

# **The Effects of anxiety on cognitive performance**

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**Signed declaration**

I hereby declare that the work in this thesis is entirely my own. Where I have consulted the work of others, this is always clearly stated.

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## Abstract

This thesis describes five studies that systematically examined the effects of anxiety on cognitive performance, based on high trait versus low trait anxious university students. It directly tests the main assumptions of attentional control theory (ACT, Eysenck et al., 2007).

The first two studies investigated the effects of anxiety on two central executive functions (inhibition and shifting) both jointly and separately. Task switching and an auditory distractor were used to investigate respectively the shifting and inhibition functions. Different switching tasks were used in both studies. The increased response time and switch cost in both studies suggested that anxiety impaired the shifting function. In addition, anxiety impaired response time but not accuracy (efficiency over effectiveness). These findings are as predicted by ACT.

The next study investigated separately the effects of anxiety on three central executive functions (inhibition, shifting and updating). A switching task and a computerised version of the Hayling sentence completion test were used to test respectively the shifting and the inhibition functions. A letter memory task was used to study the updating function. In accordance with ACT, the results revealed that anxiety negatively affected the shifting function. However the inhibition and updating functions were not significantly affected.

The fourth study investigated whether anxiety impairs the ability to co-ordinate the performance of two concurrent tasks. A memory and a reasoning task were used singly and concurrently. Results revealed that anxiety negatively affected the reasoning task response time when it was performed concurrently with the memory task, as predicted by ACT.

The last study investigated effects of motivation on performance of high-anxious versus low-anxious individuals. A modified version of the digit symbol test (WAIS-III) was used. Results revealed that the high-anxious felt more motivated when the goal difficulty was high than the low-anxious.

These five studies contribute to further understanding of the effects of anxiety on cognitive performance. Finally, the thesis outlines directions for future research.

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# **Chapter One**

## **Introduction**

## **Anxiety and cognitive performance**

This thesis focuses on developing an understanding of the effects of trait anxiety on cognitive performance. It centres on the assumptions of the two major theoretical approaches in this area, processing efficiency theory (Eysenck & Calvo, 1992) and attentional control theory (ACT) (Eysenck, Derakshan, Santos & Calvo, 2007). Both the ACT (Eysenck et al., 2007) and the processing efficiency theory (Eysenck & Calvo, 1992) focus only on individual differences in anxiety within normal populations. So, in order to test their predictions, this thesis focuses only in differences on anxiety within a normal population, as cognitive processes differ in normal and in clinical populations.

Anxiety has been defined as a “tense, unsettling anticipation of a threatening but vague event, a feeling of uneasy suspense” (Rachman, S., 2004 p.3). This negative affect involves the interaction between vigilance, attention, perception, reasoning, and memory, which are central in cognitive processing (Rachman, S. 2004).

Anxiety can be distinguished between trait anxiety and state anxiety (Spielberger, 1972, 1983). State anxiety is a situation-related reaction to a certain perceived threat. Therefore, it will be present only for a limited period of time after the threatening event disappears (Rachman, S. 2004). State anxiety is the current level of anxiety experienced at a certain point in a certain situation and it depends on the relationship between trait anxiety and situational stress (Eysenck, 1992).

Trait anxiety is personality related, it depends on how individuals perceive the world and react to it. People high in trait anxiety will experience more anxious situations and more intense levels of anxiety than people that are low in trait anxiety (Rachman, S. 2004). According to Spielberger (1972, 1983), trait anxiety is a predisposition to respond anxiously.

Trait and state anxiety are highly correlated as the occurrence and intensity of the anxiety felt at a certain situation (state anxiety) is influenced by the individual's susceptibility to anxiety (trait anxiety). Both state and trait anxiety have adverse effects on complex cognitive tasks (see, Eysenck, 1992). However, in this thesis the main focus will be on individual differences in trait rather than on state anxiety, as ACT focus is more on trait anxiety.

As the focus of this thesis is on the effects of anxiety on cognitive tasks that require considerable cognitive resources, it is not necessarily relevant to research on anxiety and motor performance.

The effects of anxiety on cognitive performance have been the subject of a great amount of research. Findings have generally revealed that high levels of anxiety can impair cognitive performance (e.g. Derakshan, Ansari, , Shoker Hansard & Eysenck, 2009; Ansari Derakshan & Richards 2008; Ansari & Derakshan 2010, 2011a, 2011b; Johnson & Gronlund, 2009; Derakshan & Eysenck , 2009; Ashcraft & Kirk, 2001, Williams, Watts, Macleod & Mathews, 1997; for a review see Eysenck et al., 2007; Derakshan & Eysenck, 2010; Eysenck, Derakshan, 2011; Berggren & Derakshan, 2012).

How emotion affects cognitive performance is a question that attracted research interest with the expansion/development of cognitive psychology in the 1960s. The subsequent growth on research in this field had as its basis individual differences on emotion (see Eysenck, 1992 for a review). Several theories were put forward to account for the negative effects of emotional states as anxiety on performance (e.g., Humphreys & Revelle, 1984; Eysenck & Calvo, 1992; Eysenck, et al., 2007). They were developed in the historical context of cognitive psychology, and became more precise as research

on cognitive processes increased. For example, Humphreys and Revelle (1984) suggested that worry interferes with attention and that it is related to task avoidance motivation. As a consequence fewer resources are allocated to the task (task effort), thus impairing performance. Sarason (1984, 1988) explained the negative effects of anxiety on performance in terms of the effect of thoughts of worry about performance, which reduce attention and affect cognitive performance.

Humphreys and Revelle's (1984) and Sarason's (1984, 1988) theories were developed when the knowledge on the cognitive processes of working memory was limited. Thus, they were limited to the existing research. Although their theories were a good attempt to explain the effects of anxiety on cognitive performance they were not precise. Even in the early nineties when Eysenck and Calvo (1992) developed the processing efficiency theory, little had been found on the central executive specific functions, and their theory fails to identify the central executive functions that are most affected by anxiety. As research on this field evolved and new findings brought new understanding, a more precise theory was put forward, the ACT (Eysenck, et al., 2007).

ACT is a development and upgrade of the previous processing efficiency theory. These two theories are of central importance in this field of study. They have brought light to the understanding of how anxiety affects cognitive performance and this thesis represents an attempt to test the predictions of these theories.

Processing efficiency theory distinguishes between performance effectiveness (quality of performance) and performance efficiency (relationship between effectiveness of the performance and the processing resources invested in task performance). Efficiency decreases as more processing resources of the central executive (a component of the working memory) are used to achieve a satisfactory

performance. Anxiety generally has less impact on effectiveness due to the use of extra processing resources by anxious individuals in order to minimise the negative effects of anxiety on performance (Eysenck & Calvo, 1992; see Eysenck et al., 2007 for a review).

ACT (Eysenck, et al., 2007) identifies specific central executive functions involved in attentional control that are impaired by anxiety during cognitive performance. According to the theory, anxiety affects the capacity to exert positive attentional control, re-directing attention within and between tasks as the task demands (shifting function). It also affects the capacity to exert negative attentional control, inhibiting attention to task irrelevant stimuli and responses (inhibition function). Although anxiety impairs the efficiency of attentional control (shifting and inhibition functions) it has less effect on performance effectiveness (see also, Derakshan & Eysenck, 2009).

There is a considerable amount of empirical support for ACT (see Eysenck, et al., 2007; Derakshan & Eysenck, 2009; Eysenck & Derakshan, 2011, for reviews). This thesis focuses on testing the main assumptions of ACT, and to provide research of direct relevance to it.

The structure of this literature review is as follows. First, I will discuss anxiety as a personality dimension from a cognitive approach. Second, I will present an overview of the theories developed to account for the effects of anxiety on performance. Third, my main focus will then be on processing efficiency theory and ACT, which is an update of the former theory, paying particular attention to the ACT assumptions regarding the effects of anxiety on the central executive functions. Fourth, I will address the relation between motivation and anxiety from an ACT perspective. Fifth, I will

review evidence for the assumption that anxiety affects processing efficiency to a greater extent than performance effectiveness.

### **Cognitive approach to trait anxiety**

The experience of anxiety is a complex process that involves behaviour, cognitive, emotional or affective processes. “Cognition is the process by which individuals make meaning of the environment, it reflects one’s thoughts, beliefs and modes of thinking and problem-solving” (Wilt, Oelhlerbg, Revelle, 2011, p. 987). How anxiety affects cognitive processes is the focus of this thesis.

To investigate how anxiety affects cognitive processes, researchers have chosen either to investigate individual differences in anxiety within normal individuals that differ in anxiety as a personality trait (individuals with susceptibility to anxiety) by comparing high with low-anxious individuals; or to investigate anxiety by comparing clinically anxious patients with normal individuals. This distinction is due to different research foci. Clinical studies are generally concerned with the causes and maintenance of anxiety disorders as well with appropriate therapies. The studies within normal populations that investigate individual differences in anxiety focus more on the effects of anxiety on cognitive performance (Eysenck, 1992). However, there is an emphasis on cognitive biases such as attentional bias and interpretive bias within both approaches.

Spielberger, Gorsuch and Lushene (1970) separated anxiety into trait anxiety and state anxiety. Trait anxiety is concerned with the individual vulnerability or propensity to anxiety. Trait anxiety is a personality dimension, and thus is relatively stable over time. In contrast, state anxiety is a reaction to a threatening situation event or stimuli, which generate tension, apprehension and increased physiological response

(e.g. increase heart rate). State anxiety is transitory as it lasts only a certain, generally short, amount of time as it is a reaction to an immediate threat.

Spielberger developed the State-Trait Anxiety Inventory (STAI) which is a self-report measure that assesses trait and state anxiety separately. This self-report measure of anxiety has been used extensively in research and in clinical practice since it was developed. In addition Spielberger (1983) reported that both state and trait scales have high discriminate and convergent validity with other measures. However, Beck, Epstein, Brown & Steer (1988) pointed that the STAI was built based on non clinical samples (see Spielberger et al., 1970), and that the STAI did not discriminate anxiety from depression suggesting that it was not a “pure” measure of anxiety (see also Beilegim, Antony & Swison, 1998), to address this points Beck et al. (1988) developed the BAI (Beck Anxiety Inventory) which was based in clinical samples, aimed to measure clinical anxiety and differentiate between anxiety and depression. Although at present the STAI is less used in clinical practice than when it was developed, is still one of the most used self reported measures in research. It has been translated to several languages and its structure has been examined in a great number of different samples generally revealing two factors state anxiety and trait anxiety The STAI was chosen to assess trait anxiety in the studies developed in this thesis. Spielberger intention when he first developed the STAI in 1970 was to distinguish and assess state and trait anxiety using a brief self reported measure.

Anxiety as a personality dimension or trait anxiety was first proposed by Spielberger et al. (1970). However, it resembles neuroticism, one of the three central personality dimensions proposed by H.J. Eysenck (1967). The author explained this vulnerability to anxiety in terms of heredity (genetic factors) but later the contribution



of the genetic factors for individual differences in anxiety was found to be much less strong than it was initially proposed by H. J. Eysenck or by Gray (1982) (see Eysenck, 1997). William et al. (1988, 1997) suggested that trait anxiety represents a stable tendency to react to threat either by directing attention towards or away from the potential threat, and that this attentional bias increased as state anxiety increased, suggesting an interaction between trait and state anxiety. On the same line Eysenck, (1992) also proposed that anxiety was associated with cognitive bias (attentional bias, interpretative bias, negative bias) and this bias would increase as state anxiety increased.

Later, based on several previous cognitive theories including the above, Eysenck (1997, 2000) proposed the four-factor theory of trait anxiety. It states that anxiety as an emotional experience is related to four information sources. One is related with how the individual attends to and interprets the situation; another regards the physiological information (e.g. heart rate). The next information source relates with the possible outcomes for future events/situations that are stored in the long-term memory (e.g. worries), and the last information source is related with information about the individual's own behaviour.

According to the four-factor theory, the experience of anxiety depends on how the information from the four information sources is attended to and interpreted. In accordance with the previous theories, one of the major assumptions is that anxiety leads to cognitive biases related with potential threat which can be caused either by external stimuli that are interpreted as threatening or by internal stimuli as worries. Attentional and interpretative biases are associated with anxiety. These biases are determined by an interaction between trait anxiety (the individual vulnerability to

anxiety) and state anxiety (situational stress). Empirical support has been found for the four-factor theory assumptions (see Eysenck, 2000 for a review on the four-factor theory and research support).

For research purposes, anxiety trait and state have been often studied separately. In the present thesis, the main focus is on the effects of trait anxiety (anxiety as a personality dimension). The reasons trait anxiety was chosen over state were the following: most of the research in the field of anxiety and cognitive performance has focused on trait rather than on state anxiety. A substantial number of important findings have been obtained based on the trait approach and Eysenck et al. (2007) based their theory on these major findings.

Moreover, high trait anxiety seems to have more effect on the executive system when processing non-emotional/affective information, being more structural as a personality dimension and not a reaction to a situation. State anxiety is situational related and affects the attentional networks more related with vigilance or context sensitivity, as found by Pacheco-Unguetti, Acosta, Callejas and Lupianez (2010). It can be argued that trait anxiety relates to habitual ways in which the cognitive system deals with numerous situations; whereas state anxiety relates more to immediate processing of threat-related stimuli.

## **Theories of anxiety and cognitive performance**

### **Cognitive interference theory**

Sarason's theory had its origins in the 1950s and/or 1960s. The general assumption of cognitive interference theory (Sarason, 1984) is that anxiety causes

thoughts of worry that affect cognitive performance. Worries are thoughts about possible negative outcomes, and a component of anxiety (Eysenck, 1992). When experiencing anxiety individuals are affected by task-irrelevant thoughts, for example worries about performance, and these thoughts affect performance because they reduce the attention available to perform the task (Sarason, 1984). According to Sarason (1984), worry over evaluation and self-preoccupations impairs cognitive performance and are referred to as test anxiety. When the task is complex/difficult and evaluative individuals high in susceptibility to worry over evaluation and self-preoccupation (high in test anxiety) will have poorer performance than the ones low in test anxiety.

The limitations of cognitive interference theory were addressed by Eysenck (1992). First, the theory exaggerates the role of self-preoccupation and worry. According to interference theory, individuals high in anxiety should have worse performance than low-anxious ones because of the interference of the worries (task-irrelevant thoughts) (Eysenck, 1992). Some studies failed to get evidence for this assumption since there was no significant difference in performance between high and low-anxious individuals (e.g. Blankstein, Toner, & Flett, 1990, Calvo, Alamo, & Ramos, 1990). Second, the interaction between anxiety and task difficulty is oversimplified, being only associated with the attentional processes that the task demands, ignoring other processes (e.g. storage) (Eysenck, 1992). Third, the theory fails to specify which components of the cognitive system are directly affected by worry (Derakshan & Eysenck, 2009).

**Information processing theory**

The information processing theory (Humphreys & Revelle's, 1984) centres on the relations among personality, motivation and performance. According to the theory, several factors are involved in the effects of anxiety on performance. Anxiety generates worry that increase avoidance motivation, but also generates arousal. Arousal caused by anxiety reduces short-term memory. Tasks that require the involvement of short-term memory to a greater extent are more impaired by anxiety than tasks that require little use of short-term memory (Humphreys & Revelle, 1984), this is due to the negative effects of anxiety (arousal) on short-term memory.

To sum up, the theories developed by Sarason (1984, 1988), and Humphreys and Revelle (1984), have attempted to explain the adverse affects of anxiety on cognitive performance. Despite of their limitations they brought new ideas about the roles of worry and arousal, on cognitive performance. Next I am going to look at processing efficiency theory (Eysenck, & Calvo, 1992) and the ACT (Eysenck, et al., (2007), these theories have been inspired by some of the ideas developed in the above mentioned theories. For example, the relation between worry and performance (Sarason, 1984, 1988) and the relation between task difficulty and performance (Humphreys & Revelle, 1984).

**Processing efficiency theory**

The processing efficiency theory was developed by Eysenck and Calvo (1992) to account for the effects of anxiety on cognitive performance. In order to address the limitations of this theory, an extension and upgrade of this theory was developed

recently: ACT (Eysenck et al., 2007). I will start by explaining processing efficiency theory and address the limitations.

One of the central points of the processing efficiency theory (Eysenck & Calvo, 1992) is the distinction between performance effectiveness and performance efficiency. Performance effectiveness is related to the quality/result of performance and is generally measured in terms of response accuracy. On the other hand, performance efficiency is the relation between the resources and effort used to achieve a certain performance and the result of that performance (performance effectiveness). Response time is generally used as an indirect measure of efficiency. Performance efficiency decreases when increased effort or resources are used to achieve a good task result.

According to processing efficiency theory, a high-anxious individual's performance is more affected in terms of efficiency than in terms of effectiveness. Because worries caused by anxiety interfere with the task at hand they drain the limited attentional resources available in the central executive, and leave fewer resources available which impair processing efficiency.

Worries can be defined as a chain of thoughts and images, related to expectations of possible negative outcomes, for example as concerns over failure and evaluation (e.g. Barkovec, Pruzinsky DePree, 1983). Worries are a component of anxiety, which is generally activated in stressful situations. High trait anxious individuals in general report to have more worries than low trait anxious (see Barkovec et al., 1983) because they are more prone to experience or interpret a certain situation as more stressful than low-anxious individuals, (for a review see, Eysenck, 1992).

To deal with the effects of worry on the central executive the high-anxious individuals use compensatory measures, they increase effort and use of extra resources,

being more motivated to achieve a satisfactory result. This use of extra resources and effort is likely to impair processing efficiency. However, performance effectiveness is less likely to be affected.

Another important assumption of the processing efficiency theory is that worries are responsible for the effects of anxiety on cognitive performance (Eysenck & Calvo, 1992). Worries (thoughts or images) are related with a response to a stressful situation or event it involves preoccupation over evaluation and failure, and negative outcomes. Anxiety has been associated with worrisome thoughts, for example, individuals high in trait anxiety have reported more worry thoughts or self- preoccupation compared with the low-anxious (see Eysenck, 1992 for a review). Morris, Davis & Hutchings (1981) found that the effects of anxiety on performance were caused by worries, and that they were maintained or caused by stressful situations.

Another important assumption is that the effects of anxiety affect mostly the central executive, but it can also affect the phonological loop, as both are components of working memory. The central executive supervises the other working memory components and has attentional control as its central role. The phonological loop is responsible for simple verbal processing including rehearsal. Processing efficiency theory based its assumptions on the Baddeley model of working memory which has three components; the central executive, the visual sketchpad and the phonological loop (see Baddeley, 2001 for a review). More recently, the author added a new component, the episodic buffer.

Evidence for the processing efficiency theory assumptions has been found in several studies that centred on the effects of anxiety on working memory capacity. For example, Aschraft and Kirk (2001) used a letter-transformation task and a number-

transformation task that required different levels of demand on the working memory and the results revealed that the adverse effects of anxiety were significantly greater when the demands on working memory were higher (see also Eysenck, 1985; Daneman & Carpenter, 1980, Derakshan & Eysenck, 1998).

Eysenck and Payne (2006) assessed differences in performance between high trait anxious and low trait anxious individuals in evaluative conditions and non-evaluative conditions using the probe paradigm in a letter-transformation task with different levels of complexity. Probes were auditory stimuli presented sporadically that allowed the researchers to assess spare processing capacity through reaction times. The probe task (secondary task) revealed that high-anxious individuals had slower reaction times than low-anxious ones during the evaluative conditions. The opposite result was found for the low-anxious. The analysis of the primary task (letter-transformation) showed that the high individuals had impaired processing efficiency although no significant differences in performance effectiveness between high and low-anxious individuals were found.

These findings show that as the tasks become more demanding on the central executive, processing efficiency is affected. Worries or self-preoccupation caused by anxiety will leave only part of the processing resources available to complete the task. In order to cope with this, high-anxious individuals will make use of extra resources, being more motivated to achieve a good result as a compensatory strategy to deal with the adverse effects of anxiety.

Evidence of the use of compensatory strategies by high-anxious participants has been found in several studies. For example Calvo, Eysenck, Ramos, and Jimenez (1994) using a reading and comprehension task found that, high and low-anxious groups did

not differ in performance comprehension. Although high-anxious participants during text reading produced more reading regressions than the low-anxious, in order to have the same performance effectiveness they had to use compensatory strategies to achieve the same level of comprehension as low-anxious participants (see the processing efficiency and performance effectiveness and motivation sections for more information on high-anxious compensatory strategies).

### **Processing efficiency theory limitations**

According to Eysenck et.al, (2007), there were two major limitations to the processing efficiency theory; it was vague about the effects of anxiety on the central executive, as the theory identified the central executive as the working memory function most impaired by anxiety but did not identify which central executive functions were impaired by anxiety. In addition, the theory did not give an explanation about why high-anxious individuals are more distracted than the low- anxious by task-irrelevant stimuli (e.g. Hopko et al., 1998; Calvo & Eysenck, 1996). Furthermore, the theory needed to be updated to take in account for recent findings.

To sum up, the processing efficiency theory is based on the distinction between performance effectiveness and performance efficiency. According to the theory anxiety produce worries that drain working memory processing resources (mostly from the central executive) affecting processing efficiency to a greater extent than performance effectiveness. However the theory does not clearly identify which executive functions are most affected by anxiety and it needed to be updated.



## **Attentional control theory**

### **Introduction**

Attentional control theory (ACT) (Eysenck et al. 2007) is a development and an upgrade of the previous processing efficiency theory that addresses the limitations of the previous theory while keeping its basic approach (Eysenck & Calvo, 1992).

The main ACT assumption is that anxiety impairs attentional control. Attentional control can be goal-driven or stimulus-driven but there is a balanced interaction between the goal and the stimuli-driven systems (Yantis, 1998). According to the theory, anxiety disrupts the balance between these two attentional systems, which affects central executive as it involves attentional control. In addition, the theory states that the central executive functions most impaired by anxiety are the inhibition and the shifting functions (the capacity to inhibit distractors or prepotent responses, and the capacity shift attention between and within tasks, respectively).

This is one of the advantages of the ACT over the processing efficiency theory. It is more specific and clearer and it identifies which central executive functions can be impaired by anxiety. The processing efficiency theory suggested that worrisome thoughts caused by anxiety affected processing efficiency but it was not clear about which processes were affected.

ACT maintains one of the central assumptions of the processing efficiency theory, that anxiety affects processing efficiency to a greater extent than performance effectiveness. The ACT suggests that this is due to the effects of anxiety on the attentional control of the inhibition and shifting functions. While the processing efficiency suggested that it was due to worrisome thoughts caused by anxiety. These

ideas are related, if someone high in trait anxiety has poor inhibition they will not be able to prevent worrying thoughts from interfering with task performance

ACT accounts for the effects of task-irrelevant stimuli, both emotional and neutral, and suggests that high-anxious individuals are more prone to distraction independent of stimulus valence. The theory identifies the effects of anxiety on the inhibition function as the cause of distraction. The processing efficiency theory did not provide an explanation for why the high-anxious individuals are more easily distracted than low-anxious.

Each strength of the ACT is now going to be addressed in detail, as well as the points in common with the processing efficiency theory.

### **The adverse effects of anxiety in the central executive**

According to ACT (Eysenck et al. 2007), anxiety has negative effects on attentional control which is one of the main roles of the central executive. This limited capacity system is a central component of the working memory that is responsible for several functions involved in attentional control (Baddeley, 2002). Several functions have been attributed to the central executive, however researchers have not reach agreement (e.g. Smith, & Jonides, 1999; Barret, Tugate & Engle, 2004, Miyake et al., 2000, Fournier-Vicent, Larigauderie, & Gaonac'h, 2008).

