances in Research and Theory.Vol. 4* (pp. 1-18). New York: Plenum.

Nurmi, J. E., Aunola, K., Salmela-Aro, K., & Lindroos, M. (2003). The role of success expectation and task-avoidance in academic performance and satisfaction: Three studies on antecedents, consequences and correlates. *Contemporary Educational Psychology, 28,* 59-90.

Ottenbreit, N. D. & Dobson, K. S. (2004). Avoidance and depression: the construction of the Cognitive-Behavioral Avoidance Scale. *Behaviour Research and Therapy, 42,* 293-313.

Owens, M., Stevenson, J., Norgate, R., & Hadwin, J. A. (2008). Processing efficiency theory in children: working memory as a mediator between trait anxiety and academic performance. *Anxiety Stress Coping, 21,* 417-430.

Papp, L. A., Klein, D. F., & Gorman, J. M. (1993). Carbon-Dioxide Hypersensitivity, Hyperventilation, and Panic Disorder. *American Journal of Psychiatry, 150,* 1149-1157.

Parker, G. et al. (1999). The influence of anxiety as a risk to early onset major depression. *Journal of Affective Disorders, 52,* 11-17.

Parkin, A. J. (1998). The central executive does not exist. *Journal of the International Neuropsychological Society, 4,* 518-522.

Perneger, T. V. (1998). What's wrong with Bonferroni adjustments. *British Medical Journal, 316,* 1236-1238.

Pine, D. S., Cohen, P., & Brook, J. (2001). Adolescent fears as predictors of depression. *Biological Psychiatry, 50,* 721-724.

Pine, D. S. (1999). Pathophysiology of childhood anxiety disorders. *Biological Psychiatry, 46,* 1555-1566.

Powers, D. E. (1986). *Test anxiety and the GRE general test* (Rep. No. 86-45). Princeton, NJ: Educational Testing Service.

Preacher, K. J. & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments & Computers, 36,* 717-731.

Putwain, D. (2007a). Researching academic stress and anxiety in students: some methodological considerations. *British Educational Research Journal, 33,* 207-219.

Putwain, D. W. (2007b). Test anxiety in UK schoolchildren: prevalence and demographic patterns. *British Journal of Educational Psychology, 77,* 579-593.

Quas, J. A., Bauer, A., & Boyce, W. T. (2004). Physiological reactivity, social support, and memory in early childhood. *Child Development, 75,* 797-814.

Rapee, R. M. (2002). The development and modification of temperamental risk for anxiety disorders: prevention of a lifetime of anxiety? *Biological Psychiatry, 52,* 947-957.

Rapee, R. M. & Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behaviour Research and Therapy, 35,* 741-756.

Rapee, R. M., Kennedy, S., Ingram, M., Edwards, S., & Sweeney, L. (2005). Prevention and Early Intervention of Anxiety Disorders in Inhibited Preschool Children. *Journal of Consulting and Clinical Psychology, 73,* 488-497.

Raven, J., Raven, J. C., & Court, J. H. (1998). *Manual for Raven's Progressive Matrices and Vocabulary Scales. Section 3: Standard Progressive Matrices.* San Antonio, TX: Harcourt.

Raven, J. (2000). The Raven's Progressive Matrices: Change and Stability over Culture and Time. *Cognitive Psychology, 41,* 1-48.

Roese, N. J. (1997). Counterfactual thinking. *Psychological Bulletin, 121,* 133-148.

Rohde, T. E. & Thompson, L. A. (2007). Predicting academic achievement with cognitive ability. *Intelligence, 35,* 83-92.

Roozendaal, B. (2000). Glucocorticoids and the regulation of memory consolidation. *Psychoneuroendocrinology, 25,* 213-238.

Rosenthal, R. (1991). Effect Sizes - Pearson Correlation, Its Display Via the Besd, and Alternative Indexes. *American Psychologist, 46,* 1086-1087.

Russell, B. (1996). *History of Western Philosophy*. London: Routledge.

Sahakian, B. J. & Owen, A. M. (1992). Computerized assessment in neuropsychiatry using CANTAB: discussion paper. *Journal Of The Royal Society Of Medicine, 85,* 399-402.

Salthouse, T. A. & Pink, J. E. (2008). Why is working memory related to fluid intelligence? *Psychonomic Bulletin & Review, 15,* 364-371.

Sapolsky, R. M. (2000). Glucocorticoids and hippocampal atrophy in neuropsychiatric disorders. *Archives of General Psychiatry, 57,* 925-935.

Sarason, I. G. (1978). The Test Anxiety Scale: Concept and Research. In C.D.Spielberger & I. G. Sarason (Eds.), *Stress and anxiety* (pp. 193-218). Washington, D.C.: Hemisphere Publishing Corp.

Sarason, I. G. (1984). Stress, anxiety, and cognitive interference: reactions to tests. *Journal of Personality & Social Psychology, 46,* 929-938.