Miyake et al., (2000) identified the three major central executive functions: “shifting function (shifting between mental sets or tasks), inhibition function (inhibition of prepotent responses and distractors) and updating (information updating and monitoring”) pp86, only on the basis of empirical research something that had not been done before. The authors used a latent variable analysis to indentify the executive

functions, using tasks that had been associated with the executive functioning by several prior studies.

ACT follows the Miyake approach to the central executive and identified the inhibition and shifting functions as those most affected by anxiety during cognitive performance. The shifting and inhibition functions both involve attentional control. Shifting involves positive attentional control shifting attention between tasks or mental sets and inhibition involves negative attentional control inhibiting distractor stimuli or prepotent responses from interfering with the task (Miyake, 2000; Eysenck, et al., 2007, Derakshan & Eysenck, 2009). Anxiety affects attentional control and therefore affects the shifting and inhibition functions of the central executive during cognitive performance (Eysenck et al., 2007)

There is significant research evidence that the shifting and inhibition functions are affected by anxiety, (for a review see Eysenck et al, 2007; Eysenck & Derakshan, 2011). Recently several studies have found support for the negative effects of anxiety on the inhibition function (e.g. Bar-Haim et al., 2007; Reinholdt-Dunne, Mogg, & Bradley, 2009; Pacheco-Unguetti, et al., 2010; see Derakshan & Eysenck, 2009) and although less research has been developed on the shifting function there is also some support (e.g. Derakshan, Smyth, , & Eysenck, 2009b) of the central executive (research developed on the inhibition function and shifting functions are described in detail on the sections regarding these functions).

The updating function is expected to be less affected by anxiety and research in this field has found inconsistent results (e.g. Dutke & Stöber, 2001; see Eysenck et al. 2007 for a review) see the updating section for more detail.

Miyake et al., (2000) suggested that dual-task coordination might be an independent central executive function as it was not related to the three functions identified by the authors (inhibition, shifting and updating). D'Esposito et al., (1995) and Collette et al., (2005) found that dual-task coordination activated areas related with the executive functioning. The ACT is not clear about the effects of anxiety on dual-task coordination, as the theory did not include dual-task coordination as an executive function and only considered the executive inhibition, shifting and updating functions. However, the authors stated that “performing two tasks concurrently typically requires attentional control (especially the shifting function) to coordinate processing on two tasks in addition to the demands of each task separately” (Eysenck et al., 2007, p7), thus it seems to suggest that anxiety might affect dual-task coordination.

ACT predicts that the adverse effects of anxiety on the central executive increase as the demands on attentional control increase, requiring more processing resources. The more demanding the task is, the more resources and effort will be required to overcome the negative effects of anxiety and achieve a satisfactory task result. (Eysenck, 1992; Eysenck, et al., 2007).

Research that tested the effects of increased demands on the central executive generally used two different paradigms, the loading paradigm or a single task with different levels of task complexity (e.g. Derakshan & Eysenck; 1998; Derakshan, Smyth & Eysenck, 2009; Eysenck, 1985; Calvo, 1985 for a review see Eysenck 1992; Eysenck, et al., 2007).

The loading paradigm involves a primary and a secondary task that are performed concurrently, the demands of the secondary task (load) are manipulated and performance on the primary task is assessed, during high or low load. The results

generally revealed that anxiety affects performance of the primary task when the load is high (secondary task) (e.g. Derakshan & Eysenck, 1998, Eysenck, Payne & Derakshan, 2005). Derakshan, Smyth & Eysenck (2009) used a single task with two different levels of task complexity and found that participants high in state anxiety had longer response times than those with low state anxiety in a high complexity switching task, but not when the task was low complexity.

In a study that investigated the neural activity, Fales et al. (2008) showed that the high-anxious had increased transient activation on the most difficult trials (lure-trials) in a 3-n back task, compared to the low-anxious. In addition, anxiety did not affect performance. The results indicate that high-anxious were less efficient in controlling attention when the task was more demanding.

### **The central executive**

The central executive is the central component of the working memory, acting as an attentional control structure responsible for the control and regulation of the cognitive processes, being supported by the two other components visual sketchpad and phonological loop, which are responsible for visual and spatial information, and for verbal and acoustic information. (Baddeley & Hitch, 1974; Baddeley, 1986; Baddeley, 2002). This multi-component model of the working memory was proposed by Baddeley and Hitch (1974) as an alternative to the unitary model proposed by Atkinson and Schiffrin (1968). Baddeley (1986) adopted the supervisory attentional subsystem (SAS) model proposed by Norman and Shallice (1986), a model that explains attentional control as the best model to explain the central executive.

Several functions have been attributed to the central executive; however researchers have not found a consensus. For example, Baddeley (2002) suggested that

the central executive has three central functions; the ability to focus the available attentional capacity; the capacity to divide attention and the capacity to switch attention.

Smith and Jonides (1999) proposed five functions for the central executive: selective attention and inhibition, updating working memory contents to accomplish a certain goal, coding working memory and planning subtasks.

Miyake et al. (2000), reviewed the components of the central executive that have been most studied by several theorists as well as the tasks used to study those components (e.g. Baddeley, 1996; Smith, & Jonides, 1999). As discussed above Miyake et al. (2000) identified three main functions of the central executive: the inhibition function, the shifting function and the updating function.

The inhibition function is the capacity “to inhibit, automatic or dominant or prepotent responses” (p.57) and involves using attentional control in a negative way, to resist disruption from task irrelevant stimuli and responses. The shifting function is the capacity to shift attention “back and forth between multiple tasks, operations or mental sets” (p.55) using attentional control in a positive way switching attention according to the task demands. The updating function is the capacity to “update working memory representations” (p.56), which is the ability to replace old, no longer important, information by the new one (Miyake et al., 2000). Miyake et al. (2000) examined the relationship between the executive functions to understand to what extent the executive functions were unitary or separable, and found that although separable they also were moderately correlated and had some overlapping processes (see also Friedman & Miyake, 2004, Hedden & Gabrieli, 2010; Collette et al., 2006).



Figure 1: A schematic representation of the executive functions as both unitary and separable functions, based on Miyake et al. (2000).

Miyake et al (2000) found that dual-task coordination was not associated with any of the executive functions identified in their study and suggested that it might be an independent executive function.

Recently, Fournier-Vicent et al. (2008) identified five executive functions based on a comprehensive latent variable analysis, similar to the one developed by Miyake et al. (2000). It can be speculated that the increase in the number of the executive functions found by Fournier-Vicent et al. relates to sub functions of the executive functions found by Miyake et al. (2000).

ACT identifies the central executive functions that are most impaired by anxiety during cognitive performance as the shifting function and the inhibition functions, assuming the Miyake et al. (2000) model of the central executive. As a development of the processing efficiency theory, ACT succeeds in indentifying the functions of the central executive involved in performance of complex cognitive tasks. It states which functions are most affected by anxiety, being specific where processing efficiency theory was vague.

**Attentional control**

Yantis (1998) distinguished between two types of attentional control systems; goal-driven attention and stimulus-driven attention (see also Posner & Peterson, 1990, Corbetta & Shulman, 2002). This distinction was first made more than a century ago by William James (1890) although it was then called passive mode of attention or active mode of attention.

Stimulus-driven attentional system works in a bottom-up way and occurs when attention is captured by a salient stimulus that is task irrelevant. Stimulus-driven attention is both faster and more potent than goal-driven attentional control (e.g. Jonides, 1981, Yantis, 1998). On the other hand goal-driven attention (top-down) is active and it requires voluntary control of attention to a certain stimulus or point that is relevant to the task at hand, (Yantis, 1998). Stimulus-driven attentional processing is more automatic as attention is captured immediately by a certain stimulus (Yantis, 1998). This system is activated when relevant sensory events are detected especially if they are salient or threatening. Stimuli-driven attention has been associated with the right hemisphere ventral frontoparietal network which involves the capacity of “*reorienting*” a response by “breaking” ongoing activity or focus of attention. Conversely, top-down attention has been associated with a dorsal frontoparietal network that is involved in stimuli selection and response. When attention is focused on a stimulus the ventral network is suspended in order to keep attention from driving to distractor stimuli. These two networks interact with each other constantly (see, Corbetta, Patel & Shulman, 2008 for a review).

ACT states that anxiety impairs attentional control, affecting these two attentional systems (stimuli-driven and goal-driven). Anxiety disrupts the balance



between the stimulus-driven and the goal-driven attentional systems (Corbetta & Shulman, 2002; Corbetta, Patel & Shulman, 2008). Anxiety disrupts attentional control, increasing the influence of stimulus-driven attention and decreasing goal-driven attentional control. This means that the high-anxious individuals' attention will be more likely to attend task irrelevant stimuli than that of the low-anxious. There is considerable support for this prediction from studies that have used distractor stimuli, either threatening or neutral (relevant research is described on the inhibition function section).

ACT was inspired by several studies as, for example, those developed by Derryberry and Reed (2002), Fox, Russo, and Dutton (2002) and others (see Eysenck et al., 2007 for review). The results of these studies suggested that high-anxious had less attentional control and an attentional bias to threat. As an example, Mogg, Garner and Bradley (2007) found similar results using an eye movement methodology. The main purpose of the study was to study attention bias in initial orienting gaze to threatening emotional faces versus fearful faces, in high and low-anxious participants. The findings suggested that high-anxious individuals had more tendency to direct gaze at threatening faces (whether they were fearful or angry faces). Based on the findings the authors suggested the existence of a system to process threat and to modulate vigilance for potential threatening stimuli. There are many research findings that support an attentional bias to threat stimuli. For example, Telzer, Mogg Bradley, Mai, Ernst, Pine, and Monk (2008) found also an attention bias to threat, with trait anxiety being associated with attention bias to angry faces (see also Bar-Haim et al., 2007; for a review).

In accordance with ACT anxiety impairs attention efficiency of the inhibition function and of the shifting function, as the role of these two executive functions is directly related with attentional control (Eysenck et al., 2007). There is evidence that anxiety impairs attentional control efficiency of these two executive functions (research on the inhibition and shifting functions as well as the description of their role and relation with anxiety can be found in the shifting section and inhibition sections).

Attentional control can also be assessed by self-report measures (e.g., Cognitive Failures Questionnaire, Attentional Control Scale). Nevertheless, self-report measures are based on the individual's ability to introspect about a certain condition (e.g., their own attentional control) and this ability is limited, thus, these measures are better used in support of experimental data.

The most used questionnaires are Cognitive Failures Questionnaire (CFQ) (Broadbent, Cooper, FitzGerald, and Parkes (1982) and the Attentional Control Scale (ACS) developed by Derryberry & Reed, (2002). The CFQ assesses the individual's attentional control by analysing the individual differences in the small daily errors that can occur, showing mostly inadequate attentional control. The ACS is the result of the combination of two separate scales which were used by Derryberry and Rothbart (1988). One of the scales measured attentional focus (capacity to focus attention and resist distractors), which closely resembles the inhibition function, while the other scale measured attentional shifting (capacity to shift attention as desired) which closely resembles the shifting function. The ACS total score has been found to be negatively correlated with trait anxiety (e.g. Derryberry & Reed, 2002; Ayduk et al., 2008). This self-report measure of attentional control was chosen to be used in the studies

developed in this thesis, because the effects of anxiety on attention are the central core of ACT.

### **Shifting function**

According to Miyake et al. (2000), the shifting function is the capacity to shift attention between tasks or mental sets one of functions the central executive. The authors found that task switching was associated with the shifting function. Norman and Shallice (1986) had already stated that the capacity to shift attention between tasks or mental sets was one of the essential aspects of the executive control. Wager, Jonides, and Reading (2004) identified seven brain areas that were systematically activated during shifting tasks, suggesting that there is a single and essential shifting function.

Aron, Monsell, Sahakian and Robbins (2004) examined task switching performance and identified the localization in the brain of two task switching components inhibition. The inhibition of task sets, which was associated with the right inferior frontal gyrus (IFG)/ pars opercularis (POp), and the top-down (goal-driven) attentional control of the task set which was associated with the left middle frontal gyrus (MFG). According to the authors the left hemisphere has an important role in selection and maintenance of *task-set*, and the right hemisphere is associated with inhibitory control. Monsell, Yeung & Azuma (2000, p.250) defined *task set* as “our ability to configure the processing resources available in the brain to perform one rather than another of many cognitive tasks that an upcoming stimulus may afford”.

There is a cost inherent to the switch trials, the cost of changing tasks rapidly compared to repeating the same task, which is called switch cost. In research this is generally measured by reaction times and it corresponds to the difference between the times taking to perform switch trails compared to repetitive. Switch cost involves *task*

*set reconfiguration* (TSR). TSR can include shifting attention between task stimuli, retrieving the task goal from memory or external cues and then putting it into action, taking the right working memory procedures, inhibiting or deleting no longer adequate responses and adjusting to the right task response (Monsell, 2003).

Task switching requires alternating between two tasks in rapid succession, the task can change either from trial to trial (classic task switching paradigm, see Jersild 1927) or the task change can be unpredictable (unpredictable task switching, see Meiran, 1996). Longer reaction times or errors are expected right after the switch when compared with single task performance, (control condition) (Monsell, 2003).

According to ACT, the shifting function is impaired by anxiety because anxiety reduces attentional control, which becomes more stimuli-driven than goal-driven (Eysenck et al., 2007, Derakshan & Eysenck, 2009), affecting the capacity to switch attention rapidly between tasks

Only a few studies have investigated the effects of anxiety on tasks involving the shifting function. For example, Derakshan, Smith, and Eysenck (2009) used a task switching paradigm that involved mentally calculating additions and subtractions (low complexity task) or multiplications and divisions (high complexity task). Participants were required to perform both repetitive and task switching blocks. The results revealed that the high-anxious group had significantly longer response time during task switching compared to when the task was repetitive, but only when the task complexity was high.

Ansari, Derakshan, and Richards (2008) used a mixed antisaccade paradigm to study the effects of anxiety in task switching. Participants had to perform a single task that required only performing an antisaccade task or only a prosaccade task. Participants

had also to perform a mixed task where they had to random alternate between anti and prosaccade trials, and a cue signalled if the trial was prosaccade or antisaccade. Generally there is a switch benefit, with antisaccade performance improving compared when prosaccade and antisaccade are performed individually (Cherkasova, Manoach, Intriligator, & Barton, 2002). The results revealed that the low-anxious group had faster correct antisaccade latencies in task switching than in repetitive tasks, while the high-anxious group did not show any switch benefit (Ansari et al, 2008).

Johnson (2009) used a cue task switching paradigm that involved both neutral and emotional stimuli to study the effects of anxiety on task shifting, the results revealed that high-anxious were slower to switch from neutral to emotional stimuli compared to low-anxious.

Miyake et al. (2000) found that the shifting function was especially related with the WCST (Wisconsin Card Sorting Test), a task that involves shifting sorting categories after a certain number of successful trials (e.g. Berg, 1948). Goodwin and Sher (1992) used the WCST and found that high-anxious had poorer performance compared with low the low-anxious. However, the WCST is a complex task and cannot be considered a pure case of shifting.

The comprehensive trail-making test (CTMT) trial 5 involves set shifting. Orem, Petrac and Bedwell (2008) used this test which included trial 3 and 5. The results revealed that participants with high stress levels were slower than the participants with low stress on trial 5. Suggesting that high stress (probably high anxiety) affected participants in a task that required the shifting function.

The above results are in accordance with ACT; as anxiety impairs attentional control of the shifting function.

**Inhibition function**

The inhibition function is a central executive function responsible for inhibition of dominant and automatic, or prepotent responses or distractors when necessary (Miyake et al., 2000; Friedman & Miyake, 2004). Several types or dimensions of inhibition processes have been proposed (e.g. Nigg 2000; Harnishfeger, 1995). For example Friedman & Miyake, 2004 studied three inhibition related functions, resistance to proactive interference (ability to resist memory intrusions that are no longer relevant for the task), prepotent response inhibition (ability inhibit prepotent automatic responses) and resistance to distractor interference (ability to resist/inhibit task irrelevant stimuli to the task at hand). The authors found that prepotent response inhibition and resistance to distractor were both closely associated suggesting that both share some common processes while resistance to proactive interference was not associated with the other two inhibition functions.

ACT adopted the Miyake et al (2000) and Friedman & Miyake (2004) approach of the inhibition function, suggesting that it concerns the ability to inhibit distractor stimuli and automatic prepotent responses. This means to inhibit irrelevant stimuli to the task, these stimuli can be exterior (e.g. environment related) or interior (e.g. worry thoughts) (Eysenck et al., 2007; Derakshan & Eysenck, 2009).

Anxiety affects the inhibition function because it is related to attentional control. Anxiety impairs attentional control, which becomes more stimulus-driven than goal-driven increasing the probability that processing resources will be directed to task-irrelevant stimuli affecting the inhibition function efficiency (Eysenck et al., 2007).

Both emotional and neutral stimuli have been used in studies that involve the inhibition function. According with ACT anxiety can affect efficiency of the inhibition function with neutral or emotional stimuli.

There is a considerable number of studies that have investigate the inhibition function using threatening stimuli (see Cisler & Koster, 2010, Eysenck et al., 2007 for a review). In accordance with ACT high-anxious individuals are more distracted by task irrelevant threatening stimuli or prepotent responses than low-anxious (Eysenck et al., 2007). Researchers have agreed that high-anxious individuals have an attentional bias to threat (see Bar-Haim, et al., 2007, for a review).

One of the classic paradigms that involve the inhibition function is the Stroop task. This paradigm requires inhibition of prepotent responses, and has been used often to investigate the capacity to inhibit either emotional or neutral stimuli (see Eysenck et al., 2007, Cisler & Koster, 2010; Bar-Haim, et al., 2007 for a review).

For example, Reinholdt-Dunne, Mogg, & Bradley (2009) used an emotional word Stroop task and an emotional face Stroop task, to assess the effects of trait anxiety and attentional control in the processing of emotional stimuli. Participants were divided into four groups, high/low trait anxiety and high/low attentional control. The findings revealed that threatening stimuli (angry faces), had greater colour naming interference in high-anxious participants with poor attention control compared with the other groups.

The findings above are in accordance with ACT, suggesting that anxious individuals when facing threatening stimuli had more difficulty inhibiting prepotent responses compared to the other groups.

Miyake et al., (2000) found that the antisaccade task was associated with the inhibition function. This task involves the presentation of a visual cue and participants

are instructed to look to the opposite side of the cue as quickly as possible. In the control condition participants perform a pro-saccade task in which their task is to look at the cue. The latency of the first correct saccade is measured for pro and anti saccades and then compared Eysenck & Derakshan, (2011).

Several studies have used this paradigm to investigate the inhibition function using neutral or emotional stimuli. For example, Derakshan, Tahereh, Hansard, Shoker and Eysenck (2009a) studied the effects of anxiety on inhibition using an antisaccade task. Two experiments were developed, in the first experiment neutral stimuli were used while in the second emotional stimuli were used. In the first experiment an oval object was used as a cue while in the second experiment, angry, happy or neutral facial expressions were presented as cues. The results of the first experiment revealed differences between groups only in the antisaccade task. The high-anxious participants had a slower first correct saccade than the low-anxious. The same result was found in the second experiment, especially when a threatening cue was presented (angry face). No differences between groups were found in terms of error rate.

Garner, Ainsworth, Gould, Garner and Baldwin (2009) also found differences between groups on the antisaccade task but not on the pro-saccade with the high-anxious group having more eye movement errors than the low-anxious group (see also, Wieser, Pauli & Mulhlberger, 2009).

In a different study, Deraskhan et al. (2011) used an antisaccade task, and measured event-related potential (ERP) activity. The results revealed slower antisaccades latencies for the high-anxious than for the low-anxious when they had to inhibit an oval shape by directing their gaze away. In addition, just prior to inhibiting the target the high-anxious group had lower ERP activation on frontocentral and central



recording sites than the low-anxious group. These sites are associated with top-down attentional control suggesting that anxiety impaired attention efficiency of the inhibition function; but no differences between groups were found in error rate.

Studies that have used antisaccade paradigm have consistently found support for the ACT that anxiety impairs processing efficiency of the inhibition function.

Bishop (2009) used fMRI to assess the impact of distraction on dorsolateral prefrontal cortex (DLPFC) activation during a letter search task. The distractors used were letters that could be either congruent (same as the target letter) or incongruent (different from the target letter) with the target letter. The task could be performed under low perceptual load (6 repeated letters) or high perceptual load (1 letter target and 5 non target). When the task was more demanding (high load) no significant differences in target detection time were found for both groups. However, the high-anxious group showed a greater activation in the left dorsolateral prefrontal cortex (DLPFC), compared to the low-anxious. These findings are in accordance with ACT, as the DLPFC has been associated with attentional control. The findings suggest that the high-anxious had to make use of more attentional control resources (showed by a greater activation on the DLPFC) than the low-anxious, to achieve a similar performance. ACT states that increased activation on neural areas related with attentional control can be a measure of inefficiency in tasks that require the inhibition function. In the easy condition (low load), the results revealed that trait anxiety slowed performance, with the high-anxious group (but not the low-anxious) decreasing performance when incongruent distractors were present compared to congruent. In addition, they showed reduced activation of the DLPFC, while the low-anxious showed increased activation. These findings in the easy condition are not readily explicable by ACT. However, they

may be due to a minimal use of the attentional control mechanisms when the task was easy, which slowed performance of the high-anxious (Eysenck & Dreakshan, 2011).

Bishop (2009) suggested a different explanation for the high-anxious group reduced activation of the DLPFC on the easy condition (low load). Suggesting that it was due to an inefficient or failure to use of attentional control mechanisms.

Hopko et al. (1998), developed a task to study the capacity to inhibit attention from distracting stimuli, the authors used three different reading conditions that consisted in maths related or non maths related paragraphs. Three different distracters were used, control, unrelated distracters and maths distracters (task related). The results revealed that maths anxious participants had more difficulty in inhibit the distractor, even when paragraphs were unrelated to mathematics, which suggested that high-anxious had an inhibition function less efficient than the low-anxious.

Pacheco-Unguetti, et al. (2010) used neutral distractors (arrows) that could be congruent (same direction as the target arrow) or incongruent (opposite direction of the target arrow) with the target. The participants' task was to identify the direction of the target arrow. The results revealed that when the distractor was incongruent there was a greater interference on the high anxiety group than on the low anxiety group.

Calvo, Gutiérrez and Fernandez-Martin (2012) investigated the effects of anxiety on threat detection, for that purpose they used threat and neutral distractor words in a lexical decision task. The distractors could be presented in unattended (parafoveal) or attended (foveal) locations, and an unrelated probe word was presented at 300ms or 1000ms after the distractor. The results showed that differences between groups were only present when the distractor was a threat word presented at an attended fixation location, with the high-anxious group having greater interference from the

distractor than the low-anxious group when the probe word was presented at 1000ms. At 300ms differences between groups were not found. In accordance with the ACT the results suggest that anxiety affected the efficiency of the inhibition function when the distractors were at an attended location. The distractor interference was longer for the high-anxious than for the low-anxious.

Evidence that threatening stimuli are more distractive for high-anxious participants; has also been found in neuropsychology studies. For example Bishop, Duncan, Brett, and Lawrence (2004) found that participants with high state anxiety had decreased activation of the lateral prefrontal cortex, which is associated with attentional control, when distracting threat related stimuli were presented, while those with low state anxiety showed increased activation. The authors suggested that anxiety negative effects affected the top-down attentional control when distracting threatening stimulus is presented.