Sarason, S. B., Mandler, G., & Craighill, P. G. (1952). The effect of differential instructions on anxiety and learning. *Journal of Abnormal Psychology, 47,* 561-565.

Schlotz, W. et al. (2008). Covariance between psychological and endocrine responses to pharmacological challenge and psychosocial stress: A question of timing. *Psychosomatic Medicine, 70,* 787-796.

Schoofs, D., Preuss, D., & Wolf, O. T. (2008). Psychosocial stress induces working memory impairments in an n-back paradigm. *Psychoneuroendocrinology*.

Schwarzer, R. (1990). Current trends in anxiety research. In P.J.D.Drenth, J. A. Sergeant, & J. R. Takens (Eds.), *European perspectives in psychology.* (pp. 225-244). Oxford, England: John Wiley & Sons.

Segerstrom, S. C., Stanton, A. L., Alden, L. E., & Shortridge, B. E. (2003). A multidimensional structure for repetitive thought: What's on your mind, and how, and how much? *Journal of Personality and Social Psychology, 85,* 909-921.

Segerstrom, S. C., Tsao, J. C. I., Alden, L. E., & Craske, M. G. (2000). Worry and rumination: Repetitive thought as a concomitant and predictor of negative mood. *Cognitive Therapy and Research, 24,* 671-688.

Seibert, P. S. & Ellis, H. C. (1991). Irrelevant Thoughts, Emotional Mood States, and Cognitive Task-Performance. *Memory & Cognition, 19,* 507-513.

Seipp, B. (1991). Anxiety and academic performance: A meta-analysis of findings. *Anxiety Research, 4,* 27-41.

Service, E. & Turpeinen, R. (2001). Working memory in spelling: Evidence from backward typing. *Memory, 9,* 395-421.

Shackman, A. J. et al. (2006). Anxiety selectively disrupts visuospatial working memory. *Emotion, 6,* 40-61.

Shiffrin, R. M. & Atkinson, R. C. (1969). Storage and retrieval processes in long-term memory. *Psychological Review, 76,* 179-193.

Shrout, P. E. & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: New procedures and recommendations. *Psychological Methods, 7,* 422-445.

Smith, E. E., Jonides, J., & Koeppe, R. A. (1996). Dissociating verbal and spatial working memory using PET. *Cerebral Cortex, 6,* 11-20.

Smith, R. J., Arnkoff, D. B., & Wright, T. L. (1990). Test anxiety and academic competence: A comparison of alternative models. *Journal of Counseling Psychology, 37,* 313-321.

Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. In S.Leinhardt (Ed.), *Sociological Methodology* (pp. 290-312). San Francisco, CA: Jossey-Bass.

Sobel, M. E. (1986). Some new results on indirect effects and their standard errors in covariance structure models. In N.B.Tuma (Ed.), *Sociological methodology* (pp. 159-186). Washington DC: American Sociological Association.

Somers, J. M., Goldner, E. M., Waraich, P., & Hsu, L. (2006). Prevalence and incidence studies of anxiety disorders: a systematic review of the literature. *Canadian Journal of Psychiatry - Revue Canadienne de Psychiatrie, 51,* 100-113.

Spielberger, C. D., Edwards, C. D., Lushene, R. E., Montuori, J., & Platzek, D. (1973). *Preliminary test manual for the State-Trait Anxiety Inventory for Children.* Palo Alto, CA: Consulting Psychologists Press, Inc.

Squire, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys, and humans. *Psychological Review, 99,* 195-231.

St Clair-Thompson, H. L. & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology, 59,* 745-759.

Starkman, M. N., Giordani, B., Berent, S., Schork, A., & Schteingart, D. E. (2001). Elevated cortisol levels in Cushing's disease are associated with cognitive decrements. *Psychosomatic Medicine, 63,* 985-993.

Starkman, M. N., Giordani, B., Gebarski, S. S., & Schteingart, D. E. (2003). Improvement in learning associated with increase in hippocampal formation volume. *Biological Psychiatry, 53,* 233-238.

Sternbach, R. A. (1963). Congenital insensitivity to pain: A critique. *Psychological Bulletin, 60,* 252-264.

Stober, J. & Pekrun, R. (2004). Advances in test anxiety research. *Anxiety Stress and Coping, 17,* 205-211.

Stopa, L. & Clark, D. M. (2000). Social phobia and interpretation of social events. *Behaviour Research and Therapy, 38,* 273-283.

Strand, S. (2002). *The cognitive abilities test (CAT) and standard grade indicators: Final report-Autumn 2002.* Windsor, UK: NFER Nelson.

Sullivan, P. F., Neale, M. C., & Kendler, K. S. (2000). Genetic epidemiology of major depression: Review and meta-analysis. *American Journal of Psychiatry, 157,* 1552-1562.