Different paradigms have been used, as the Stroop paradigm, presence of distractors and antisaccade task, to study the effects of anxiety on the inhibition function. Overall, research has consistently found that high-anxious individuals' attention control is particularly impaired in presence of distracting stimuli, either threatening or neutral, with anxiety impairing efficiency of the inhibition function.

### **Updating function**

The updating function actively monitors codes and maintains relevant information for the task at hand. This central executive function overwrites old information that is no longer relevant for new and relevant information. It does not rely on passive storage of information but actively monitors and manipulates the information in the working memory (Morris & Jones, 1990; Miyake et al., 2000).

ACT predicts that anxiety affects the updating function to a lesser extent than the inhibition and shifting functions as this central executive function is less concerned with attentional control and more with short-term memory. In addition, the authors suggest that only during stressful situations is the updating function impaired by anxiety (Eysenck, et al., 2007).

Several paradigms have been used to investigate the updating function. They all involve recall and updating working memory information, for example, running memory span tasks have been used often in research to investigate working memory updating (e.g. Miyake, 2000; Morris & Jones, 1990; Postle, 2003). This task involves presentations of a list of unpredictable number of items that have to be constantly updated and participants have to recall the last few items (generally the last 4 items are recalled).

Regarding the effect of anxiety on the updating function research findings are not coherent. There have been several studies that have investigated the effects of anxiety using reading span memory tasks and did not find significant effects of anxiety on this task suggesting that anxiety does not significantly affect the updating function (e.g. Calvo & Eysenck, 1996, see Eysenck et al., 2007 for a review).

However, a few studies have found that anxiety can affect tasks that involve the updating function. For example Drake (1988) found that under a stressful condition the high-anxious showed poorer performance in a digit span task compared with the low-anxious. Sorg and Withney (1992) in a reading span task under stressful conditions found that the high-anxious performance decreased compared to the low-anxious.

Recently Visu-Petras, Tincas, Cheie, Benga, (2010) investigated the effects of anxiety on a visual-spatial memory updating in children (non-emotional and emotional

stimuli were used). Differences between the high and low anxiety groups were found in accuracy and in detecting happy and angry faces. The high anxiety group was slower and less accurate in detecting and updating happy faces however when angry faces were presented they were more accurate. Thus, this study partially supports the assumption that anxiety affects the updating function.

Generally, research on the updating function has not provided clear results. There have been several studies that investigated the effects of anxiety using reading span memory tasks and did not find significant effects of anxiety on this task (e.g. Calvo & Eysenck, 1996, see Eysenck et al., 2007 for a review). Fales, Becerril, Luking and Barch (2010) used a task that involved the updating function and measured neural activity, their results revealed that anxiety had not significantly affected the neural activity or performance, suggesting that efficiency of the updating function was not affected by anxiety. These non-significant findings suggest that there was no need to use extra processing resources, the demands on the central executive did not increase and as such performance effectiveness was also not affected.

Overall, with several studies finding inconsistent or non-significant effects of anxiety in tasks involving the updating function (e.g. Dutke & Söber 2001; Calvo & Eysenck, 1996; Santos & Eysenck, 2005 unpublished), significant differences have only been found in studies which involved stressful conditions or emotional stimuli (see Eysenck et al., 2007 for a review).

### **Dual-task coordination**

Dual-task coordination has been associated with the central executive (e.g. Baddeley, 1996, Collette, Hogge, Salmon & Van der Linden, 2006). For example, Miyake et al. (2000) considered that dual-task coordination might be an independent

executive function before rejecting the idea. The authors identified three executive functions, however dual-task processes were not significantly related with the identified executive functions (see also Fournier-Vicent et al., 2008), suggesting that dual-task coordination might be an independent executive function. In an earlier study, Baddeley (1996) had already suggested that the capacity to co-ordinate two different tasks was one of the important functions of the central executive.

In accordance, Collette, Olivier, Van der Linden, Laureys, Delfiore, Luxen, and Salmon (2005), found that in a single versus dual-task paradigm there was an increased activity in the areas that have been associated with the executive functioning for example the dorsolateral prefrontal cortex (see Collette, et al., 2006, for a review). A dual-task versus single task paradigm was also used by D'Esposito, Detre, Alsop, Shin, Atlas and Grossman (1995) and the fMRI results revealed that during dual-task performance (but not in the single task) there was activation of the dorsal lateral prefrontal cortex (DLPFC) (see also Szameitat, Schubert, Müller & Von Cramon, 2002).

These findings suggest that dual-task coordination might be one of the central executive functions as it activates areas related with the central executive including the DLPFC, which is associated with top-down (goal-driven) attentional control. It has been found that anxiety impairs efficiency of attentional control, a central function of the central executive (see Derakshan & Eysenck 2009 for a review).

ACT did not include dual-task coordination as one of the executive functions most affected by anxiety, and only focused on the inhibition, shifting, and updating functions identified by Miyake et al. (2000). However, the authors have suggested that

dual-task coordination might be an executive function independent of the 3 functions identified in their study.

There have been several studies that have investigated the effects of anxiety during two concurrent tasks however these studies have systematically used the load paradigm which involves a primary and a secondary task. The emphasis is on performance of the primary task and the demands of the secondary task (load) are manipulated.

For example, Macleod & Donellan, (1993) and Derakshan and Eysenck, (1998) used the loading paradigm and found that performance of the high-anxious was impaired in the primary task when the demands on the secondary task (load) were high. This suggests that anxiety affects performance of the primary task when it is performed concurrently with a demanding secondary task.

The tasks used in these studies both involved focus on the order of letters (primary task) or order of strings of numbers (load) and both were verbal tasks. Thus the findings could suggest only that anxiety impairs performance of two demanding verbal tasks concurrently. In addition, it could be argued that the effects were due to anxiety impairing verbal processing instead of dual-task coordination

It is not possible to decide from earlier research whether the adverse effects of anxiety reflect general processing limitations or specific processing limitations relating to similarities in the stimuli and processes required on the two tasks. It is important to have two tasks that require different resources, as the dual-task cost could be due to the use of the same specific resources (see Klingberg, 1998).

In future research, the effects of anxiety on dual-task coordination should be investigated using a single task versus dual-task paradigm. This paradigm involves two

single tasks (A and B) and these tasks are either performed as single tasks or concurrently. The “costs” of dual-task performance are assessed by comparing performance on tasks A and B when performed as single tasks versus when they are performed simultaneously (e.g. D’Esposito et al., 1995; Collette et al., 2005; Szameitat et al., 2002) Thus, a single versus dual-task performance provides a purer measure of dual-task performance, because performance in both tasks can be compared, with the single task acting like a control condition.

The loading paradigm only gives a measure of the effects of anxiety on performance in a task under two different levels of difficulty/memory load and it is not possible to compare performance when the task was performed singly compared to when it was performed concurrently with other task. The load paradigm provides a less accurate measure of dual-task coordination, but a good measure of the effects of increasing demands or task difficulty on the central executive.

### **Motivation and attentional control theory**

Motivation has been generally defined as the effort to achieve a certain goal, and several fields of psychology have taken motivation as an object of study.

To explain motivation, several theories have been developed (see Hull 1943; Lewin, 1936, Ryan, 1970, Locke & Bryan, 1968, 1969; Bandura, 1986; Klein, 1989; Locke & Latham, 1990). In the late 60s, the foundations were established for one of the most important theories on motivation, goal setting theory of work motivation. This theory was developed initially based on the work developed by Ryan (1970) who first pointed that conscious purposes or goals affect action. Previously, Locke and Bryan (1968, 1969) found that individuals that received feedback improved their performance



just for the dimensions for which they had goals, and that commitment to the goal acted like a moderator between goal difficulty and performance.

The goal setting theory after decades of research work on the field was put forward in 1990 by Locke and Latham. The focus of the theory is on the relationship between goals and task performance to explain motivation, with higher levels of performance being achieved when the goal is moderately difficult than when the goal is easy or vague (Locke & Latham, 1990). In accordance Brown and Latham (2000) found that when specific high goals were set, performance and job satisfaction would increase in employees, therefore, goals that are specific and difficult in content tend to improve performance.

Crucial to motivation is goal commitment, the individual's determination to achieve a goal (see Locke, Latham & Erez, 1988; Locke & Latham 1990; Klein, Wesson, Hollenback, & Alge, 1999; Hollenbeck & Klein 1987; Hollenback, Klein, O'Leary & Wright, 1989; Klein, Wesson, Hollenback, Wright, & DeShon, 2001).

The role of goal commitment is of a mediator between goal difficulty and the individuals' performance; difficulty goals are expected to generate high goal commitment while the opposite is expected for easy goals (Locke, 1968). Locke, Latham & Eres, (1988) found that performance improves when both goal difficulty and the individual's goal commitment are high. However, if the individual perceives the goal as impossible to achieve, incentives can lower motivation instead of increasing it (Lee et al., 1997).

A self reported measure of goal commitment was developed Hollenbeck, Williams and Klein (1989). This measure has been most used in research and it involves attitude about a goal, and the determination to achieve it.

Motivation plays an important role on the high-anxious individuals' performance as a measure to overcome the adverse effects of anxiety (Eysenck & Calvo, 1992; Eysenck et al., 2007; Eysenck & Derakshan, 2011). In accordance with the goal setting theory Eysenck & Derakshan, (2011) suggested that difficult goals increase motivation of the high-anxious compared to easy or vague goals.

One of the most important assumptions from both processing efficiency theory (Eysenck & Calvo, 1992) and ACT (Eysenck et al., 2007) is that high-anxious individuals can use compensatory measures such as the use of extra effort and resources to overcome the adverse effects of anxiety on the central executive during cognitive performance. This increase in motivation to overcome the negative effects of anxiety lessens the effects of anxiety on performance effectiveness; however processing efficiency is affected due to use of extra resources to achieve a satisfactory task result.

A recent update of the ACT (Eysenck & Derakshan, 2011) suggested that motivation is related with task goals and is used as a compensatory measure by anxious individuals. The authors predicted that there is a two stage process, such that high-anxious individuals feel less motivated and use less attentional control mechanisms when the task is easy or the goal is unclear as they feel that attentional control is not really required. Eysenck and Derakshan, (2011) suggested that the "little everyday cognitive failures" are an example of the reduced use of the attentional control functions by high-anxious individuals. However, high-anxious individuals feel more motivated and make a substantial use of the attentional control mechanisms, when the task is difficult/demanding and the goal is clear, feeling more motivated than the low-anxious individuals.

This prediction of ACT can be related to the results obtained by Bishop (2009), when assessing the impact of distraction on DLPFC activation during a letter search task. The findings showed that anxiety slowed performance only in the extremely easy condition (low load). During the difficult condition (high load), anxiety increased the activation of the left DLPFC. The author suggested that effects of anxiety on the easy condition could be explained by an inefficient use of attentional control that could account for the “little every day cognitive failures”.

However, the findings above can be explained by the ACT two-stage process. Thus, when the task was very easy (low load) high-anxious failed in using attentional control, as they felt less motivated. But when the task was demanding (high load) the high-anxious felt more motivated and made an extra effort to compensate the negative effects of anxiety to achieve a satisfactory performance, shown by the increase in the activation of the left DLPFC and no effects of anxiety on performance. In accordance, Hayes, Macleod and Hammond (2009) found that during incidental learning conditions (less motivational condition) trait anxiety had an adverse effect on performance that was no longer present during intentional learning conditions (more motivational condition). This suggests an increase in motivation with the effort increasing when a clear and difficult goal was set, compared to when the task was incidental and thus less motivational.

Although motivation is a central assumption to both processing efficiency theory and ACT there is almost no research in this field, future studies are needed to understand the relation between anxiety and effects of motivation during cognitive performance

In sum, motivation or increased effort is used as a compensatory measure to overcome the effects of anxiety on during cognitive performance. Anxiety is associated with high motivation when the task goal is difficult but clear. However, when the task is easy or unclear anxiety is associated with low motivation as the high-anxious individuals believe that attentional control is not really required for the task.

### **Efficiency and effectiveness**

A major assumption of the processing efficiency theory is that is that high levels of anxiety affect processing efficiency (relationship between performance effectiveness and the amount of processing resources used) more than performance effectiveness (quality or result of the performance). An approximate measure of performance efficiency is reaction times or neural activation in the areas associated with attentional control, while performance effectiveness is generally measured in terms of differences in error rate.

Processing efficiency is believed to decrease when more processing resources are needed in order to achieve a good task result (performance effectiveness). The effects of anxiety on processing efficiency show that the anxious individuals try to compensate the adverse effects of anxiety by putting an extra effort and using extra resources to achieve a satisfactory task performance. As the use of processing resources increases processing efficiency decreases but performance effectiveness or the result of the performance is not significantly affected (Eysenck, et al., 2007; Eysenck & Derakshan, 2011).

There has been a large amount of research in this field that has provided indirect evidence for this assumption, as the findings generally found that differences between high and low-anxious individuals were frequently found in terms or response time but

not in terms of error rate. (e.g. Derakshan, Ansari, Hansard, Shoker & Eysenck, 2009; Ansari, Derakshan & Richards, 2008; Ansary & Derakshan, 2010, 2011a, 2011b ; Derakshan, & Eysenck 2009; Fales et al., 2008). However, it must be taken into account that response times are only an indirect measure of processing efficiency as they involve relation between the effort put into to the task, the amount of processing resources used and the task result or accuracy.

ACT states that processing efficiency of the inhibition and the shifting functions are the most affected by anxiety during cognitive performance. Several studies have found support for this assumption (e.g. Derakshan, & Eysenck, 2009).

A more direct way of investigating the effects of anxiety on processing efficiency of the executive functions is by analysing neural activity (e.g. ERPs; fMRI) while the task is performed. For example, Ansari & Derakshan (2011a) used a mixed anti and prosaccade task and measured neural activity using EEG to investigate this ACT assumption. The results revealed that in response to a warning signal used as cue the high-anxious increased activity on the frontal cortical sites (associated with cognitive control) compared with the low-anxious during long and medium intervals of offset of instructional cue and onset of a target, CTI. These findings suggested that the high-anxious used more effort and processing resources than the low-anxious to achieve a satisfactory performance as in accordance with ACT.

Using a stop signal paradigm Savostyanov, Tsai, Liou, Levin, Lee, Yurganov and Knyazev (2009) studied the inhibition function and its relationship to trait anxiety and event related EEG oscillatory reactions. In the stop signal, participants had to inhibit the motor reaction to press a right or left button when a red bar was displayed after a target picture. The EEG results revealed differences between groups with the

high-anxious group having greater desynchronization than the low-anxious. These results suggest that the high-anxious put more effort to inhibit response and more effort in controlling locomotor reactions (showed by the desynchronization), this extra use of resources affects processing efficiency as predicted by ACT (Eysenck et al., 2007). No significant differences between groups were found in performance in terms of reaction times or error rate.

The cognitive neuroscience approach has enormous potential. It provides a way of assessing processing efficiency much more directly by directly measuring the use of resources than was possible using behavioural measures.

### **Summary and conclusions**

ACT states that anxiety impairs the central executive (Eysenck et al., 2007). The theory adopts the executive functions identified by Miyake et al. (2000), (shifting, inhibition and updating) and identified the shifting, and inhibition functions, as the most impaired by anxiety. Support has been found for this assumption. There is a large amount of research that has investigated the effects of anxiety on the capacity to inhibit task irrelevant stimuli. The results generally found that high-anxious individuals have more difficulty in inhibiting task irrelevant stimuli. However, only a few studies have used tasks that require the shifting function, and there is a great need to develop research to investigate the effects of anxiety on the shifting function. Further research should be developed to test ACT's assumption that this function is one of the most impaired by anxiety.

ACT predicts that the updating function should be less affected by anxiety and generally research has provided inconsistent results regarding the effects of anxiety on the capacity to update information on the working memory. It is not clear if anxiety

affects the updating function. ACT predicts that the updating function is only impaired by anxiety during stressful situations and there are a couple of studies that have found evidence for this prediction. However, further research is needed to test the attentional control assumption and clarify the effects of anxiety on the updating function.

Dual-task coordination might be a central executive function as it activates neural areas related with the central executive functioning (Collette, et al., 2005) and is not associated with the executive functions identified by Miyake et al. (2000). ACT does not make any specific prediction regarding the effects of anxiety on dual-task coordination but it will be important to investigate if anxiety impairs this ability.

In accordance with ACT, to overcome the adverse effects of anxiety on cognitive performance the high-anxious feel more motivated and put an extra effort by using extra processing resources to achieve a good result. However, by using extra resources as compensatory measures processing efficiency is impaired (relation between resources used and the result) while performance effectiveness (result) is generally not. In addition, ACT predicts motivation will increase when the task goal is clear and difficult compared to when it is easy in accordance with the goal setting theory of motivation. There is almost no research developed to test the role of motivation on high-anxious individuals' performance although it is a central assumption that comes from processing efficiency theory and was further developed with ACT.

In conclusion, in the following empirical chapters will test the central predictions of the ACT to bring research of direct relevance for the theory, and to bring further knowledge and understanding on how individual differences in anxiety affect cognitive performance. More specifically, the empirical chapters will investigate the

effects of anxiety on the central executive functions; testing ACT's assumptions. The inhibition and shifting functions will be investigated on the first three empirical chapters (chapters 2, 3 and 4). Chapter 4 will also investigate the effects of anxiety on the updating function. The effects of anxiety will be investigated during dual-task coordination (chapter 5). Overall, the effects of anxiety on four executive functions will be tested. In addition, the role of goal setting an indirect measure of motivation will be investigated as a compensatory measure to overcome the effects of anxiety.



## **Chapter Two**

**An investigation into the effects of  
anxiety on the executive functions  
shifting and inhibition: tested together  
and separately**

The effects of anxiety on cognitive performance have been the subject of a large amount of research. Eysenck and coworkers in 2007 reviewed most of the studies in the field, and found that the results largely suggested that high levels of anxiety, whether trait or state anxiety, can negatively affect cognitive performance.

In order to provide an explanation to account for the negative effects of anxiety on cognitive performance, Eysenck et al. (2007) developed ACT based on a large research review, and as an update to the previous processing efficiency theory (Eysenck & Calvo, 1992). One of the main predictions associated with both processing efficiency and attentional control theories is that anxiety impairs mostly the central executive. In accordance with Baddeley (1986, 2001), the central executive is a central component of the working memory that controls, monitors and updates the working memory functions. It has limited capacity and attentional control is its main role.

Research developed on the central executive has identified several executive functions. However, to date no consensus has been achieved in relation to the nature or number of these functions (e.g. Smith, & Jonides, 1999; Barrett, Tugate & Engle, 2004, Miyake, 2000; Fournier-Vicent, Larigauderie, & Gaonac'h, 2008). In 2000, Miyake et al. identified three functions associated with the central executive, the inhibition function (capacity to inhibit task irrelevant stimuli, “dominant, automatic, or prepotent responses”), the shifting function (capacity to shift attention between “task or mental sets”) and the updating function (capacity of constantly “monitoring and updating of working memory representations” replacing old for new and relevant information (Miyake et al., 2000, p.54). This central executive approach has the advantage of identifying the executive functions mainly on the basis of empirical evidence, something that had hardly been done systematically before.

Recently, Fournier-Vicent et al. (2008) identified five executive functions based on a comprehensive latent variable analysis. This analysis was similar to the one developed by Miyake et al. (2000). The larger number of executive functions found by Fournier-Vicent et al. can be explained by identifying them as sub-functions of the executive functions found by Miyake et al., which can interrelate with each other. Miyake, et al. (2000) found that the executive functions were both separable from each other but also shared common processes.

In the present study, the Miyake et al. (2000) approach is followed as ACT bases its predictions on the three executive functions identified by Miyake et al. (2000). Of these, ACT identifies the inhibition and the shifting functions as the ones most impaired by anxiety, as they are directly related with attentional control, while the updating function is more related with short-term memory (Eysenck, et al. 2007).

According to ACT, anxiety impairs attentional control because it disrupts the balance between the stimulus-driven and the goal-driven attentional systems (Corbetta & Shulman, 2002). These two attentional systems interact with each other on a regular basis. Stimulus-driven (bottom-up) attentional control is faster, and more automatic than goal-driven (top-down) attentional control which involves voluntary control of attention (Pasheler, Johnston, & Ruthruff, 2001; Yantis, 1998; Hasher & Zacks, 1979). Anxiety disrupts attentional control, increasing the influence of stimulus-driven attention and decreasing goal-driven attentional control.

ACT (Eysenck et al. 2007) predicts that the anxiety affects the executive functions (inhibition and shifting), impairing processing efficiency (relation between the task result and the resources used generally measured in response times) to greater extent than performance effectiveness (result/accuracy of the performance). Processing

efficiency is believed to decrease when more processing resources are needed in order to achieve a good task result (performance effectiveness).

In order to cope with the negative effects of anxiety on the central executive, high-anxious individuals increase the use of processing resources by putting in an extra effort. Their processing efficiency decreases as they use more processing resources. However, their performance effectiveness might not be significantly affected (as it is maintained at the cost of efficiency) (Eysenck, et al., 2007; Eysenck & Derakshan, 2011).

In most of the research, time is viewed as a measure to assess processing efficiency and accuracy as the measure of performance effectiveness. There is a degree of approximation in using reaction times as they are only well correlated to efficiency if effectiveness remains reasonably constant. Even then they are an indirect measure subject to external interference.

Many studies have found differences between high and low-anxious individuals in terms of time response but not in terms of accuracy (e.g. Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009; Derakshan, Smyth & Eysenck, 2009b; see Derakshan & Eysenck, 2009 and Eysenck, et al., 2007 for a review) and so support ACT.

The inhibition and the shifting functions are the ones most impaired when task demands on the central executive are high, requiring the use of more processing resources. As such the negative effects of anxiety should be more evident when the task is complex and consequently imposes extra demands on the central executive functions (Eysenck, 1992; Eysenck, et al., 2007). There are numerous findings that support this assumption (e.g. Ashcraft & Kirk, 2001, experiment 3; for a review see Eysenck 1992; Eysenck, et al., 2007). Derakshan, Smyth & Eysenck (2009), in a study that

investigated the shifting function, found that participants high in state anxiety had increased response times over those with low state anxiety on an arithmetical switching task only when the task complexity was high.

A considerable amount of research has found support for ACT's assumption that anxiety affects the inhibition function (capacity to inhibit task irrelevant stimuli, or prepotent responses). Studies that involve the inhibition function have often used task-irrelevant stimuli or distractors, either emotional or neutral. Emotional task-irrelevant stimuli have often been used because anxiety has been associated with hyper-vigilance to threat or attentional bias to threat (Eysenck, 1992, see Bar-Haim et al., 2007 for a review). Studies that used emotional stimuli generally revealed that high-anxious individuals' performance is more susceptible to be impaired by task irrelevant emotional stimuli or distractors than that of low-anxious (e.g. Fox, Russo & Georgiou, 2005; Reinholdt-Dunne, Mogg, & Bradley, 2009; Pacheco-Unguetti, Lupiáñez, & Acosta, 2009; Wieser, Pauli & Mulberger, 2009).

However, ACT's (Eysenck et al. 2007) central notion is that anxiety impairs efficiency of attentional control mechanisms regardless of the type of stimuli (neutral or emotional). There is a consensus that threat-related stimuli easily distract high-anxious individuals but there is less agreement on the attentional control prediction that they will also be more easily distracted by neutral stimuli.

There is some support for the attentional control prediction that neutral stimuli can also distract the high-anxious more than the low-anxious (see Ashcraft & Kirk, 2001; Ansari & Deraksahn, 2010; for a review see Eysenck et al., 2007). For example, Calvo and Eysenck (1996) used meaningful speech as a distractor (presented auditorily) in a task that involved text comprehension. They found that the high-anxious group had

more difficulty in inhibit the distractor than the low-anxious group, but only in the more demanding text comprehension task.

Finally, Derakshan, Ansari, Hansard, Shoker & Eysenck (2009a) examined the effects of anxiety in the inhibition function using an anti-saccade task. This task is considered to be a good measure of inhibition as it involves inhibiting the saccade to a sudden stimulus, requiring a volitional saccade response opposite to the stimulus. In this task the latency of the first correct saccade is considered to be a measure of processing efficiency, with longer latencies suggesting increase use of processing resources. The authors developed two experiments. In the first experiment, a neutral stimulus (oval shape) was used as a cue that was presented 600ms before the target (an arrow). The analysis of the latencies of the first correct saccade revealed longer latencies for the high-anxious compared to the low-anxious. In the second experiment happy, angry and neutral face expressions were used as cues and it was found that when the cue was an angry face the high-anxious group increased the latency of the first correct saccade when compared with the low-anxious group. In both experiments the differences between groups were only found during the antisaccade task, and only in latencies (Derakshan et al. 2009a), these results support that either neutral or emotional stimuli can affect high-anxious individuals' efficiency.

Considerably less research has been carried out on the effects of anxiety on the shifting function, and it is important to understand how anxiety affects this executive function. The role of the shifting function is to drive attention in a positive, optimal and flexible way, as it involves the capacity to alternate or redirect attention between and within tasks or mental sets (Eysenck et al., 2007; Derakshan & Eysenck, 2009; Miyake et al., 2000).

Task switching has been the paradigm generally used to study the shifting function, as it is closely associated with it (Miyake et al., 2000). This paradigm involves two conditions. The task switching condition, as an experimental condition in which participants alternate rapidly between tasks A and B, and the repetitive condition, as a control condition in which the task involves repeating a block of trials of task A followed by another block of task B. Task switching involves a cost from switching rapidly from task to task, this leads to a cost after every switch that does not occur when repeating the same task (see Monsell, 2003, for a review). As Monsell, 2003, indicated, there are probably several factors that influence performance differences between task-switching and non-task-switching conditions.

The inhibition and shifting functions of the central executive are independent in their operation; however they are also correlated with each other. Miyake et al. (2000) examined the relationship between the executive functions to understand to what extent the executive functions were unitary or separable. Overall, the results suggested that the executive functions showed signs of unity and of diversity. They indicated that the three executive functions (shifting, inhibiting and updating) were separate constructs, but that they also shared some commonalities and were moderately correlated among each other. In addition, Friedman and Miyake (2004) found that task switching was related with response to distractor inhibition.

Hedden and Gabrieli (2010), in a study that investigated the neural areas associated with the inhibition and the shifting functions, found many regions with activation common to both inhibition and shifting functions, while there were also regions preferential to the inhibition function (e.g. dorsolateral and ventrolateral

prefrontal cortex, parietal lobes) and others preferential to the shifting function (e.g. parietal lobes and left dorsolateral prefrontal cortex).

Based on the above findings when looking at the effects of anxiety on cognitive performance, it is important to develop research that studies both the shifting and inhibition functions together and separately. This requires a task that involves inhibiting task irrelevant stimuli (inhibition function) and also requires shifting attention between and within tasks (shifting function). As described above, these two executive functions have some common features involving partially overlapping processes and common active brain areas (Hedden & Gabrieli, 2010). If the two executive functions were entirely separate in terms of their processing demands, it would be expected that anxiety would have different effects on each one.

Consequently, the present study aims to study the effects of trait anxiety on the inhibition and shifting functions, jointly and separately. Two studies served as basis for the present study, the Rubinstein et al. (2001) study and the more recently Derakshan et al. (2009b) study. The latter was influenced by the former and both studies used an arithmetical switching task.

Rubinstein et al. (2001) investigated the executive control of task switching. For that purpose, the authors used an arithmetical task that involved repetitive (the same operation was repeated) and switching blocks (alternation between two operations) in their second experiment. This allowed them to compare performance in both blocks under two complexity conditions, low (additions and/or subtractions) and high (multiplications and/or divisions). Arithmetical signs were used as cues in half of the blocks. This design allowed comparing performance on the repetitive vs. switching blocks which required the shifting function, and to investigate the role of task



complexity on the central executive. The findings revealed that high complexity slowed response times for both repetitive and switching task blocks, but that it was during switching that complexity had a higher effect. It was also found that cues (operation sign) made participants answer faster.

More recently, Derakshan et al. (2009b) tested the effects of state anxiety on performance with a focus on the effect of anxiety in the shifting function. The task used in their study was very similar task to the one used by Rubinstein et al. (2001, second experiment) described above. The results were in agreement with ACT, as participants high in state anxiety had significantly slower responses during the switching task than low-anxious participants when the task complexity was high. This suggests that as complexity increases and higher demands are put on attentional control, the negative effects of anxiety on the shifting function will increasingly affect response time. This is in accordance with ACT (Eysenck, et al., 2007), which states that the shifting function should be more negatively affected in high-anxious participants than in the low-anxious. As processing demands increase, high-anxious individuals have more difficulty to show positive attentional control (high complexity task), as it involves redirecting attention from within and between tasks (shifting function).

In the present study it was used a task similar to the one used in Rubinstein et al. (2001), and in Derakshan et al. (2009b). However, there are some significant differences as this study was designed to study the shifting and inhibition functions together and separately, while the former studies focused only on the shifting function.

First, no cues were used in this study in order to have a greater effect of anxiety on task performance. In Rubinstein et al (2001) study it was found that in the presence of a cue (+, -, x, or ÷ signs) the switching costs were significantly lower, thus cues act

like a task facilitator. Derakshan et al. (2009b), found that this effect was especially strong in the high-anxious group, with lower RTs in presence of cues (operation signs). Thus, not using cues potencies anxiety, and since this study purpose is to investigate the effects of anxiety on performance it makes sense not to use cues in this experiment. In addition, participants' reliance on internal attentional control is likely to be greater when operations signs are absent.

Third, the present study investigates the inhibition function as well as the shifting function, while Derakshan et al. (2009b), study focused only on the shifting function. In order to study the inhibition function a distracter was used in half of the blocks. This paradigm has been often used to study the inhibition function as previous research into this function has consistently shown that the performance of high-anxious individuals is more vulnerable to distraction of task irrelevant stimuli than that of low-anxious (e.g. Derakshan, Ansari, Hansard, Shoker & Eysenck, 2009; see Eysenck et al., 2007 for a review).

An auditory distracter related to the task was chosen to test the inhibition function, because literature on this topic has found that there is more interference from distractors that have features in common with the items in the response than from stimuli that do not (Elliott & Cowan, 2001). As the present study task involves mental calculation, it was decided to use numbers as distractors because they definitely are task-related. To display several numbers on the computer screen could cause confusion with the task numbers so it was decided to have an auditory distractor instead. Also, auditorily displayed words have been found to disrupt performance more than tones or nonsense syllables (LeCompte, Neely & Wilson, 1997). In addition, LaPointe, Heald, Stierwalt, Kemker and Maurice (2006) found that word repetition used as an auditory

distracter slows cognitive performance. These findings suggest that the use of an auditory distracter that consists of a voice reciting numbers would affect performance more than the use of tones.

Elliott and Cowan (2001, experiments 1 and 2), found that distracter habituation takes place at a lexical level, and that a change from one word to another, even in the same category, can slow participants' performance. Thus, in order to avoid habituation and based on the suggesting that change in the distracter stimuli and similarity of the distracter with the immediate response can affect more the participant response, it was decided that the auditory distracter would consist in a randomised male and female voice saying numbers from 1 to 9 in random order. The female and male voices used randomly should also contribute to lower distracter habituation as they have different sound frequencies (see Banbury, Macken, Tremplay & Jones 2001 for a review on auditory distraction). LaPointe, Heald, Stierwalt, Kemker, & Maurice, (2007) found that auditory distracters at a comfortable loudness (40dB) were more disregarded than at more uncomfortable loudness levels. Based on these results it was decided to play the auditory distracter at a louder level than 40dB.

Fourth, the difficulty rate of the arithmetical problems used in the present study was reduced due to the high error rate observed in the Derakshan et al. (2009b) study, particularly in the high complexity problems. While that experiment had cues which act like facilitators, the present study uses a distracter, which increases task difficulty and is expected to increase error rate. Based on the results of Derakshan et al. (2009b) and Rubinstein et al. (2001, second experiment) studies the difficulty rate was lowered by reducing to 50% the number of problems that required carrying or borrowing a number from the ones column to the tens, this had not been done in Derakshan et al (2009b).

Fifth, in the present study, the focus is on the effects of trait anxiety (anxiety as a personality dimension), while in the Derakshan et al. (2009b) study the focus was on state anxiety (anxiety related with the situation). Trait anxiety was chosen over state as most of the research on the field of anxiety and cognitive performance has focused on trait rather than on state anxiety. In addition, the emphasis of ACT is more on trait anxiety, most of the research reviewed within the theory is based on trait rather than on state (see Eysenck, et al. 2007).

Moreover, high trait anxiety seems to have more effect on the executive system when processing non-emotional/affective information, being more structural as a personality dimension and not a reaction to a situation. Whereas state anxiety is situation-related and affects the attentional networks more related with vigilance or context sensitivity, as found by Pacheco-Unguetti, Acosta, Callejas and Lupiáñez (2010). It could be argued that trait anxiety relates to habitual ways in which the cognitive system deals with numerous situations, whereas state anxiety relates more to immediate processing of threat-related stimuli. It is also important to understand if trait anxiety has similar effects on performance as state anxiety, which was investigated by Derakshan et al. (2009b).

Another reason to choose trait anxiety is because attentional control correlates negatively with trait anxiety, as was found by Derryberry & Reed (2002). The authors developed a self-report measure of attentional control (Attentional Control Scale - ACS) and found that individuals high in trait anxiety had significantly lower attentional control than the low-anxious. This is in accordance with ACT, as anxiety affects attentional control which is the key role of the central executive.

Also based on the above findings, it was decided to use the ACS developed by Derryberry and Reed (2002) in the present study. This self-report measure of attentional control is used to investigate its relation with trait anxiety, since the effects of anxiety on attentional control is the central core of ACT. This individual measure of attentional control is the result of the junction of two separate scales which were used by Derryberry and Rothbart (1988). One of the scales measured attentional focus (capacity to focus attention and resist distractors), which closely resembles the inhibition function, while the other scale measured attentional shifting (capacity to shift attention as desired) which closely resembles the shifting function. The ACS total score has been found to be negatively correlated with trait anxiety (e.g. Derryberry & Reed 2002; Ayduk et al., 2008). Thus the attentional control scale seems to assess both the inhibition and the shifting functions of the central executive.

This study aimed to test the effects of trait anxiety and task complexity on the attentional control functions (inhibition and shifting), separately and jointly. These effects were analysed by measuring reaction times (RTs) to arithmetical problems. Inhibition was measured as the capacity to inhibit a distractor and the shifting function as the capacity to switch between tasks.

Specific hypotheses were as follows:

- 1- That an interaction between anxiety group and task type would be found, such that, the high anxiety group should have a larger increase in response times on switching versus repetitive blocks. The high anxiety group should also have a higher switch cost.

- 2- That an interaction between anxiety group and distractor would be found, such that, when the distractor was present the high anxiety group should have larger increase in response times.
- 3- That an interaction between anxiety group and task complexity would be found, when the task complexity was high the high anxiety group should display a larger increase in response times.
- 4- That a three-way interaction between anxiety group, task type, and distractor, would be found, such that, the high anxiety group was expected to increase more in response times than the low anxiety group during task switching blocks when a distractor was present. The high anxiety group was also expected to increase more in switch cost than the low anxiety group when a distractor was present.
- 5- That a three-way interaction between anxiety group, task complexity and task type would be found, such that a greater effect of anxiety was expected when task complexity was high and task switching was required increasing the high anxiety group response times more than the low anxiety group.
- 6- That a three-way interaction between anxiety group, task complexity and distractor would be found, such that a greater effect of anxiety was expected when task complexity was high and the distractor was present, increasing high anxiety group response times more than the low anxiety group.
- 7- That a four-way interaction between anxiety group, complexity, task type and distractor response times would be found. A greater effect of anxiety was expected when task complexity was high, task switching was required and the distractor was present, increasing high anxiety group response times more than the low anxiety group.

- 8- That anxiety would affect response times to a greater extent than accuracy. Thus, interactions between accuracy and anxiety group were not expected. As in accordance with ACT anxiety affects processing efficiency to a greater extent than performance effectiveness.

## Method

### *Participants*

Seventy undergraduate students at Royal Holloway University of London participated in this study, 51 were female and 19 were male. The mean age of the participants was 21.20 ( $SD = 4.58$ ). The participants received credits or they were paid 5 pounds in exchange for their participation. Participants were selected to participate in this study based on their score, on the Trait form of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorus, & Lushene, 1970). According with the trait anxiety level reported, the students were divided into a high (scoring  $\geq 45$ ) and a low anxiety (scoring  $\leq 34$ ) groups using the upper and lower quartile of the sample. Half of the selected participants were in the high anxiety group and the other half in the low anxiety group. In the low anxiety group 23 of the participants were female and 12 were male and the mean age in this group was 21.71 ( $SD = 5.77$ ). In the high anxiety group 28 of the participants were female and 7 were male and the mean age in this group was 20.69 ( $SD = 2.94$ ).

### *Measures*

The participants were asked to complete two questionnaires.

The trait form of the State-Trait Anxiety Inventory (STAI) (Spielberger, Gorus, & Lushene, 1970) which has 20 items and it was designed to measure increasing levels of anxiety, low scores reflect low anxiety or calmness and high scores reflect high anxiety. For example, the STAI include items as “I feel nervous and restless” and “I am cool, calm, and collected”. STAI is ranked in four degrees of agreement Likert scale, ranging from “almost never” (scores 1) to “almost always” (scores 4).



The Attentional Control Scale - ACS (Derryberry & Reed, 2002), which is a 20 item scale. For example ACS includes items as “when I am working hard on something, I still get distracted by events around me”. The ACS is ranked in four degrees of agreement Likert scale, ranging from “almost never” to “always”. High scores mean high attentional control and low scores mean poor attentional control. This scale as shown to be internally consistent with reliability estimates ranging from  $\alpha = .71$  (Gyark & Ayduk, 2007) to  $\alpha = .88$  (Derryberry & Reed, 2001 cited in Derryberry & Reed, 2002).

### *Apparatus*

The computer task was programmed using Visual Basic 6 programming language. The program recorded the participants’ reaction times in milliseconds. Accuracy was registered by the experimenter. The participants used headphones (Sony stereo headphones MDR-XD100) during the whole experiment. The sound level of the distractor ranged from 59 to 65dB and it consisted of spoken numbers from 1 to 9 (randomly alternating between male and female voice), which were presented during half of the blocks.

The tasks were carried out on a Toshiba Satellite 2450-201 laptop with an Intel Pentium 4 processor. The screen was 15” with a TFT active matrix colour display and the resolution 1024 x 768 with a 60 Hz refresh rate.

### *Design*

This experiment consisted of four repetitive tasks (addition, subtraction, multiplication, division) and two switching tasks (alternating between addition and subtraction, alternating between multiplication and division). In accordance with Rubinstein et al. (2001), half of the blocks were of low complexity, they consisted of

blocks of either addition or subtraction problems and of blocks that alternated between addition and subtraction. The other half of the blocks was of high complexity and consisted of blocks of either multiplication or division problems and of blocks that alternated between them.

Participants were presented with 12 blocks of 12 trials in total, thus each participant had to perform two of the six trial types (addition, subtraction, alternating addition/subtraction, multiplication, division, alternating multiplication/division). During half of the blocks participants were exposed to an auditory distracter that consisted in recorded female and male voices randomly saying numbers from 1 to 9.

The presentation order of the blocks for each of the conditions (low/high complexity) was randomised using a simple Latin square design, with the participants completing all low complexity blocks before attempting the high complexity ones. Inside each block the order by which the numbers were presented was also randomised using another Latin square design.

#### *Experimental Conditions*

*Complexity conditions* - There were two complexity conditions in the present experiment: Low and high. Following the Rubenstein et al. (2001), the Low-complexity condition required to solve arithmetical problems addition and subtraction, while the high complexity required solving division and multiplication problems. Half of the trials were low complexity and the other half were high complexity.

*Repetitive versus Switching conditions* - The participants were asked to switch between mathematical tasks in one third of the experimental blocks, (e.g. from addition to subtraction or from multiplication to division). In the remaining two thirds of all the experimental blocks, the task was repetitive (e.g. addition, subtraction).

*Distracter versus no distracter condition* - The distracter condition consisted in an audio recorded male and female voices saying random numbers from 1 to 9, in a variable presentation rate. The participants listened to the numbers through the use of headphones, while they were trying to perform the mental calculation in order to answer the arithmetical tasks. The distracter condition was present in half of the blocks; in the other half no distracter was presented.

### ***Stimuli***

The stimuli consist in 144 arithmetical problems (addition, subtraction, multiplication and division). At each trial two black numbers were displayed in a white screen; a two digit number on the left side and a one digit number on the right side, no arithmetical sign was displayed between them.

In the low complexity condition the two digit numbers ranged from 12 to 68 and in the high complexity condition from 36 to 98, the one digit number for both conditions ranged from 2 to 9 (e.g. 42 + 6). In both conditions the numbers were never integral multiples of 10. In the low complexity condition, when addition was performed, 50% of the problems required carrying a number from the ones to the decimal column; when subtraction was performed 50% of the digits required to borrow a number from the tens column. In the high complexity condition when multiplication was performed, 50% of the problems required to carry a number from the ones to the tens decimal column, when division was performed 50% of the problems required to carry a remainder from the tens to the ones column. Solutions to all of the divisions were integrals (zero remainder).

The distractor consisted of spoken numbers from 1 to 9 (randomly alternating between male and female voice) which were presented during half of the blocks through headphones. The sound level of the distractor ranged from 59 to 65dB<sup>1</sup>.

### *Procedure*

In the beginning of each session, the participant started by reading the information sheet and filling the consent form; and the ACS and the STAI.

The participants were invited to sit in front of the computer screen and to use headphones for the whole time of the experiment. Participants were informed that the instructions were going to be displayed in the screen and that they should ignore what was going to be presented through the headphones and focus only on the task that they were asked to perform. Participants were told to solve a series of mathematical problems that were presented to them on the screen (e.g. addition, subtraction, or alternation between addition and subtraction). They were also informed that no arithmetical sign would be displayed between the numbers, so they should pay attention to the instructions given before each group of problems. That in the beginning of each group of problems the mathematical operation that they would be asked to perform would be displayed in the centre of the screen. And that they should answer as accurately and as quickly as possible. In order for their answer to be validated they should answer by saying the result aloud while pressing the space bar.

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<sup>1</sup> Auditory distractors played at 40dB have been found to be more disregarded than at a more uncomfortable loudness (LaPointe et al., 2007), in order to find at what level participants would regard the sound as uncomfortable but not upsetting, a pre-test was conducted and based on the participants' feedback the sound level was chosen.

In order to increase their levels of anxiety, participants were informed that speed and accuracy in the experiment is a marker of intelligence and that their performance was going to be compared with that of other students.

The participants started by performing four practice trials for each block of problems for a total of 24 trials, the problems presented as practice trials were not displayed again. The distracter was present in half of the practice trials. The mathematical problems did not require carrying or borrowing a number from the ones to the tens during this phase; since the objective was only to train the task. At the end of the practice trails participants could ask questions before starting the main experiment.

The length of the arithmetical task was around 35 to 45 minutes varying from participant to participant, and only one participant was tested at each time. During all the experiment, the experimenter was seated behind the participant.

### *Statistical analysis*

Only the correct responses, (trials in which participants give the correct mathematical response in accordance with the instruction) were included in the reaction time (RT) data analysis. RT-means were computed for each subject in each block for the high/low complexity condition with and without presence of distracter for both repetitive and switching tasks.

For the correction of outliers, responses above three standard deviations of the subjects mean were excluded (see Ratcliff, 1993). The average percentage of error was 11.23%, and outliers was 0.00%, this data was removed from the main analysis. The data was screened for multivariate outliers using Mahalanobis distance, no multivariate outliers were identified, ( $M = .97$ ,  $SD = 1.07$  high-anxious group;  $M = .97$ ,  $SD = 1.61$

low-anxious group). All variables were normally distributed according to Kolmogorov-Smirnoff tests.

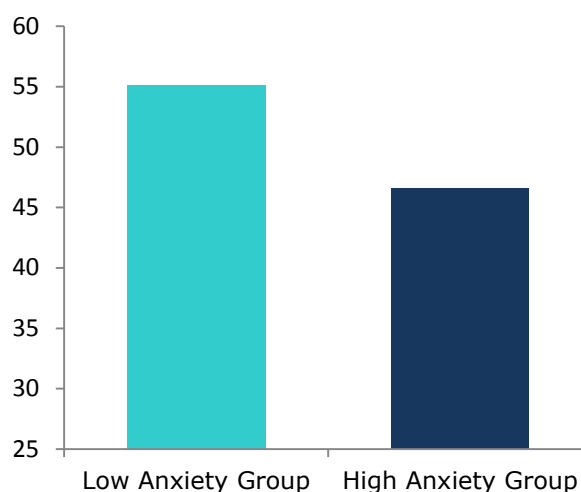
Mixed measures *ANOVA* analyses and paired and independent t tests (2-tailed) were conducted to look for group differences in performance. A subsequent analysis using mixed measures *ANCOVA* was performed with ACS as a control variable. The SPSS statistical program was used for all the data analysis. *P*-values of less than 0.05 were taken to indicate statistically significant differences. Switch cost were calculated using the following formula (RTs mean in the switch block – RTs mean in the repetitive block) x number of trials in a block / (number of trials in a block -1).

## **Results**

### ***Trait Anxiety and Attentional Control Measures***

Participants were divided in two groups, a high anxiety group ( $M = 53.74$ ,  $SD = 7.59$ ) and a low anxiety group ( $M = 29.60$ ,  $SD = 2.86$ ) based on their self reported measures of trait anxiety.

A one-way ANOVA showed a significant effect of anxiety group on the levels of attentional control (ACS) [ $F(1, 69) = 15.58$ ;  $p < .001$ , partial  $\eta^2 = .186$ ], with the low-anxious group ( $M = 55.09$ ,  $SD = 9.45$ ) scoring higher in the ACS and showing a better attentional control than the high-anxious group ( $M = 46.54$ ,  $SD = 8.64$ ). These results are in accordance with ACT, which states that anxiety negatively affects attentional control.



**Figure 1:** Mean scores for the self-reported measure of attentional control ACS for both high and low anxiety groups

### *Reaction Time Data*

To test the hypothesis, a 2x2x2x2 mixed model analysis of variance (*ANOVA*) was performed on the reaction time (RT) data, with three within subjects' conditions: complexity (high vs. low complexity); task type (repetitive vs. switching); distractor (present vs. absent) and anxiety group as between subject factor design

#### *Main effects*

There was a main effect of complexity [ $F(1, 68) = 324.85, p < .001$ , partial  $\eta^2 = .827$ ]. Participants had slower RTs on the high complexity blocks ( $M = 6612.55\text{ms}$ ,  $SD = 2616.64$ ) and faster RTs in the low complexity ( $M = 2403.56\text{ms}$ ,  $SD = 938.75$ ).

There was also a main effect of task type [ $F(1, 68) = 50.80, p < .001$ , partial  $\eta^2 = .428$ ]. On average participants had longer RTs when they had to switch between two different arithmetic problems ( $M = 5374.39\text{ms}$ ,  $SD = 2024.56$ ) than when the task was repetitive ( $M = 4656.43\text{ms}$ ,  $SD = 1830.79$ ).