Swinscow, T. D. V. (1997). Differences between percentages and paired alternatives. British Medical Journal website [On-line]. Available: http://www.bmj.com/collections/statsbk/6.dtl

Tabachnick, B. G. & Fidell, L. S. (2007). *Using multivariate statistics*. (Fifth Edition). Boston, MA: Pearson.

Tobias, S. (1985). Test anxiety: Interference, defective skills, and cognitive capacity. *Educational Psychologist, 20,* 135-142.

Tohill, J. M. & Holyoak, K. J. (2000). The impact of anxiety on analogical reasoning. *Thinking & Reasoning, 6,* 27-40.

Toren, P. et al. (2000). Neurocognitive correlates of anxiety disorders in children: A preliminary report. *Journal of Anxiety Disorders, 14,* 239-247.

Turner, J. C. et al. (2002). The classroom environment and students' reports of avoidance strategies in mathematics: A multimethod study. *Journal of Educational Psychology, 94,* 88-106.

Van Ameringen, M., Mancini, C., & Oakman, J. M. (1998). The relationship of behavioral inhibition and shyness to anxiety disorder. *Journal of Nervous and Mental Disease, 186,* 425-431.

van West, D., Claes, S., Sulon, J., & Deboutte, D. (2008). Hypothalamic-pituitary-adrenal reactivity in prepubertal children with social phobia. *Journal of Affective Disorders, 111,* 281-290.

Vandierendonck, A., Kemps, E., Fastame, M. C., & Szmalec, A. (2004). Working memory components of the Corsi blocks task. *British Journal of Psychology, 95,* 57-79.

Vasey, M. W., Elhag, N., & Daleiden, E. L. (1996). Anxiety and the processing of emotionally threatening stimuli: Distinctive patterns of selective attention among high- and low-test-anxious children. *Child Development, 67,* 1173-1185.

Vedhara, K. et al. (2003). An investigation into the relationship between salivary cortisol, stress, anxiety and depression. *Biological Psychology, 62,* 89-96.

Visu-Petra, L., Ciairano, S., & Miclea, M. (2006). Neurocognitive correlates of child anxiety: A review of working memory research. *Cognitie Creier Comportament, 10,* 517-541.

Wager, T. D. & Smith, E. E. (2003). Neuroimaging studies of working memory: A meta-analysis. *Cognitive, Affective & Behavioral Neuroscience, 3,* 255-274.

Watkins, E. R. (2008). Constructive and unconstructive repetitive thought. *Psychological Bulletin, 134,* 163-206.

Waugh, N. C. & Norman, D. A. (1965). Primary Memory. *Psychological Review, 72,* 89-104.

Weems, C. F., Zakem, A. H., Costa, N. M., Cannon, M. F., & Watts, S. E. (2005). Physiological response and childhood anxiety: Association with symptoms of anxiety disorders and cognitive bias. *Journal of Clinical Child and Adolescent Psychology, 34,* 712-723.

Wells, A. & Carter, K. (1999). Preliminary tests of a cognitive model of generalized anxiety disorder. *Behaviour Research and Therapy, 37,* 585-594.

Widiger, T. A. & Samuel, D. B. (2005). Diagnostic categories or dimensions? A question for the diagnostic and statistical manual of mental disorders-fifth edition. *Journal of Abnormal Psychology, 114,* 494-504.

Wilkinson, G. S. & Robertson, G. J. (2006). *Wide Range Achievement Test - Fourth Edition.* Odessa, FL: Psychological Assessment Resources.

Wine, J. (1971). Test Anxiety and Direction of Attention. *Psychological Bulletin, 76,* 92-104.

Wittchen, H. U., Stein, M. B., & Kessler, R. C. (1999). Social fears and social phobia in a community sample of adolescents and young adults: prevalence, risk factors and co-morbidity. *Psychological Medicine, 29,* 309-323.

Wittchen, H. U. (2002). Generalized anxiety disorder: Prevalence, burden, and cost to society. *Depression and Anxiety, 16,* 162-171.

Wittchen, H. U. & Jacobi, F. (2005). Size and burden of mental disorders in Europe--A critical review and appraisal of 27 studies. *European Neuropsychopharmacology, 15,* 357-376.

Wood, J. (2006). Effect of anxiety reduction on children's school performance and social adjustment. *Developmental Psychology, 42,* 345-349.

Wren, D. G. & Benson, J. (2004). Measuring test anxiety in children: Scale development and internal construct validation. *Anxiety, Stress & Coping: An International Journal, 17,* 227-240.

Zajonc, R. B. (1980). Feeling and Thinking - Preferences Need No Inferences. *American Psychologist, 35,* 151-175.

Zajonc, R. B. (1984). On the Primacy of Affect. *American Psychologist, 39,* 117-123.

Zeidner, M. (1998). *Test anxiety: The state of the art*. New York, NY: Plenum Press.