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A main effect of the distractor was also found [ $F(1, 68) = 15.95, p < .001$ , partial  $\eta^2 = .190$ ], such that RTs were faster when the distractor was absent ( $M = 4540.99\text{ms}$ ,  $SD = 1547.59$ ), than when the distractor was present ( $M = 4883.28\text{ms}$ ,  $SD = 1806.54$ ).

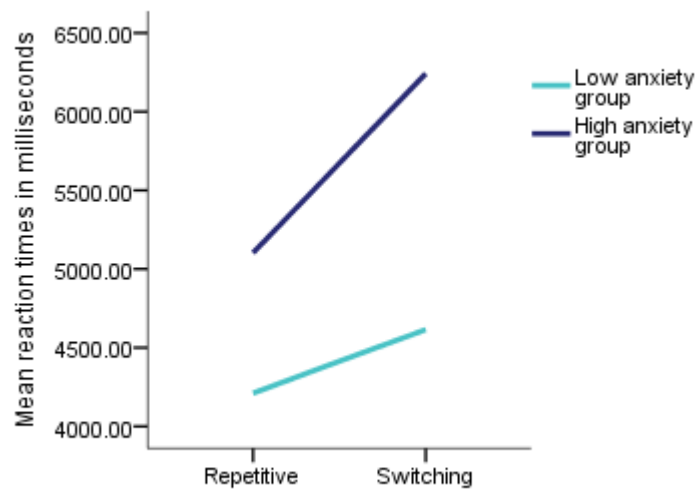
A significant main effect was also found for trait anxiety group such that the high anxiety group ( $M = 5227.28\text{ms}$ ,  $SD = 1969.10$ ) had overall longer RTs than the low anxiety group ( $M = 4207.12\text{ms}$ ,  $SD = 1052.18$ ) [ $F(1, 68) = 9.13, p = .004$ , partial  $\eta^2 = .118$ ].

### *Effects of Anxiety on Task Type RTs, Distractor RTs, and Task Complexity Separately*

#### *Anxiety x task type (hypothesis 1)*

As predicted in Hypothesis 1 the results from the main ANOVA (p.79) revealed a significant interaction between the type of task and anxiety group [ $F(1, 68) = 11.52, p = .001$ , partial  $\eta^2 = .145$ ] (see figure 2). To investigate differences between groups further an independent  $t$ -Test (2-tailed) was performed, the results revealed that the high-anxious group had significantly longer RTs ( $M = 5861.20\text{ms}$ ,  $SD = 2129.28$ ) than the low-anxious group ( $M = 4434.92\text{ms}$ ,  $SD = 1070.32$ ) during task switching [ $t(68) = 3.54, p = .001$ ] and also during the repetitive task [ $t(68) = 2.17, p = .034$ ] (high-anxious,  $M = 4924.98\text{ms}$ ,  $SD = 1952.28$ ; low-anxious  $M = 4101.44\text{ms}$ ,  $SD = 1110.09$ )





**Figure 2:** Mean reaction times (ms) for the switching task and the repetitive task, as function of anxiety group.

This 2-way interaction was qualified by a 3-way interaction between task type x distractor x anxiety group ( $p < .001$ ).

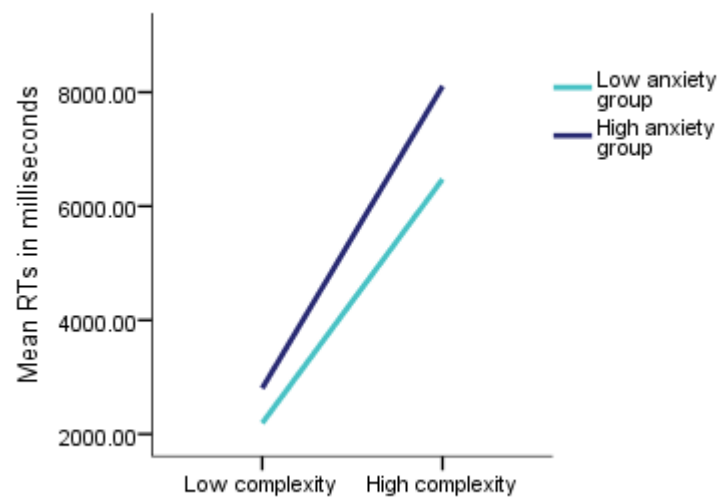
#### *Anxiety x distractor (hypothesis 2)*

The main *ANOVA* did not reveal a significant interaction between anxiety group and distractor condition so hypothesis 2 was unable to be confirmed [ $F(1, 68) = 1.180$ ,  $p = ns$ , partial  $\eta^2 = .017$ ].

#### *Anxiety x complexity (hypothesis 3)*

The main *ANOVA* revealed a significant interaction between anxiety group and task complexity [ $F(1, 68) = 4.89$ ,  $p = .030$ , partial  $\eta^2 = .067$ ] in accordance with hypothesis 3 (see figure 3). To investigate differences between groups further, an independent *t*-Test (2-tailed) was performed, the results revealed that when the task was

high complexity, the high-anxious group showed longer RTs ( $M = 8108.85\text{ms}$ ,  $SD = 3512.65$ ) when compared with the low-anxious group ( $M = 6473.07\text{ms}$ ,  $SD = 1787.67$ ), [ $t(68) = 2.46$ ,  $p = .018$ ]. When the task was low complexity, RTs were faster, but the same pattern of results was present, with high-anxious group having significantly longer RTs ( $M = 2803.46\text{ms}$ ,  $SD = 1044.75$ ) than the low-anxious ( $M = 2191.68\text{ms}$ ,  $SD = 516.90$ ), [ $t(68) = 3.11$ ,  $p = .003$ ].



**Figure 3:** Mean reaction times (ms) for the low complexity task (additions and subtractions) and high complexity (multiplications and divisions) task in function of the group.

This 2-way interaction qualified in a 3-way interaction, complexity x task type x anxiety group (see p84).

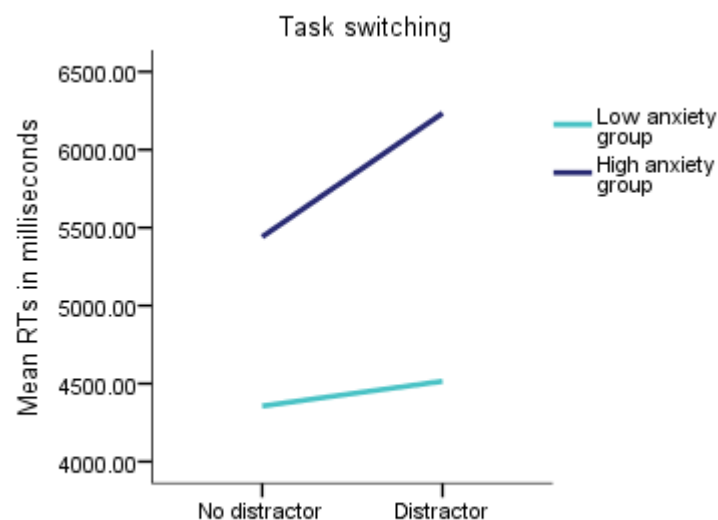
#### *Effects of Anxiety on Task Type and Distractor RTs, Concurrently (hypothesis 4)*

The 2-way interaction task type x anxiety group [ $F(1, 68) = 11.52$ ,  $p = .001$ , partial  $\eta^2 = .145$ ] was qualified by a significant three-way interaction of task type vs. distractor vs. anxiety group [ $F(1, 68) = 6.34$ ,  $p = .014$ , partial  $\eta^2 = .085$ ] (see p.79 main

*ANOVA*). To investigate this interaction further, two additional two-way *ANOVAs* (distractor present vs. absent X high vs. low anxiety group) were conducted for the repetitive task and the switching task respectively.

During the repetitive task no significant interaction was found between the distractor and anxiety group [ $F(1, 68) = 1.980, p = .ns$ ].

During task switching, there was a significant interaction between distractor and anxiety group [ $F(1, 68) = 4.65, p = .035, \text{partial } \eta^2 = .064$ ] (see figure 4). Two dependent *t*-Tests (2-tailed) were performed to investigate differences between groups further. The results revealed that the high-anxious group increased significantly the RTs when the distractor was present ( $M = 6233.70\text{ms}, SD = 2337.85$ ) compared with it was absent ( $M = 5441.25\text{ms}, SD = 2076.58$ ). During task switching this significant increase on RTs when the distractor was present during task switching was not found for the low-anxious group [ $t(34) = .87, p < .ns$ ].



**Figure 4:** Mean reaction times (ms) for the switching task in presence and in absence of the distractor, in function of the group.

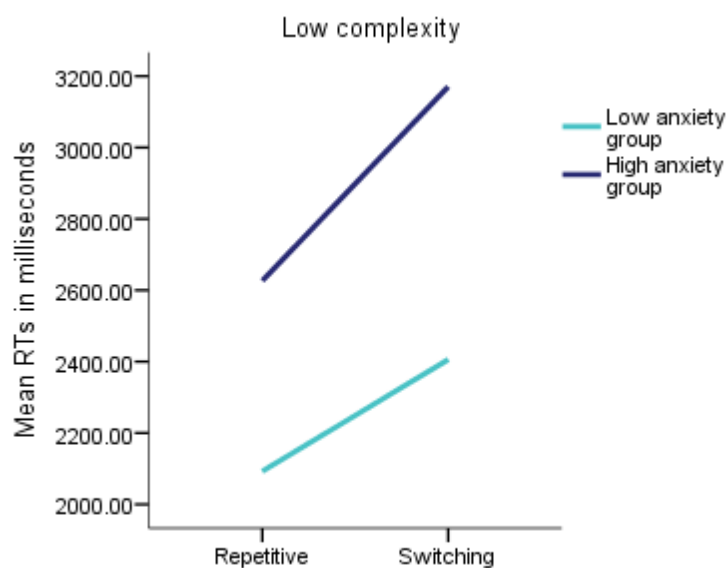
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*Effects of Anxiety on Complexity and Task Type RTs (hypothesis 5)*

The significant interaction between complexity and anxiety group [ $F(1, 68) = 4.89, p = .030, \text{partial } \eta^2 = .067$ ] was qualified by a three-way interaction between complexity, task type and anxiety [ $F(1, 68) = 5.258, p = .025, \text{partial } \eta^2 = .072$ ] (see p.79 main ANOVA) as was predicted in hypothesis 5. To deconstruct this three-way interaction, 2 additional two-way ANOVAs were performed with anxiety group X task type, for the high complexity problems and for the low complexity problems separately.

In the low complexity task, an interaction was also found between anxiety and task type [ $F(1, 68) = 3.99, p = .050, \text{partial } \eta^2 = .055$ ]. To investigate the differences between groups further an independent *t*-Test (2-tailed) was performed the results revealed that when switching was required the high-anxious had consistently longer RTs ( $M = 3170.36\text{ms}, SD = 1200.35$ ) than the low-anxious ( $M = 2405.82\text{ms}, SD = 602.08$ ), [ $t(68) = 3.37, p = .001$ ].

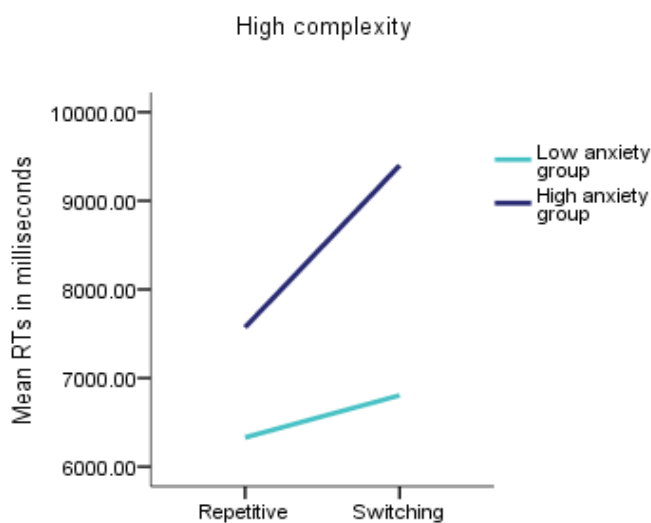
When the task was repetitive differences between groups were also found, with the high-anxious group showing consistently longer RTs ( $M = 2626.60\text{ms}, SD = 1002.96$ ) than the low-anxious group ( $M = 2092.55\text{ms}, SD = 534.14$ ), [ $t(68) = 3.78, p < .007$ ].



**Figure 5:** Mean reaction times RTs (ms) when the task was low complexity for the repetitive and switching tasks in function of the group.

In the high complexity task it was also found an interaction between anxiety and task type [ $F(1, 68) = 8.029$   $p = .006$ , partial  $\eta^2 = .106$ ]. To investigate the differences between groups further an independent  $t$ -Test (2-tailed) was performed. During task switching the high-anxious group took significantly longer time to respond ( $M = 9400.78\text{ms}$ ,  $SD = 4213.64$ ) when compared with the low-anxious ( $M = 6804.86\text{ms}$ ,  $SD = 1910.49$ ), [ $t(68) = 3.32$ ,  $p = .001$ ].

During the repetitive task there was no significant differences between the two groups [ $t(68) = 1.86$ ,  $p = .067$ ].



**Figure 6:** Mean reaction times RTs (ms) when the task was high complexity for the repetitive and switching tasks in function of the group.

No other interactions were found involving anxiety groups.

Regarding hypothesis 7, there was no significant interaction between task complexity, the distractor and the anxiety group, [ $F(1, 68) = .25, p = ns, \text{partial } \eta^2 = .004$ ] contrary to the hypothesis.

Regarding hypothesis 8 there was no significant four-way interaction between complexity, switching, distractor and anxiety [ $F(1, 68) = .66, p = ns, \text{partial } \eta^2 = .010$ ] contrary to the hypothesis.

***Attentional control as a covariate***

Subsequently it was carried out mixed measures *ANCOVA* on RTs with the following variables; task-type (repetitive vs. switching) and distractor (present vs. absent) and complexity (high vs. low) as within-subject design, anxiety group as between subject factor design and attentional control self-report measure ACS measured as a covariate.

Overall the *ANCOVA* revealed a slight decrease in the effect size in all the relevant interactions previously revealed by the main *ANOVA*. In the interaction between complexity and anxiety [ $F(1, 1.66) = .152$ ,  $p = .152$ , partial  $\eta^2 = .030$ ] there was a decrease by more than half in the effect size compared to the one reported in the main *ANOVA* (p 81) in addition this interaction was no longer significant, suggesting that the covariate variable attention control affected this interaction the most.

***Switch Cost (hypothesis 1, 4, 5, 7)***

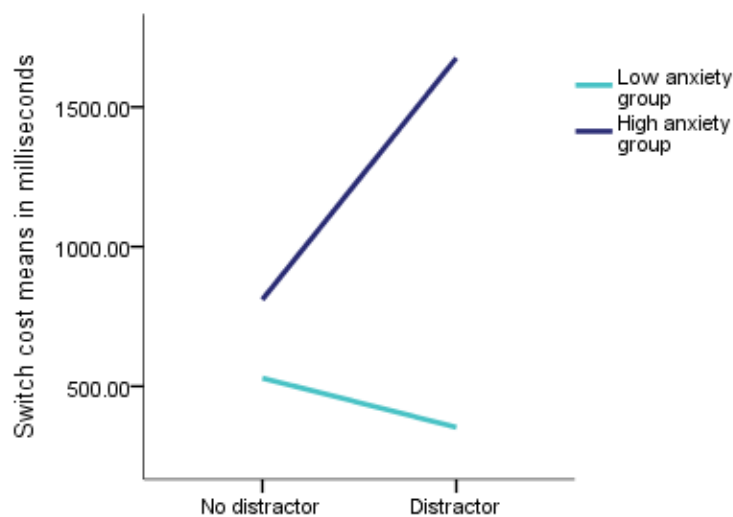
A 2x2x2 *ANOVA* was performed on the switch cost data, with complexity and distracter as within subjects design and anxiety group as between subjects design.

There was a significant main effect of task complexity [ $F(1, 68) = 9.72$ ,  $p = .003$ , partial  $\eta^2 = .125$ ]. Both groups increased the switch cost from the low complexity task ( $M = 374.55\text{ms}$ ,  $SD = 666.63$ ) to the high complexity task ( $M = 965.07\text{ms}$ ,  $SD = 2309.83$ ). There was also a significant main effect of anxiety group such that the high-anxious group had longer switch cost ( $M = 1021.33\text{ms}$ ,  $SD = 990.44$ ) than the low-anxious ( $M = 363.80\text{ms}$ ,  $SD = 747.27$ ), [ $F(1, 68) = 11.52$ ,  $p = .001$ , partial  $\eta^2 = .145$ ]

confirming hypothesis 1. A significant main effect of the distractor was not found [ $F(1, 68) = 2.78, p = ns$ ].

*Effects of anxiety on switch cost regarding the distractor (hypothesis 4)*

There was a significant interaction between the distractor and the anxiety group, [ $F(1, 68) = 6.34, p = .014, \text{partial } \eta^2 = .085$ ]. The high-anxious group increased significantly the switch cost when the distractor was present ( $M = 1675.88\text{ms}, SD = 1539.42$ ) compared to when it was absent ( $M = 810.34\text{ms}, SD = 1303.72$ ) [ $t(34) = 2.95, p = .006$ ] as predicted in hypothesis 4. The low-anxious group did not show any significant changes in switch cost when the distractor was present [ $t(34) = .605, p = ns$ ]

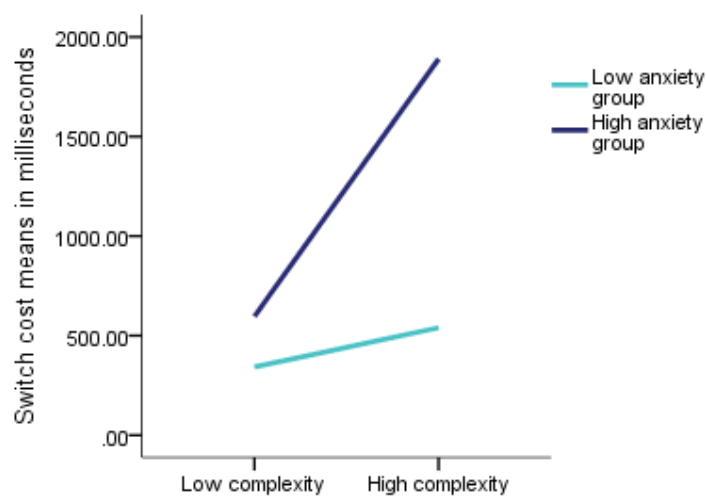


**Figure 7:** Switch cost RTs, when the distractor was present and when it was absent, for the high-anxious and for the low-anxious groups.



*Effects of anxiety on switch cost regarding task complexity (hypothesis 5).*

There was significant interaction between complexity and anxiety group [ $F(1, 68) = 5.26, p = .025, \text{partial } \eta^2 = .072$ ] (see figure 7). To further investigate the differences between groups a paired  $t$ -Test (2-tailed) was preformed. The high-anxious group significantly increased the switch cost from the low complexity condition ( $M = 593.20\text{ms}; SD = 562.68$ ) to the high complexity condition ( $M = 1994.44\text{ms}; SD = 2732.42$ ) [ $t(34) = 2.89, p = .007$ ]. However, low-anxious group switch cost did not increase significantly from the low complexity blocks to the high complexity blocks [ $t(34) = .74, p = .ns$ ] confirming hypothesis 5.



**Figure 8:** Switch cost RTs (ms) for the low-anxious group and for the high-anxious group as function of task complexity.

A 3-way significant interaction between anxiety group, complexity and distractor [ $F(1, 68) = .660, p = ns$ ] was not found and so hypothesis 7 was not able to be confirmed.

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**Error rates (hypothesis 8)**

A 2x2x2x2 mixed ANOVA was performed on the error with three within subjects conditions complexity (high vs. low), task type (repetitive vs. switching), and distractor (presence vs. absence) and with anxiety group as a between group condition (see table 1 for error rate mean % in all the conditions for both groups).

A significant main effect of complexity was found in terms of error rate [ $F(1, 68) = 87.93, p < .001, \text{partial } \eta^2 = .564$ ] with participants being less accurate when the complexity of the task was high ( $M = .13, SD = .10$ ) than when the complexity was low ( $M = .04, SD = .05$ ). There was a significant main effect of task type [ $F(1, 68) = 37.14, p < .001, \text{partial } \eta^2 = .353$ ] with participants having higher error rate when switching was required ( $M = .15, SD = .09$ ) than when the task was repetitive ( $M = .08, SD = .06$ ).

A main effect of group was not found [ $F(1, 68) = .51, p = \text{ns}$ ] and there were no significant interactions with anxiety group as predicted in hypothesis 8.

There was a significant interaction between complexity and task type [ $F(1, 68) = 5.70, p = .020, \text{partial } \eta^2 = .077$ ]. To investigate this interaction further, a paired *t*-Test (2-tailed) was performed. During the high complexity blocks, the participants error rate increased significantly more when task switching was required ( $M = .22, SD = .15$ ) than when the task was repetitive ( $M = .13, SD = .22$ ) [ $t(68) = 5.17, p < .001$ ]. The same pattern of results were present during low complexity blocks, with error rate increasing significantly more when switching was required ( $M = .08, SD = .10$ ) than when the task was repetitive ( $M = .04, SD = .05$ ), [ $t(68) = 3.12, p = .003$ ].

There was a significant interaction between task type and distractor [ $F(1, 68) = 5.85, p = .018, \text{partial } \eta^2 = .079$ ]. To investigate this interaction further a paired *t*-Test (2-tailed) was performed. During the repetitive task, the error rate increased

significantly more when the distractor was present ( $M = .10$ ,  $SD = .08$ ) than when the distractor was absent ( $M = .08$ ,  $SD = .06$ ), [ $t(69) = 3.10$ ,  $p = .003$ ]. However, during the switching task there were no significant differences in terms of error rate between presence and absence of distractor [ $t(69) = .997$ ,  $p = ns$ ].

In general there was positive relation between RTs and the error rate ( $r = .464$ ,  $p < .001$ ). This relation between RTs and error rate was also analysed for both groups separately. In the high-anxious group it was found a positive relationship between the RTs and error rate ( $r = .541$ ,  $p = .001$ ) with error rate increasing as the RTs increase. A positive relation between RTs and error rate was also found for the low-anxious group ( $r = .350$ ,  $p = .039$ ), although less strong than the relationship found for the high-anxious group.

Table 1. Error rate percentages in function of task type, complexity, distractor

| Task Type  | Task       |            | Low Anxiety          | High Anxiety         | Error rate total (%) |
|------------|------------|------------|----------------------|----------------------|----------------------|
|            | Complexity | Distractor | Group error rate (%) | Group error rate (%) |                      |
| Repetitive | low        | absent     | 4.40                 | 3.81                 | 4.11                 |
|            | low        | present    | 4.29                 | 7.74                 | 6.02                 |
|            | high       | absent     | 11.67                | 14.05                | 12.86                |
|            | high       | present    | 14.76                | 16.90                | 15.83                |
| Switching  | low        | absent     | 8.57                 | 7.62                 | 8.10                 |
|            | low        | present    | 8.81                 | 7.14                 | 7.98                 |
|            | high       | absent     | 20.48                | 22.86                | 21.67                |
|            | high       | present    | 18.57                | 20.24                | 19.41                |

*Note.* Error rate in % for the low anxiety group, high anxiety, and for all the participants, in function of the task type, complexity and distractor.

Table 2. Hypothesis tested

| <i>Hypothesis</i>  | <i>Measure</i>           | <i>HA means (ms)</i> | <i>LA means (ms)</i> | <i>Test statistic (ANOVA)</i>  | <i>Success</i> | <i>Notes</i>                               |
|--|--------------------------|----------------------|----------------------|--|----------------|--|
| <b>1- Anxiety group x task type</b> – The HA group should have a larger increase in RTs on switching versus repetitive blocks. The HA group should have higher switch cost.  | RTs (repetitive task)    | $M = 4849.27$        | $M = 3887.35$        | $F(1, 68) = 11.52, p = .001$   | confirmed      |  |
|  | RTs (switching task)     | $M = 5441.25$        | $M = 4356.38$        |  |                |  |
|  | Switch cost              | $M = 1021.33$        | $M = 363.80$         |  |                |  |
| <b>2- Anxiety group x distractor</b> –The HA group should display a larger increase in RTs on blocks with distractor.  | RTs                      | na                   | na                   | $F(1, 68) = 1.180, p = ns$   | not confirmed* |  |
| <b>3- Anxiety group x complexity</b> – The HA group should display a larger increase in RTs in high complexity task.   | RTs (high complexity)    | $M = 8108.85$        | $M = 6473.07$        | $F(1, 68) = 4.89, p = .030$  | Confirmed      |  |
|  | RTs (low complexity)     | $M = 2724.04$        | $M = 2083.07$        |  |                |  |
| <b>4- Anxiety group x task type x distractor</b> – The HA group was expected to increase more in RTs than the LA during task switching when a distractor was present. The HA group was expected to increase more in switch cost than the LA when a distractor was present. | RTs                      | na                   | na                   | 3-way Anova<br>$F(1, 68) = 6.34, p = .014$                           | confirmed      | RTs and switch cost confirm the hypothesis |
|  |                          |                      |                      | 2-way Anova Repetitive (group x dist.)<br>$F(1, 68) = 1.98, p = ns$  |                |  |
|  |                          |                      |                      | 2-way Anova Switching (group x dist.)<br>$F(1, 68) = 4.65, p = .001$ |                |  |
|  | switch cost (distractor) | $M = 1675.88$        | $M = 352.99$         | $F(1, 68) = 6.34, p = .014$  |                |  |
| switch cost (no distractor)  | $M = 810.34$             | $M = 529.27$         |                      |  |                |  |

|  |                                  |             |             |  |                |   |
|--|----------------------------------|-------------|-------------|--|----------------|---|
|  |                                  |             |             | 3-Way ANOVA<br>$F(1, 68) = 5.26, p = .025$                           |                |   |
| <b>5- Anxiety group x task type x complexity</b> – A greater effect of anxiety was expected when complexity was high and task switching was required increasing HA RTs more than the LA. The high-anxious was expected to increase more in switch cost when the complexity was high. | RTs                              | na          | na          | 2-Way ANOVA HC<br>(group x task-type)<br>$F(1, 68) = 8.03, p = .006$ | confirmed      |   |
|  |                                  |             |             | 2-Way ANOVA LC<br>(group x task-type)<br>$F(1, 68) = 3.99, p = .050$ |                |   |
|  | Switch cost<br>(low complexity)  | M = 593.20  | M = 341.74  |  |                | The switch cost confirms the hypothesis       |
|  |                                  |             |             | $F(1, 68) = 5.26, p = .025$  | confirmed      |   |
|  | Switch cost<br>(high complexity) | M = 1994.44 | M = 518.35  |  |                |   |
| <b>6- Anxiety group x complexity x distractor</b> – A greater effect of anxiety was expected when complexity was high and the distractor was present, increasing HA RTs more than the LA.  | RTs                              | na          | na          | $F(1, 68) = .256, p = ns$  | not confirmed* |   |
| <b>7- Anxiety group x complexity x task switching x distractor</b> – A greater effect of anxiety was expected when complexity was high, task switching was required and the distractor was present, increasing HA RTs more than the LA.  | RTs                              | na          | na          | $F(1, 68) = 5.26, p = ns$  | not confirmed* |   |
| <b>8- Anxiety group x error rate</b> – Anxiety was expected to affect RTs more than error. No interactions between anxiety group and error rate were expected.   | error rate                       | na          | na          | $F(1, 68) = .51, p = ns$   | confirmed      | *significant main effect of the anxiety group |
|  | RTs                              | M = 5227.28 | M = 4207.18 | $F(1, 68) = 9.13, p = .004^*$  |                |   |

**Note.** HA (high anxiety); LA (low anxiety); HC (high complexity); LC (low complexity); group (anxiety group); task type (task switching vs. repetitive); dist. (distractor); na. (not applicable).

### Discussion

The general aim of the current study was to investigate the effects of trait anxiety on the executive functions inhibition and shifting as well as on task complexity by testing ACT's assumption that anxiety impairs mostly attentional efficiency of the inhibition and shifting functions (see Eysenck et al., 2007; Derakshan & Eysenck, 2009).

The shifting function has been associated with task switching (Miyake et al., 2000), while the inhibition function has been associated with resistance to a distractor (Friedman & Miyake, 2004). To study these variables and the interactions between them, an arithmetical task was developed which involved two different levels of task complexity, task switching and a distractor.

The findings of the present study can be summarised as follows: First, during task switching the high-anxious group took significantly longer to switch between arithmetical problems than the low-anxious group. Although differences between groups were also found during the repetitive task, differences on the switching task were significantly larger therefore hypothesis 1 was confirmed, suggesting that anxiety impaired efficiency of the shifting function.

Second, the predicted hypothesis of a significant interaction between the distractor and the anxiety group (hypothesis 2) was not confirmed.

Third, regarding the effects of task complexity, response time increased for both anxiety groups as task complexity increased. The high-anxious group had consistently longer response times than the low-anxious. However, the response times increased significantly more for the high-anxious group when the complexity of the task

increased, thus hypothesis 3 was confirmed suggesting that adverse effects of anxiety increase as the task complexity increase.

Fourth, there was an interaction between distractor, task type and anxiety group, such that when task switching was required and the distractor was present (requiring the shifting and inhibition functions simultaneously) the high-anxious group response time increased significantly compared with the low-anxious group. There was a significantly larger increase for the high-anxious group on the switching trials with distractor compared to when the distractor was absent. In addition, there was a significant interaction between anxiety and the distractor on switch cost, with the high-anxious group having larger increase in switch cost than the low-anxious when the distractor was present, compared to when it was absent. All the results above were in accordance with hypothesis 4, suggesting that when the inhibition and shifting functions are required jointly the adverse effects of anxiety increase impairing attentional efficiency of both functions.

Fifth, the clearest effect of task complexity on performance was revealed by a significant larger increase in switch cost from the low complexity to the high complexity task for the high-anxious group (hypothesis 5). Also, when the task was high complexity and switching was required response times increased significantly more for the high-anxious group than for the low-anxious group, this was only marginally significant when the task was low complexity. The effects of anxiety are more significant when complexity is high in accordance with hypothesis 5.

Sixth, the predicted (hypothesis 6) interaction between anxiety group, task complexity and distractor was not confirmed.

Seventh, hypothesis 7 predicted four-way interaction between anxiety group, complexity, distractor and task type was not found to be significant, so the hypothesis was not confirmed.

Eight, overall anxiety impaired processing efficiency slowing response time of the high-anxious, but did not impair response effectiveness as differences between groups were not found in terms of task result (error rate).

The main objective of the study was to test ACT assumptions, from the above set of findings, three important theoretical findings came out, that support ACT. Anxiety impairs the shifting function; anxiety impairs both the shifting and inhibition functions when they are required simultaneously. The adverse effects of anxiety increase as the task complexity increases.

Starting by the effect of anxiety on the shifting function, the present findings revealed that anxiety impaired attentional control efficiency of the shifting function as measured by task switching. Task switching has been associated with the shifting function; this executive function involves the capacity to direct attention between and within tasks or mental sets as required (Miyake et al., 2000). Task switching involves a cost, the cost to switch attention from one task to another that makes responses slower (Monsell, 2003).

The findings obtained during task switching clearly suggested that anxiety affects the capacity to drive attention from one task to the other as the high-anxious group was much slower than the low-anxious group. Larger switch costs were also found for the high-anxious group as it was predicted in hypothesis 1. These results are in full agreement with ACT that states that anxiety impairs the shifting function. The results also agree with those found by Derakshan, et al. (2009b) in a study that



investigated the effects of state anxiety on the shifting function. There, the authors used a similar arithmetical task to the one used in the present study. The results revealed that the high-anxious group had significantly longer response time during task switching compared to when the task was repetitive and when the task complexity was high.

Previously, Ansari, Derakshan, and Richards (2008) investigated the effects of anxiety on the shifting function using a mixed antisaccade paradigm, which involved mixed blocks of anti and prosaccade (switching blocks that were signalled by a cue), repetitive blocks of each task were also performed. The results revealed that the low-anxious group had faster correct antisaccade latencies in task switching than in repetitive task, while high-anxious group did not show this switch benefit, suggesting the shifting function of the high-anxious was impaired to some extent. A switch benefit has been associated with the antisaccade task when the task is performed with other demanding task, in this case task switching. As both require attention and this affects the reflexive response which facilitates the antisaccade (see Kristjansson, Chen, & Nakayama, 2001).

To the best of my knowledge, the two studies above are the only that have tried to directly test ACT's assumption that anxiety impairs the shifting function. As researchers have to date not devoted much attention to test this ACT assumption the present findings are of great importance particularly in light of the very significant interactions found in this study between anxiety and shifting.

It is noted that differences between groups were also found during the repetitive task although less significant. A possible explanation is that the arithmetical task was very demanding on working memory even when it was repetitive (no switching was

required). The repetitive arithmetic task involved mentally calculating blocks of additions, subtractions, multiplications or divisions. Even if it did not require the shifting function of the central executive it could have involved other processes that were also impaired by anxiety. In accordance with Hitch, (1978) mental calculation involves splitting the problem in more easy steps, which require the use of both temporary storage of information and the long term memory. Arithmetic tasks, whether mentally calculated or not, have long been related with the working memory. Research generally has found that arithmetical tasks require the central executive and also the phonological loop (e.g. Lemaire, Abdi & Fayol, 1996; Logie, Gilhooly, & Wynn, 1994; Fürst & Hitch, 2000; Seitz & Schumann- Hengsteler, 2000, 2002; DeSetfano & LeFevre, 2004; see Raghubar, Barnes, & Hecht, 2010 for a review). Further research is needed to investigate the effects of anxiety on arithmetic tasks in order to identify which working memory processes are most affected.

The attentional control assumption that the inhibition function is impaired by anxiety was tested using a distractor. Distractor inhibition has been associated with inhibition function (Friedman & Miyake, 2004). In accordance with ACT it was hypothesised that when the distractor was present a larger increase in response time for the high-anxious would occur. However this hypothesis (2) was not confirmed. It was expected there would be effects of anxiety when the inhibition function was required on its own but such interaction between anxiety group and presence of distractor was not found to be significant. This non-significant finding is unexpected especially since efforts were made to produce strong distraction effects.

An important finding of the present study regards the effects of anxiety when the inhibition and the shifting function were needed simultaneously (measured by task switching in presence of distractor), the results revealed that anxiety impaired processing efficiency of both executive functions inhibition and shifting. It was hypothesised (hypothesis 4) that the high anxiety group would increase more in response times when the distractor was present during task switching (when both executive functions were tested simultaneously). Similarly it was also expected an increase in switch cost under distraction. This hypothesis was confirmed with the high-anxious group response times and switch cost being slowed by distraction while the low-anxious group responses were not.

These findings are in accordance with the hypothesis 4 with the results indicating that the effects of anxiety on the shifting and inhibition functions are potentiated when the functions are required jointly. However, they should be treated with some caution. Analysis of this 3-way interaction is rendered somewhat more complex by the results of the two way interactions anxiety versus switching (shifting) and anxiety versus distracter (inhibition). The two way interaction between anxiety and switching was very significant but not the one between anxiety and distracter (which, although in the right direction, is far from significance levels).

Still, two main conclusions can be drawn. First, the findings suggest that the inhibition and shifting functions share some common processes because anxiety affected both functions in the same way by increasing response times. If these two executive functions were totally independent then it would be expected different anxiety effects on each one. These findings are in accordance with Miyake et al. (2000), which found that the shifting and inhibition functions were independent but they also shared

some central executive processing resources. In addition, Friedman and Miyake (2004) found that response distractor inhibition and switch cost were found to be related, such that task switching involved the capacity to select the relevant task set and use it to filter out or inhibit distraction. In addition, Hedden and Gabrieli (2010), found many neural regions with activation common to both inhibition and shifting functions, while there was also regions preferential to each function, which is in accordance with Miyake and co-workers.

Second, the findings suggest that when both the shifting and the inhibition functions were required simultaneously, processing efficiency of the high-anxious was impaired the most. These findings are in accordance with ACT's assumption that anxiety impairs shifting and inhibition functions as they are directly related with attentional control. The demands on the central executive were higher during task switching in presence of distractor, in accordance with ACT's predictions that the effects of anxiety on performance increase as the task demands on the central executive increase (Eysenck, et al., 2007).

It still remains to be explained why the effects of anxiety on the capacity to inhibit the distractor were only found to be highly significant when task switching was required. In the repetitive condition both groups could inhibit the distractor. It is possible that the repetitive condition involved a sufficiently modest use of executive functions that high-anxious individuals sufficient processing resources to resist distraction under those circumstances.

A great number of studies that have used a distractor paradigm to study the inhibition function and generally found that anxiety affected the capacity to inhibit task

irrelevant stimuli or distractors (e.g. Bishop, 2009; Hopko et al., 1998; Calvo, Gutiérrez & Fernandez-Martin, 2012; Pacheco-Unguetti, et al., 2010). However, most of the studies have used visual distractors, except for Calvo and Eysenck (1996), which used an auditory distractor (irrelevant speech) in a text comprehension task, and found that the distractor had a higher effect on the high-anxious individuals when the task demands were high.

For the present study an auditory distractor was selected. As the task was arithmetical it was decided to use numbers as distractors, as it has been found that distractors with features in common with the target response cause more interference (Elliott & Cowan, 2001). However, to display several distractor numbers on the computer screen could cause confusion with the task numbers so an auditory distractor was preferred over a visual one. It could be argued that visual and auditory distractors differ in the interference caused and that could explain some of the results obtained in this study. In future research it would be worth to compare the effects of anxiety with visual as well as auditory distractors.

Another important finding is that in general the effects of anxiety increased as the task complexity increased. It was hypothesised that when task complexity increased the high-anxious group would display a larger increase in response times (hypothesis 3). This hypothesis was confirmed suggesting that the adverse effects of anxiety increase as the demands on the central executive increase.

In this study, task complexity was manipulated to produce two different levels of demands in the central executive (low and high demand). However the levels of complexity were not meant to affect anxiety levels but only the central executive demands. This approach was also used by Derakshan, et al. (2009b). The authors found

an interaction between state anxiety, task type and complexity with differences between the high and the low state anxiety groups found only during the high complexity blocks of task switching, with the high-anxious group being slower. Similarly, in this study it was found an interaction between anxiety-group x task type x complexity as predicted in hypothesis 5).

The findings revealed that during task switching (but not on the repetitive task) task complexity had a greater effect on high-anxious processing efficiency, increasing switch cost from the low complexity blocks to the high complexity blocks in accordance with hypothesis 5. These findings are in accordance with ACT's prediction that anxiety impairs the shifting function when the demands on the central executive increase (Eysenck, et al., 2007) and is in agreement with Derakshan, Smyth and Eysenck (2009b).

In the present study, it was also predicted an interaction between complexity, distractor and anxiety group, but it was not confirmed (hypothesis 6). However, it is important to note that the interaction between anxiety group and task complexity was significant and in accordance with ACT. The only unpredicted finding is that overall distraction did not impact more strongly on the high-anxious group than on the low-anxious group. As discussed before this may be due to the type of the distractor, auditory instead of visual, and would be worth investigating in future research.

This study also hypothesised a four-way interaction between anxiety-group, complexity, task type, and distractor. A greater effect of anxiety was expected when the task complexity was high and task switching was required. However this interaction was not found to be significant and thus hypothesis 7 was not confirmed. It is important to note that significant interactions were found between anxiety and complexity,

between anxiety and task type with anxiety versus distractor being the only interaction that was not found to be significant.

Generally, studies that investigated the effects of anxiety on performance used neutral stimuli (as in the present study) and manipulated task difficulty by having different levels of task difficulty or working memory load. The results have generally found that when the task does not involve threatening stimuli the negative effects of anxiety were present only in the most difficult tasks (e.g. Eysenck, 1985; Calvo, 1985; Calvo, Ramos, & Estevez, 1992; Ascraft & Kirk, 2001; Derakshan, et al., , 2009b). More recently, Fales et al. (2008), showed that the high-anxious had increased transient activation on the most difficult trials (lure-trials) in an 3-n back task, compared to the low-anxious which indicates that they were less efficient in controlling attention when the task was more demanding. However, in the present study the effects of task complexity were present in both high complexity and low complexity condition, with complexity having a significantly larger effect on the high-anxious performance only during task switching increasing the switch cost of the high-anxious but not of the low-anxious.

Another important result of the present study regards the fact that overall anxiety affected response times to a greater extent than error rate. The adverse effects of anxiety consistently affected response times slowing the high-anxious group response times when compared with the low-anxious. However, anxiety did not affect error rate as significant differences between groups were not found. These results suggest that performance effectiveness (quality of the performance) was not affected but only processing efficiency (relation between the effort and results of the performance, e.g. measured by RTs) confirming hypothesis 8. These findings fit into a voluminous

literature showing that the adverse effects of anxiety affect processing efficiency more than performance effectiveness (e.g. Derakshan et al., 2009; Ansari, Derakshan & Richards, 2008; Ansari & Derakshan 2010, 2011a, 2011b; Fales et al., 2008; Eysenck & Derakshan, 2009). The findings support the processing efficiency theory (Eysenck & Calvo, 1992). The assumption that the adverse effects of anxiety should be greater on processing efficiency than performance effectiveness on tasks that require the central executive functions, is a central prediction that was included in ACT, which is a development and a update of the former theory (see Eysenck et al., 2007).

In accordance with ACT, anxiety reduces processing efficiency more than performance effectiveness because high-anxious individuals will put an extra effort and use extra processing resources to compensate from the adverse effects of anxiety on attentional control, which is the main function of the central executive. However, as the use of more processing resources increases to achieve a good task result (performance effectiveness) the processing efficiency decreases but not performance effectiveness. The increase in use of processing resources is used to keep the task results at levels with the low anxiety-group. This compensatory measure is used when the task demands are high on the central executive.

The findings of this study are in accordance with this assumption as anxiety impaired response time but not error rate. However, response time is only an indirect measure of processing efficiency as processing efficiency involves the relation between effort and resources used and task result. Recently, fMRI studies have provided support for this ACT assumption. For example Fales et al. (2008), found that high-anxious individuals increased Dorsolateral and ventrolateral prefrontal cortex activity (DLPFC; VLPFC) on a 3-back task when the task was demanding. These neural areas have been



related with executive functions and with attentional control, which suggest that anxiety affected processing efficiency of attentional control; however performance effectiveness was not affected. These findings are in accordance with ACT and with this study's findings.

Also according to ACT, anxiety affects attentional control by disrupting the balance between the two attentional systems the stimulus-driven (bottom-up attentional control) and goal-driven (top-down attentional control) as distinguished by Corbetta and Shulman (2002). There is a constant interaction between these two systems (Yantis, 1998; Pashler, Johnston & Ruthruff, 2001), however, the adverse effects of anxiety disturb the balance of that interaction and attention becomes more stimuli-driven than goal-driven (Eysenck et al. 2007).

The self-report measure of attentional control (ACS) (Derryberry & Reed, 2002), was used as an additional measure of attentional control, the findings revealed that high-anxious individuals have less attentional control than the low-anxious which is also in accordance with ACT's prediction and as reported by Derryberry and Read (2002) and more recently by Reindoldt-Dunne, Mogg & Bradley (2009) and Ólafsson et al. (2011). The ACS was used as a covariate variable; the most relevant result found when controlling the variable attentional control was that the interaction between anxiety and task complexity showed a decrease by half in effect size. Also, it was no longer significant suggesting that this interaction can be explained at least partially in terms of attention control. This finding was not unexpected because in accordance with the ACT high-anxious individuals have poorer attentional control than low-anxious as it has been confirmed in the present study, therefore it is expected that the effects of

anxiety on attention control to be greater when the task is more complex or demanding. Thus the present results also confirm the ACT.

In conclusion, the findings of this study support the following attentional control predictions: Anxiety impairs the shifting function, as showed by a greater increase in response times during task switching. Anxiety affects the inhibition and the shifting function, showed by a greater increase on response time and switch cost when both functions were required jointly and this is the first study that clearly focused in study the two functions together. The effects of anxiety increase as the task complexity increases, as shown by a greater increase in response times when the task involved high complexity problems. Anxiety affects processing efficiency to a greater extent than performance effectiveness, as anxiety slowed response times, but did not affect the task result.

The only unpredicted finding in this study regards the effects of anxiety on the inhibition function when it is required on its own, as measured by the capacity to inhibit an auditory distractor.

Nearly all the key predictions of the ACT that were being tested in this study were supported. Of particular relevance were the effects of anxiety on the central executive functions; shifting (separately) and shifting/inhibition (jointly). High-anxious individuals have shown a clear deterioration in processing efficiency when those functions were required while having a much less marked loss of effectiveness.

## **Chapter Three**

**The effects of anxiety on the executive shifting and inhibition functions: tested together and separately using alternating and unpredictable task switching paradigms**

One of the main assumptions of ACT is that anxiety impairs processing efficiency (relationship between effort and the resources used, generally measured by reaction times) of the shifting and inhibition functions to a greater extent than performance effectiveness (quality or result of the performance, generally measured by accuracy). Several studies have found support for this assumption (for a review see Eysenck et al., 2007), however; there is considerable more research on the inhibition function than on the shifting function.

In chapter 2 the central executive functions shifting and inhibition were studied simultaneously and separately, using respectively a task switching and a distractor paradigm. The results clearly supported the attentional control predictions that anxiety negatively affects the shifting function. However, regarding the inhibition function the results were not so clear, as it was only found that anxiety impaired the inhibition function when the shifting function was also required. This study intends to clarify the results obtained in chapter 2 particularly regarding the inhibition function as well as provide alternative tests for the ACT, for that purpose the inhibition and shifting functions will be studied together and separately using a different task.

To study the inhibition function a considerable number of studies have used a distractor paradigm (e.g. Hopko et al., 1998; Bishop, 2009; Calvo, Gutiérrez & Fernandez-Martin, 2012) or an antisaccade task (e.g. Derakshan et al., 2011) as this task involves inhibiting a response that is fairly automatic, and thus is a good measure of the inhibition function (Miyake, et al., 2000).

For example, Derakshan et al. (2011) used an antisaccade task, and measured event-related potential (ERP) activity. The results revealed slower antisaccade latencies for the high-anxious than for the low-anxious when they had to inhibit an oval shape by

directing their gaze away. In addition, prior to inhibiting the target, the high-anxious group displayed lower ERP activation on frontocentral and central recording sites than the low-anxious group. These sites are associated with top-down attentional control. The findings suggest that anxiety impaired efficiency of attentional control of the inhibition function; but not processing effectiveness as no differences between groups were found in task accuracy.

There is also support for the shifting function being impaired by anxiety. Only a few studies have investigated the effects of anxiety in tasks that involve the shifting function. One of the paradigms associated with the shifting function is task switching (Miyake, et al., 2000). For example, Derakshan et al. (2009b) used a task switching paradigm to study the effects of state anxiety on the shifting function. The task consisted in mentally calculating additions and subtractions (low complexity task), or multiplications and divisions (high complexity task). Participants were required to perform both repetitive and task switching blocks. The results revealed that the high-anxious group had significantly longer response time during task switching compared to when the task was repetitive, but only when the task complexity was high. This result supports ACT's predictions, by suggesting that anxiety only impairs efficiency of the shifting function when the task demands on the central executive are high. In addition anxiety only affected efficiency of the shifting function but not performance effectiveness as no significant differences between groups were found in terms of accuracy (see also, Ansari, Derakshan, & Richards, 2008)

Most of the research has investigated the inhibition and shifting functions separately; however, there are two main reasons why the inhibition and shifting functions should also be investigated when they are required simultaneously.

First, although the inhibition and shifting functions are independent in their functions they are also correlated with each other (Miyake et al., 2000). For example, it was found that task switching is related to response to distractor inhibition (Friedman & Miyake, 2004). In accordance, the inhibition and shifting functions were found to activate neural areas that are common to both functions as well as areas more specific to each function (Hedden & Gabrieli, 2010).

Second, in chapter 2 it was found that the adverse effects of anxiety increased when both executive functions were required. Thus, these findings suggest that they are independent but also share some common processes and those should be studied together and separately. It is important to investigate whether anxiety has similar effects on the shifting and inhibition functions or if the effects are independent.

The study presented in chapter 2 investigated the inhibition and shifting functions together and separately and the results revealed that trait anxiety impaired the shifting function as it slowed high-anxious individuals' responses as they took longer time to switch between tasks than the low-anxious. In addition, when the task required shifting and inhibition simultaneously (task switching in presence of distractor) the high-anxious group was greatly affected by anxiety taking longer time to switch between problems. This suggests that it was when both executive functions were needed simultaneously that efficiency of attentional control was the most impaired. However, it was not confirmed whether anxiety affected the inhibition function when on its own.

Also in chapter 2's study there were no significant differences between the anxiety groups in terms of error rate. Overall, the results suggest that anxiety affected processing efficiency to a greater extent than performance effectiveness.

The present study was carried out as an attempt to clearly understand the effects of anxiety on the two executive functions, inhibition and shifting, when they are needed jointly and separately and to provide alternative tests of ACT.

An arithmetical task was used in the present study, different from the one used in the first study (chapter 2). When searching for a new task to investigate the effects of anxiety on shifting and inhibition functions, two points were taken into consideration. First, the task had to be complex enough as task complexity has been linked with negative effects of anxiety on performance. Second, the stimuli should be neutral as this thesis does not focus on the effects of anxiety on emotional stimuli. Third, in order to investigate the shifting function, the task should include switching between trials, as task switching as been found to be a good measure of the shifting function (see Miyake et al., 2000). Task switching involves a cost, the cost from changing from one task to the other rapidly, this switch cost is generally assessed by comparing blocks of trials in which participants had to switch between tasks with blocks of repetitive trials in which participants repeat the same task in all trials (see Rubinstein et al., 2001, Allport et al., 1994).

Having taken the above into account, the task chosen was an arithmetical task inspired by the tasks used by Gopher, Armony and Greenspan (2000) to study determinants and cost of control during task switching. The authors presented a row with several digits of the same value to the participants. On task A participants had to decide if the digit value was larger or smaller than 5, on task B they had to decide if the number of digits elements was higher or smaller than 5.

In the current study some major changes were made to this task as the aim was to investigate the effects of anxiety on the shifting and inhibition functions. Changes

were made both to increase the complexity of the task and to better study the shifting function.

High-complexity tasks have been associated with negative effects of anxiety on processing efficiency or performance effectiveness, as they put more demands on the central executive than less complex or difficult tasks (e.g. Eysenck, 1985; Calvo, 1985; Calvo, Ramos, & Estevez, 1992; Ashcraft & Kirk, 2001, Derakshan, , et al., 2009b). To make the task more complex several changes were made. Instead of presenting one row of digits of the same value it was decided to present three rows of digits, the digits would change between rows but each row would have the same digit value. In task A participants had to multiply the digit value in the first row by the digit value in the second row by the digit value in the third row (digits task). In task B participants had to multiply the number of digit elements present in each row instead of the value of digits (numerosity task).

In order to study the shifting function, the task would involve a switching paradigm, which would include switch blocks were participants would have to switch between trails of numerosity task and trials of digit task, and repetitive blocks of both tasks. Two different task switching paradigms were used, a pure alternation design in which participants had to switch between A and B from trial to trial, and an unpredictable switch which involved a mixed block design, in each block task A and B were unpredictably mixed in a random way. To signal which task to perform, the position of the rows of numbers in the screen acted as a cue (e.g. left task A, right task B). The difference between these two switching tasks is that one uses predictable alternation trials blocks while the other uses unpredictable trials that are randomly presented with the task required in the next trial being unknown and with a cue being



used to inform the participant of the task to perform (Monsell, 2003; Monsell, Sumner & Waters, 2003). The cue was presented jointly with the stimuli and so there was no cue-stimuli interval for preparation. This task was considered to cause more arousal both because the switching trials were unpredictable and because it did not allow time to prepare. All of these would cause the unpredictable task switching to be more demanding than the alternating switching task.

In accordance with ACT the adverse effects of anxiety on processing efficiency of the shifting and inhibition functions increase as the overall demands on the central executive increase, because extra processing resources are used to cope with the effects of anxiety on performance (Eysenck, et al., 2007).

It would seem logic that the demands on the shifting function would be significantly greater when switching is unpredictable than when it is predictable for the reasons already mentioned above. Arguably, this would increase the impairment effect of anxiety on shifting.

The distractor used in the present study to assess the inhibition function was the same auditory distractor used in the first study (see chapter 2) that consisted of a randomised male and female voice saying numbers from 1 to 9 in random order. First, because in the present study an arithmetical task was also used, and it has been found that there is more interference from distractors that have features in common with the items in the response than from stimuli that do not (Elliott & Cowan, 2001; Elliot et al., 1998). Second, because the use of the same auditory distractor with a different arithmetical task switching might bring a more clear understanding about the results found in chapter 2, as no effects of anxiety were found when distractor inhibition was required during a repetitive task but only during task switching.

The focus in this study is on the effects of trait anxiety, as it was on the previous study (chapter 2). This is mainly due to ACT basing its assumptions in studies that mostly had investigated the effects of trait anxiety (see Eysenck et al., 2007), and this study testing the assumptions of the ACT. It can also be argued that trait anxiety relates to habitual ways in which the cognitive system deals with numerous situations; whereas state anxiety relates more to immediate processing of threat-related stimuli. Finally, the present study intends to clarify the results of the previous study (chapter 2) particularly the effect of anxiety on distractor inhibition. As trait anxiety was investigated in the first study it is important to also investigate trait anxiety in the present one.

The attentional control scale (ACS) is a self reported measure of attentional control developed by Derryberry and Reed (2002), and it was used to investigate its relation with trait anxiety, as one of the main assumptions of the ACT is that anxiety impairs attentional control. This attentional control measure was used in the study reported in chapter 2 and it was found that the high-anxious group had less attentional control than the low-anxious, as found by Derryberry and Reed (2002). This is in accordance with ACT, so it is important to use the ACS as an additional way to test the attentional theory control predictions.

The main aim of the current study was to investigate the effects of anxiety when inhibition and shifting functions are required together and separately as measured by reaction times (RTs) to arithmetical problems. To assess the shifting function two different switching paradigms were used, a pure alternating task switching and an unpredictable task switching. The inhibition function was measured as the capacity to inhibit the distractor.

Specific hypothesis include:

1. That an interaction between anxiety group and task type response times would be found. The high-anxious group would have a larger increase in response time when switching was required (alternating task switching and unpredictable task switching) It was also expected that the interaction between anxiety group and task type when unpredictable switching was required would be larger when comparing unpredictable switching blocks with repetitive blocks than when comparing alternating switching blocks with repetitive blocks.
2. That an interaction between trait anxiety and the distractor would be found with the high-anxious group having a larger increase in response times when the distractor was present.
3. That a three-way interaction between anxiety group, task type and the distractor would be found. The high-anxious group would have a larger increase on response times when the switching was required (either alternating or unpredictable) and/or the distractor was present.
4. On switch cost data, a larger switching cost for the high-anxious group than for the low-anxious group was expected, either in the alternating switch or in the unpredictable switch. In addition, it was expected a two-way interaction between anxiety group and the distractor, with the high-anxious group having a larger switch cost than the low-anxious when the distractor was present.
5. Overall, it was expected stronger effects of anxiety on processing efficiency (measured in terms of response time) than on performance effectiveness

(measured in terms of error rate). Thus, no significant differences between groups were expected in terms of accuracy.

## Method

### *Participants*

Sixty-two undergraduate students at Royal Holloway University of London participated in this study, 40 were female and 22 were male. The mean age of the participants was 21.08 ( $SD = 3.77$ ). The participants either received credits or they were paid 5 pounds in exchange for their participation. Participants were selected to participate in this study based on their score on the Trait form of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970). According to the trait anxiety level reported, the students were divided into a high (scoring  $\geq 45$ ) and a low anxiety groups (scoring  $\leq 34$ ) as in the first study (chapter 2), since it represented the upper and lower quartile of the sample<sup>2</sup>. Half of the selected participants were in the high anxiety group and the other half in the low anxiety group. In the low anxiety group 17 of the participants were female and 14 were male, the mean age in this group was 21.52 ( $SD = 4.30$ ). In the high-anxious group, 23 of the participants were female and 8 were male, the mean age in this group was 20.65 ( $SD = 3.16$ ).

### *Measures*

As described in chapter 2 (p.72)

### *Apparatus*

As described in chapter 2 (p. 72)

### *Stimuli*

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<sup>2</sup> It was found in the first study (chapter2) that these values corresponded to the upper and lower quartile of trait anxiety in a sample of university students at Royal Holloway. The present study followed the same cut-off points as in the first study.

The stimuli consisted in numbers that ranged from 2 to 7. The numbers were white displayed against a black screen. On each trial, 3 rows of digits were displayed on the screen. All of the digits in a row were of equal value (e.g., 4 4 4 4 4 4). The digits (the value of the digit present in the row) and the numerosity (the number of times each digit is presented in a row) could vary between 2 and 7.

The task consisted always of multiplication but it could involve either the actual digits or their numerosity. The task consisted on multiplying the first row digit or numerosity by the second row digit or numerosity, with the result of this multiplication being multiplied by the third row of digits or numerosity. For example, in case of a numerosity task, if the first row was [6 6 6], the second row was [2 2 2 2] and the third row [3 3 3 3 3], the multiplication to be calculated would be  $[3 \times 4 \times 5]$ . But if instead it consisted of a digit task the multiplication to be calculated would be  $[6 \times 2 \times 3]$ .

The position of rows on the screen indicated if the task was a numerosity task or a digits task. That is, if the task required only numerosity the three rows were displayed on the right side of the screen under each other in a parallel way. In contrast, if the task requires only digits, then the three rows were displayed in the left side of the screen under each other in a parallel way. Half of the participants had the stimuli presented on the left position with focus on digits and the stimuli on the right position with focus on numerosity, the other half had the opposite.

In the task switching condition, the trials displayed alternated between digits and numerosity, being either on the left side or on the right side in accordance with what was already defined for a digits or numerosity task. In the unpredictable task switching condition, the position of the rows of numbers acted as a cue informing participants of which task to perform.

The value of digits and the number of digit elements (numerosity) presented in each row were sampled randomly from the set of 36 ( $6 \times 6$ ) possible combinations of digit values (6) and number of digit elements (6). This resulted in a total of 46,656 ( $36 \times 36 \times 36$ ) possible combinations for the three rows. The numbers presentation was randomised such that participants did not repeat the same operation.

In each trial 3 rows of number were displayed, in the second row 50% of the problems required to carry a number from the ones to the tens decimal column and the overall total for each trial always exceeded 100 for 50% of the trials.

### *Design*

Participants were presented with a total of 8 blocks; each participant had to perform two blocks of numerosity, digits, switching and unpredictable switching. In total participants performed 4 blocks of repetitive task, 2 of alternating task switching and 2 of unpredictable task switching. Each block had 12 trials. During half of the blocks participants were exposed to an auditory distractor, the distractor was the same as used in chapter 2 (see chapter 2 for further details on the distractor). The task training included 32 practice trials, 4 for each block; the problems presented as practice were not presented in the main experiment.

### *Experimental Conditions*

*Task type:* included the repetitive conditions as the control condition, and two levels of task switching. In total task type had 3 levels, repetitive (numerosity and digit task), alternating switching task, and unpredictable switching task.

*Repetitive:* consisted in entire blocks of one task only: multiplication using either the number of digits elements presented in the rows (numerosity task) or

multiplication using the value of the digits presented in the row (digit task). This repetitive condition acted as a control condition.

*Task switching:* Participants had to alternate between the two types of task: they were required to alternate between multiplication using a digit task and multiplication using a numerosity task.

*Unpredictable task switching:* Participants did not know which type of task to perform; (numerosity or digits), until the rows of numbers were displayed in the screen with the type of task being indicated by the position of the rows of numbers on the screen (left or right).

*Distractor versus no distracter condition:* The auditory distractor was present in half of the blocks; participants performed each condition under distractor and without.

### ***Procedure***

The participants were instructed to read the information sheet and sign the consent form if they were willing to participate. Afterwards, they were asked to fill the Trait form of the STAI (Spielberger, Gorsuch, & Lushene 1970) and the ACS, a self-report measure of attentional control (Derryberry & Reed, 2002).

Participants were then asked to sit in front of the computer. Participants were also instructed to wear headphones for the whole of the experiment. They were told to ignore what they were going to listen to and focus only in the task they had to perform. The task instructions were then displayed on the screen.

The participants started by performing the training and after they confirmed that they had understood the task, the main experiment started.

Before each block instructions were displayed. If the block was repetitive, the instruction was the following “pay attention to the position of the rows of numbers on



the screen, digits on the left side of the screen, number of digits on the right side of the screen”. If the task required to switch between digits and numerosity, the instruction would be “ now you are required to alternate between number of digits and digits pay attention to the position of the rows of numbers on the screen as they indicate the task that you are required to perform, digits left side, number of digits right side”. Participants were told that they could rest for a short time if they felt tired after which time the experiment would resume. In total the experiment would not take longer than 35 minutes.

### *Statistical analysis*

In the reaction time data analysis, only the correct responses (trials on which participants gave the correct mathematical response in accordance with the instructions) were included. RT –means were computed for each subject in each block for each type of task (repetitive, switching and unpredictable switching). In the repetitive condition means were computed together for the repetitive multiplication with digits and multiplication using numerosity.

For the correction of outliers, responses above three standard deviations of the subjects mean were excluded. Practice trials were not included in the analysis. The average percentage of error was 15.77%, and outliers were 0%, this data was removed from the main analysis. The data was screened for multivariate outliers using Mahalanobis distance, no multivariate outliers were identified, ( $M = .97$ ,  $SD = 1.07$  high-anxious group;  $M = .97$ ,  $SD = 1.61$  low-anxious group). All variables were normally distributed according to Kolmogorov-Smirnoff tests.

The SPSS statistical program was used for all the data analysis. P-values of less than 0.05 were taken to indicate statistically significant differences.

Switching cost was calculated using the following formula (Rts mean in the switch block – Rts mean in the repetitive block) x number of trials in a block / (number of trials in a block -1).

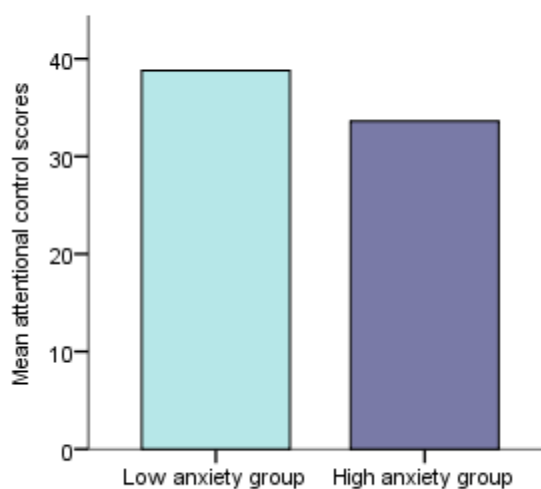
Mixed measures ANOVA analyses and paired *t* tests (2-tailed) and independent *t* tests were conducted to look for group differences in performance. Subsequently an analysis using a mixed measures ANCOVA was performed on the response times with attentional control as measured by self the self reported measure ACS as a control variable. Greenhouse-Geisser correction was used when necessary.

## Results

### *Trait anxiety and Attentional control measures*

Participants were divided in two groups, a high anxiety group ( $M = 51.90$ ,  $SD = 6.40$ ) and a low anxiety group ( $M = 31.16$ ,  $SD = 3.45$ ) based on their self-report measures of trait anxiety.

A one-way ANOVA showed a significant effect of anxiety group on the levels of attentional control (ACS) [ $F(1, 60) = 7.45$ ;  $p < .008$ , partial  $\eta^2 = .110$ ], with the low-anxious group ( $M = 38.81$ ,  $SD = 9.12$ ) scoring higher in the ACS and showing a better attentional control than the high-anxious group ( $M = 33.61$ ,  $SD = 5.39$ ) (see figure 1).



**Figure 1:** Mean scores for the self reported ACS measure for both high and low anxiety groups.

### *Reaction time Data*

A 3x2x2 mixed model analysis of variance (*ANOVA*) was performed on the reaction time (RT) data, with two within subjects conditions: task type (repetitive vs. switching vs. unpredictable switching); distracter (present vs. absent), and anxiety group as between subject factor design.

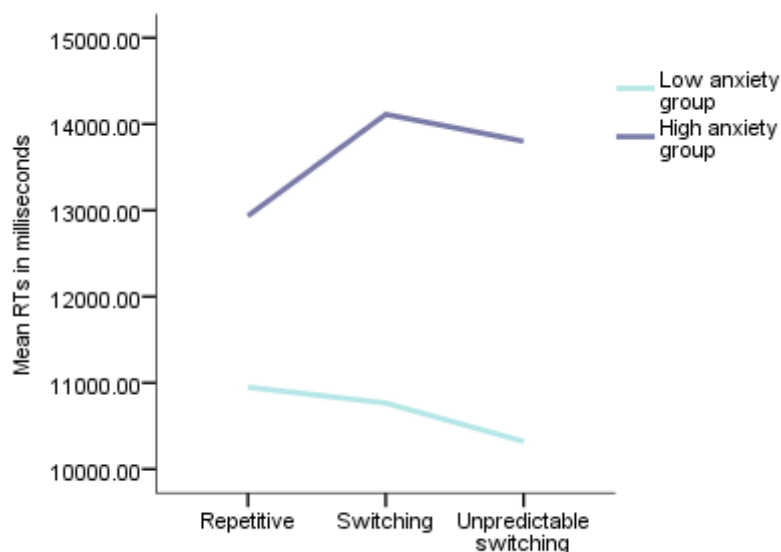
There was a significant main effect of the anxiety group [ $F(1, 60) = 11.36, p = .001$ , partial  $\eta^2 = .159$ ]. The high-anxious group had slower RTs ( $M = 13473.06, SD = 3982.53$ ) than the low-anxious group ( $M = 10740.09, SD = 2658.69$ ). No other significant main effects were found.

There was a significant interaction between task type and anxiety group [ $F(1.82, 109.02) = 5.32; p = .008$ , partial  $\eta^2 = .081$ ] (Greenhouse-Geisser correction was used) as predicted in hypothesis 1. To further investigate the differences between groups paired

*t*-Test (2-tailed) were performed, the results revealed that the high-anxious group increased significantly the RTs from the repetitive task ( $M = 12934.14$ ,  $SD = 3873.50$ ) to the switching task ( $M = 14113.37$ ,  $SD = 5125.08$ ), [ $t(30) = 2.37$ ,  $p = .024$ ]. While no significant increase in RTs were found for the low-anxious group [ $t(30) = .64$ ,  $p = ns$ ] (see figure 2).

A similar pattern of results was found for the unpredictable task switching, the high-anxious group significantly increased RTs from the repetitive task ( $M = 12934.14$ ,  $SD = 3873.50$ ) to the unpredictable switch task ( $M = 13799.92$ ,  $SD = 3771.92$ ) [ $t(30) = 3.45$ ,  $p = .021$ ], while the opposite happened to the low-anxious group [ $M = 10949.65$ ,  $SD = 2904.88$ ] repetitive; ( $M = 10320.02$ ,  $SD = 2627.34$ ) unpredictable], [ $t(30) = 2.51$ ,  $p = .018$ ] (see figure 2). The results support hypothesis 1.

The high-anxious group did not show significant differences in reactions times from the switching task to the unpredictable task switching [ $t(30) = .695$ ,  $p = ns$ .] While the low-anxious group showed a marginally significant decrease in reaction times [ $t(30) = 1.973$ ,  $p = .058$ ].



**Figure 2:** RTs means for the repetitive task and switching and unpredictable switching tasks for both groups, high and low-anxious.

To further investigate the interaction between task-type and anxiety group two 2x2 mixed ANOVAs were performed on task anxiety vs. task type, one comparing alternating switching with repetitive blocks and the other comparing unpredictable switching with repetitive blocks.

Interactions were found both between anxiety and alternating task switching [ $F(1, 60) = 5.63, p = .021, \text{partial } \eta^2 = .086$ ] and between anxiety and unpredictable switching [ $F(1, 60) = 11.86, p = .001, \text{partial } \eta^2 = .165$ ]. Both these interactions and the fact that the interaction involving unpredictable task switching is larger than the one involving alternating task switching are in agreement with hypothesis 1.

The results did not reveal an interaction between distractor and anxiety group [ $F(1, 60) = .34, p = \text{ns}$ ], thus the results were unable to prove hypothesis 2. Moreover no

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three-way interaction was found between task type X distractor X anxiety group [ $F(2, 120) = 1.81, p = ns.$ ], so hypothesis 3 was also unable to be confirmed.

Subsequently it was carried out mixed measures *ANCOVA* on RTs with the following variables; task-type (repetitive vs. switching vs. unpredictable switching) and distractor (present vs. absent) as within-subject design, anxiety group as between subject factor design and attentional control measured as a covariate.

The significant interaction between task-type and anxiety revealed almost no increase in effect size [ $F(1.82, 107.36) = 5.257, p = .008, \text{partial } \eta^2 = .082$ ] when compared with the main ANOVA values (see p 123). Therefore the covariate attention control does not seem to account for the results.

#### ***Switch cost***

A 2x2x2 mixed model analysis of variance (*ANOVA*) was performed on the switching cost data; with task-type switch cost (switch vs. unpredictable switch) and distractor (present vs. absent) as within subjects design and anxiety group as between subjects design.

There was a main effect of the anxiety group [ $F(1, 60) = 11.30, p = .001, \text{partial } \eta^2 = .158$ ] the high-anxious group had a positive switching cost ( $M = 1376.61, SD = 2736.16$ ) while the low-anxious group had a negative switching cost ( $M = -626.94, SD = 1877.64$ ).

There was a tendency for three-way interaction between task-type switching cost (switching vs. unpredictable switching), distractor and anxiety group [ $F(1, 60) = 3.11, p = .083, \text{partial } \eta^2 = .049$ ] however it did not reach significance levels (hypothesis 5). To investigate this interaction 2 two-way *ANOVAs* were performed with anxiety group X

distractor for the alternating switch cost and for the unpredictable switch cost, separately.

In the alternating switch cost data it was found a significant main effect of the anxiety group [ $F(1, 60) = 5.63, p = .021$ , partial  $\eta^2 = .086$ ], with the low-anxious group having a negative switch cost ( $M = -204.49, SD = 1785.34$ ), and the high-anxious group having a positive switching cost ( $M = 1310.25, SD = 3073.25$ ).

In the unpredictable switch cost was also found a significant main effect of the anxiety group [ $F(1, 60) = 11.86, p = .001$ , partial  $\eta^2 = .165$ ], with the low-anxious group having a negative switch cost ( $M = -1049.40, SD = 2331.59$ ) and the high-anxious group having a positive switch cost ( $M = 1442.97, SD = 3286.47$ ).

The difference between the switch cost of both groups being larger in the unpredictable than in the alternating switching seems to also support hypothesis 1.

No interactions were found between anxiety group and distractor on the switch cost data [ $F(1, 60) = .038, p = ns.$ ], thus hypothesis 4 was unable to be confirmed.

### ***Error rate***

In general, there was a positive relation between RTs and the error rate ( $r = .374, p = .003$ ). This relation between RTs and error rate was also analysed for both groups separately. In the high-anxious group it was found a positive relationship between the RTs and error rate ( $r = .442, p = .013$ ) with error rate increasing as the RTs increase. A positive relation between RTs and error rate was also found for the low-anxious group ( $r = .115, p = .538$ ), however, the correlation is not significant.

A 3x2x2 mixed model analysis of variance (ANOVA) was performed on the error rate data, with two within subjects conditions: task type (repetitive vs. switching

vs. unpredictable switching); distractor (present vs. absent), and anxiety group as between subject factor design.

The results revealed a significant main effect of the task type [ $F(1.80, 120) = 4.96, p = .011, \text{partial } \eta^2 = .076$ ], (Greenhouse-Geisser correction was used) such that the error rate was significantly higher on the repetitive task ( $M = .17, SD = .10$ ) than on the unpredictable task switching ( $M = .13, SD = .11$ ), [ $t(61) = 3.32, p = .002$ ] no other significant differences were found.

There was also a main effect of the distractor [ $F(1, 60) = 8.75, p = .004, \text{partial } \eta^2 = .127$ ] with participants having a higher error rate when no distractor was present ( $M = .17, SD = .10$ ) than when the distractor was present ( $M = .14, SD = .09$ ), [ $t(61) = 2.41, p = .019$ ].

No significant differences were found between groups in error rate in accordance with hypothesis 5.



### Discussion

The aim of the present study was to investigate ACT's assumption that the inhibition and the shifting functions are impaired by anxiety during cognitive performance (Eysenck et al., 2007). These central executive functions were investigated together and separately as in the first study (chapter 2), but a different task was used, in order to provide different tests for ACT. In addition, whereas previous research typically used predictable switching between tasks, there was a focus on comparing the effects of anxiety on predictable and unpredictable switching.

One of the most relevant findings was a significant interaction between anxiety and task type (repetitive vs. task switching vs. unpredictable task switching). The high-anxious group significantly increased response time from the repetitive task to task switching while there was not a significant change in the low-anxious response time. Similarly, the high-anxious group also increased response time from the repetitive to the unpredictable task switching, but the low-anxious group improved performance decreasing response time. It is also important that a greater effect of anxiety was observed when the switching trials were unpredictable.

Task switching has been associated with the shifting function (Miyake, et al., 2000), and the findings described above suggest that anxiety affects the shifting function, the capacity to shift attention rapidly between and within task (see Miyake, et al., 2000). As the high-anxious group was the only one to show performance when the task switching was required (alternating or unpredictable) the findings are in accordance with the first hypothesis and with ACT.

Anxiety affected both task switching paradigms (alternating and unpredictable). These results are both interesting and new. To the best of my knowledge the effects of

anxiety have not been investigated on unpredictable task switching. On the basis of previous research with predictable switching, it could be argued that those high in trait anxiety have their mental set for alternating tasks less strongly represented than those low in trait anxiety.

This explanation is not directly relevant for the unpredictable switch trials because it is not possible to have a clear-cut pre-programmed strategy during unpredictable switch trials and thus it cannot account for the slower response times of the high-anxious individuals.

The switch cost results revealed that the high-anxious group had a switch cost while the low-anxious had a switch gain suggesting that only the high-anxious group decreased efficiency of the shifting function. The low-anxious group improvement in performance during the unpredictable task switching when compared with the repetitive task was unexpected. Derakshan, Smyth and Eysenck, (2009) also found that the high state anxious had a switch cost but the low state anxious had a switch gain, in an arithmetical task switching paradigm. This switch gain or switch benefit is not expected from the task switching paradigm. Task switching involves a switch cost, the cost from changing from one task to another and longer reaction times or errors are expected right after the switch when compared with single task performance (control condition) (Monsell, 2003). However, this switch benefit could suggest that the unpredictable task switching increased the motivational level as it was more challenging and demanding.

The switch cost findings partially supported the hypothesis 4 which predicted that overall the high-anxious were expected to have longer switch cost than the low-anxious. A switch cost was indeed found for the high-anxious showing a decrease in performance during task switching (alternating and unpredictable) while the low-

anxious improved performance (switch gain). It is also of note that the difference between the switch cost for the high-anxious and the switch gain for the low-anxious is larger when the switching was unpredictable. Overall, response time and switch cost have shown that the high-anxious group slowed performance while such effect was not found for the low-anxious.

It is important to note that participants performed the same tasks under repetitive, alternating task switching or unpredictable task switching conditions, so the task demands are comparable.

Overall, response time and switch cost increased only for the high-anxious group which suggest that the central executive shifting function was impaired by anxiety. This is as predicted by ACT (Eysenck et al., 2007; Derakshan & Eysenck, 2009) and in accordance with the few studies that have used tasks involving the shifting function to study the effects of anxiety on cognitive performance (Ansari, Derakshan, & Richards, 2008; Derakshan, Smith, & Eysenck, 2009b; Orem, Petrac and Bedwell, 2008). For example, Derakshan, et al. (2009b), investigated the effects of state anxiety on the shifting function, for that purpose the authors also used an arithmetical task switching that also required mental calculation (similar to the one used on chapter 2). Their results revealed that the high-anxious group had significantly longer response time during task switching compared to when the task was repetitive, but only when the task complexity was high, suggesting that anxiety affected the efficiency of the shifting function.

The comprehensive trail-making test (CTMT) trial 5 involves set shifting. Orem, Petrac and Bedwell (2008) used this test and found that participants with high stress levels were slower than the participants with low stress on trial 5. Suggesting that high

stress (that probably links to high anxiety) affected participants in a task that required the shifting function.

The findings revealed that overall the high-anxious group were slower to perform the arithmetical tasks than the low-anxious; this was probably related to task complexity. Task complexity is known to increase the effects of anxiety on performance; and the task used in this study was very complex even when the task was repetitive, as it required performing multiplications using either digits or number of elements. In accordance with ACT when the task complexity is high the negative effects of anxiety should impair processing efficiency more than when the task is easy (e.g. Eysenck, 1985; Calvo, 1985; Calvo, Ramos, & Estevez, 1992; Ascraft & Kirk, 2001, Derakshan, et al., 2009b).

In the present study, there was not a significant effect of the distractor or interactions with the distractor in terms of response time; switch cost data, thus hypothesis 2 and 3 were not confirmed as they predicted that anxiety would increase response times when the distractor was present. In addition, an interaction between anxiety and the distractor on switch cost was also predicted, which was not found. Switch cost data revealed only that the high-anxious were slower to switch between trials than the low-anxious, consequently, hypothesis 4 was only partially confirmed.

In the first study (chapter 2) effects of the distractor were found, but this study uses a different arithmetical task which may account for the differences in terms of the effects of the distractor. From the present results it cannot be concluded whether anxiety affects the inhibition function.

Another important result of the present study is that anxiety was found to impair response time, an indirect measure of processing efficiency, but that it did not impair

performance effectiveness as no significant differences between groups were found in the error rate. This suggests that the high-anxious individuals made use of extra resources in order to overcome the adverse effects of anxiety on attention efficiency of the shifting function. This extra use of processing resources decreased efficiency (relationship between the resources used and the task result) but performance effectiveness (task result) was not affected. The findings are in accordance with ACT and with a great number of research findings that have found that anxiety impairs efficiency to a great extent than performance effectiveness (e.g. Derakshan, et al., 2009b; ; Ansari Derakshan & Richards, 2008; Ansari & Derakshan, 2010, 2011a, 2011b; Eysenck & Derakshan, 2009).

The attentional control scale (ACS - Derryberry & Reed, 2002) results were also consistent with the response time results as they shown that high-anxious had significantly lower attentional control than the low-anxious. Attentional control is one of the main roles of the central executive, thus the central executive functions related with attentional control (shifting and inhibition) should be the most impaired by anxiety. When the attentional control scale was covariate the results showed that the interaction between anxiety and task-type did not seem to get weakened or strengthened by the covariate variable, the effect size was almost the same as well as the significance. This suggests that the differences in response time are explained in terms of individual differences in trait anxiety and not in terms of individual differences in attentional control as measured by the ACS. The study found support for the negative effects of anxiety on the shifting function, but it was unable to confirm that anxiety affects the inhibition function. Thus, the present results were unable to clarify the effects of anxiety on the inhibition function and on the inhibition and shifting functions simultaneously

that were found on chapter 2. The present study encourages further research to clarify the effects of anxiety on the inhibition function.

Overall, anxiety slowed performance of both alternating and unpredictable task switching. Therefore, this study supports the prediction that anxiety impairs the shifting function of the central executive, in accordance with ACT (Eysenck et al., 2007) and in agreement with the previous study results (chapter 2). The present results are important as there are only a few studies that have investigated the effects of anxiety on the shifting function. It is also of relevance that a greater effect of anxiety was found when the switching was unpredictable. Studies to date have focused almost only on predictable switching.

Furthermore, the differences between the high and low-anxious groups were only found in terms of response times. This suggests that anxiety impairs performance efficiency but not performance effectiveness since there were no significant differences between groups in terms of accuracy. This is in accordance with ACT, with research findings and with the previous study.

## **Chapter Four**

### **The effects of anxiety on central executive functions: inhibition, shifting and updating**

In the previous chapters 2 and 3, the effects of anxiety on the executive functions shifting and inhibition were studied simultaneously and separately, and although support for the ACT prediction that anxiety impairs the shifting function was found, the results regarding the inhibition function were either inconclusive or did not support the ACT prediction that anxiety impairs the inhibition function. The present study intends not only to clarify the results regarding the inhibition function as well as to study the three executive functions identified by Miyake et al., (2000), inhibition shifting and updating, in which the ACT is based.

According to ACT, anxiety affects the processing efficiency of the shifting and inhibition functions as they are the ones most related with attentional control. The updating function is more related with short-term memory and thus it should be less affected by trait anxiety. However, state anxiety produced by a stressful situation impairs the efficiency of the updating function (Eysenck et al., 2007).

Anxiety affects processing efficiency because it disrupts the balance between the stimulus-driven and the goal-driven attentional systems in favour of the stimulus-driven (Eysenck et al., 2007). These two attentional systems interact with each other on a regular basis, stimulus-driven (bottom-up) attentional control is faster, and more automatic than goal-driven (top-down) attentional control which involves a voluntary control of attention (Pashler, Johnston, & Ruthruff, 2001; Yantis, 1998; Hasher & Zacks, 1979). Providing support for the assumption that anxiety affects attentional control, it has been found in several studies that high-anxious individuals have less attentional control than low-anxious ones (e.g., Derryberry & Reed, 2002).



Support has also been found for the prediction that anxiety impairs the shifting and the inhibition functions, which is in agreement with the attentional control prediction as discussed below.

Regarding the shifting function, support comes from studies that have used the task switching paradigm, which has been associated with the shifting function (Miyake et al., 2000, Friedman & Miyake, 2004). Results have generally involved increased switch cost or greater increase in response time for the high-anxious individuals over the low-anxious ones when task switching is required (e.g. Ansari, Derakshan & Richards, 2008; Derakshan, et al., 2009b; see also chapter 2 and chapter 3).

Regarding the inhibition function, support comes from studies that have used either neutral or emotional stimuli as task-irrelevant stimuli. Studies that have used emotional stimuli as task-irrelevant stimuli found that high-anxious individuals had greater difficulty with inhibiting emotional task-irrelevant stimuli (Fox, Russo & Georgiou, 2005; Reinholdt-Dunne, Mogg, Bradley, 2009; Pacheco-Ungietti, Lupiañez, & Acosta, 2009; Wieser, Pauli & Mulberger, 2009 for a review see Eysenck et al., 2007). There are also a good number of studies that have found that neutral task-irrelevant stimuli can also affect attentional control (e.g. Calvo & Eysenck, 1996; Ashcraft & Kirk, 2001; Derakshan, Ansari, Hansard, Shoker & Eysenck 2009a).

Regarding the updating function, ACT predicts that this executive function should be less affected by anxiety as its role is less concerned with attentional control and more involved with short-term memory. In addition, the authors suggest that only during stressful situations is the updating function impaired by anxiety. When stress is high the demands on the central executive increase and as consequence processing efficiency decreases and performance might be affected (Eysenck, et al., 2007).

The effects of anxiety on the updating function are still unclear, as only a few studies found that anxiety affected the updating function, generally under stressful conditions (e.g. Drake, 1988). In many cases, research in this field has either found inconsistent results (e.g. Visu-Petras, Tincas, Cheie, Benga, 2010; Dutke & Stöber, 2001), or non-significant effects of anxiety (e.g. Fales, Becerril, Luking & Barch, 2010; Calvo Ramos & Estevez, 1992; Santos & Eysenck, unpublished).

There is some support that anxiety impairs the updating function from studies that used a reading span task under stressful conditions, with the high-anxious having a poorer performance than the low-anxious in reading span task when under the stress (e.g. Calvo et al., 1992; Darke, 1988; see Eysenck et al., 2007 for a review). Reading span involves reading comprehension of a block of sentences and then recall of the last word of each sentence, and has been associated with the updating function (Daneman & Merikle, 1996).

Recently, Visu-Petras, Tincas, Cheie, Benga, (2010) investigated the effects of anxiety on visual-spatial memory updating in children; using the odd-one-out task and a modified version of an adult affective memory task, both non-emotional and emotional stimuli (angry, happy and sad faces) were used. Differences between the high and low anxiety groups were found in accuracy and in detecting happy and angry faces. The high-anxiety group was slower and less accurate in detecting and updating happy faces. However, when angry faces were presented they were more accurate, suggesting that anxiety affected the updating function when emotional stimuli were present. Efficiency and effectiveness improved in the presence of threatening stimuli (angry faces) and worsened in the presence of emotional positive stimuli (happy faces).

Christopher and MacDonald (2005) in a study with clinically anxious and depressed patients investigated, among other tasks, the central executive using a letter-memory task (which has been associated with the updating function; Miyake et al., 2000). The task required constant updating of new letters in order to recall the last 4 letters. The task was performed under two different conditions: easy and standard suppression of the word “the”. The results revealed that performance was poorer for both the anxiety and depression groups compared with the control group. The results suggested that anxiety affected updating of a letter memory task in a clinical anxious sample. However, clinical anxious individuals can differ considerably from nonclinical so conclusions are limited in scope.

Overall, there is some evidence that anxiety can impair performance on tasks involving the updating function if stress is high. However, it is important to emphasise that the results are not conclusive.

The aim of the present study is to investigate the effects of anxiety on the three executive functions: shifting, inhibition and updating.

First, to test the attentional control prediction that the shifting and inhibition functions are the ones most impaired by anxiety during cognitive performance because they are the most related with attentional control. In chapters 2 and 3, it was found that anxiety impaired the shifting function. However, with respect to the inhibition function, the findings were inconclusive as in the first study anxiety impaired the inhibition function only when it was required simultaneously with the shifting function (task switching in presence of distraction), while in the second study, anxiety did not significantly affect the inhibition function.

Second, to investigate if anxiety impairs the updating function, which is more related with memory than with attentional control. There is some evidence that anxiety affects the updating function under high stress as described before, however, several studies have found results difficult to interpret, or non-significant.

In addition, there is a lack of behavioural studies in this field. For these reasons, it is important to clarify the effects of anxiety on the updating function, and to test the attentional control prediction that anxiety effects updating. If it does affect the updating function, then ACT must be revised provided that stress levels are low.

In order to study the inhibition function, the Hayling Task (Burgess & Shallice, 1996) was chosen. This task involves inhibition of prepotent responses and thus differs from the tasks used in chapter 2 and 3, in which neutral auditory distractors were used to study this executive function. However, this task does not involve emotional stimuli and thus is in line with the previous studies and with the aim of this thesis. One of the reasons to choose a different inhibition task was due to the inconclusive results regarding the effects of anxiety on inhibition, revealed in the two first studies.

The Hayling task has two different parts, with minimal differences in the characteristics of the task. The task consists in presenting sentences with the last word missing. The first part of the task requires the participant to produce a sensible word in the context to complete the sentence, while in the second part of the task the participant must give an irrelevant word in the sentence context, thus involving inhibition of the obvious response.

In order to study the shifting function, a task-switching paradigm was used based on the plus-minus (high-complexity) task developed by Jersild, (1927). This switching task involves additions and subtractions, participants either add 17 or subtract

13. In the repetitive tasks either additions or subtractions are performed while during task switching, participants are required to alternate between additions and subtractions. This arithmetical task has often been used and has been associated with the shifting function (see Miyake et al., 2000).

It was decided to use only addition and subtractions in the present study (unlike the first and second studies which also included multiplications and divisions). They are complex enough to deliver significant differences between anxiety groups in terms of reaction times (as seen in chapter 2) but with an error rate that is low and fairly constant across conditions.

To study the updating function, a letter-memory task was used based on the one developed by Morris and Jones (1990) and the one used by Miyake et al. (2000). The task used in the present study differs from the one used by Miyake et al. only in the number of letters presented in each string. In the present study they vary between 6 and 8, while in Miyake study they could vary between 5, 7, 9 or 11. Following Miyake study, participants had to update the letters out loud for this task. It was decided to use the 6 letters strings as the easier task as it only required 2 letters to be updated, while the strings of 8 letters required 4 letters to be updated and were considerably more difficult, and made for the more demanding task.

Having two different conditions, one easier and another more difficult, which imposes more demands on the central executive, allows investigating the effect anxiety on the updating function when the task requires more processes. Problems with the efficiency of executive control processes might mean that high trait anxiety would have more of a negative effect with the more complex items.

Anxiety is expected to impair the updating function to a much lesser extent than the shifting and inhibition functions and the adverse effects of anxiety are only expected on the more demanding/stressful condition (see Eysenck et al., 2007).

One of the central predictions of ACT is that anxiety affects attentional control. To investigate this prediction further, a self-reported measure of attentional control was used. The Attentional Control Scale correlates negatively with trait anxiety (Derryberry & Reed, 2002), with the previous two studies confirming this finding (e.g. Derryberry & Reed 2002; Ayduk et al., 2008). This individual measure of attentional control is the result of the junction of two separated scales which were used by Derryberry and Rothbart (1988). One of the scales measured attentional focus, which is related with the capacity to inhibit distractors, while the other scale measured attentional shifting. So even though they use different terminology they seem to assess the inhibition and shifting functions.

The current study aims to test the effects of trait anxiety on the central executive functions inhibition, shifting and updating (separately as measured by reaction times (RTs) and accuracy). Inhibition will be measured as the capacity to inhibit prepotent responses, the shifting function as the capacity to switch between tasks and the updating function as the capacity to update information.

The specific hypotheses include:

1. That in the plus-minus task, anxiety would have a greater effect on response times when switching was required than when the task was repetitive with the high-anxious group having a greater increase in reaction times than the

low-anxious when switching was required. In addition, switch cost are expected to be larger for the high-anxious than for the low-anxious.

2. That in the Hayling task, anxiety would have a greater effect on response times when the task requires inhibition of the obvious response (response inhibition) than when the task required giving an obvious word (prepotent response). The high-anxious should have a significantly larger increase in reaction times than the low-anxious when the task required inhibition of the prepotent response. However, there will be no effect of anxiety when the prepotent response is required.
3. That in the letter-memory task, there would be an interaction between anxiety and complexity of the task measured in reaction times and/or accuracy. The high-anxious participants should have a larger increase in reaction times and a larger decrease in accuracy when going from the less demanding condition (strings of 6 letters) to the more demanding condition (strings of 8 letters).
4. Overall, it is expected that anxiety will affect processing efficiency as measured by response times to a greater extent than performance effectiveness as measured by error rate. Response times should be higher for the high-anxious compared with the low-anxious with no significant differences in terms of performance accuracy.

## **Method**

### ***Participants***

Sixty-three undergraduate students at Royal Holloway University of London participated in this study, 56 were female and 7 were male. The mean age of the participants was 19.37 ( $SD = 1.80$ ). The participants received credits or they were paid 5 pounds in exchange for their participation. Participants were selected to participate in this study based on their score on the Trait form of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene 1970). According to the trait anxiety level reported, the students were divided into high (scoring  $\geq 45$ ) and a low anxiety groups (scoring  $\leq 34$ ) group. 31 participants were in the low anxiety group and 32 were on the high anxiety group. It was found in the first study that these values of trait anxiety corresponded to the upper and lower quartile of the sample of university students at Royal Holloway. Further studies (including the present study) followed the same cut-off points as the first one. In the low-anxiety group 26 of the participants were female and 5 were male, the mean age for this group was 19.32 ( $SD = 2.12$ ). In the high-anxious group, 30 of the participants were female and 2 were male, the mean age for this group was 19.41 ( $SD = 1.45$ ).

### ***Measures***

As described in chapter 2 (p 72).

### ***Apparatus***

The three different computer tasks were programmed using Visual Basic 6 programming language. The programs recorded the participants' reaction times in milliseconds. Accuracy was registered by the experimenter in both task switching and



in the letter memory task. In the Hayling task, the participants' answers were recorded using a Philips voice tracer LFH 0622.

The tasks were carried out on a Toshiba Satellite 2450-201 laptop with an Intel Pentium 4 processor. The screen was 15" with a TFT active matrix colour display and the resolution 1024 x 768 with a 60 Hz refresh rate.

### *Stimuli*

Three different tasks were presented to the participants, a switching task, the Hayling sentence completion test, and a letter-memory task.

#### *Switching task*

The switching task used was arithmetical (as in the previous studies) and involved performing additions and/or subtractions. A computer program was developed using visual basic computer language to present the numbers and record the reaction times. The stimuli presented were number pairs. The numbers were presented on the right side of the screen and on the left side of the screen; however, no arithmetical sign was displayed between the numbers [e.g. 34      17]. When addition was required participants always had to add 17 to the number, when subtraction was required participants had to subtract 13 from the given number on the left side of the screen. The numbers presented on the right side of the screen were between 24 and 82 (in order that the solution would always have 2 digits) and never ended in 3 or 0 (avoiding having either the first number or the solution divisible by 10). This allowed for the level of difficulty of the task to be kept relatively constant. The presentation was randomised using a Latin square such that the numbers would never be repeated in any of the blocks (as was the order in which the blocks were presented).

The numbers were white displayed against a black screen.

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*Hayling sentence completion test*

The Hayling sentence completion (Burgess & Shallice, 1996) test has two parts; the first part (part A) involves completing a sentence with an obvious response (prepotent response) and the second (part B) requires inhibition of an obvious word (inhibition of a prepotent response). Part A is always performed before part B. Each part has 15 sentences with the last word missing. In the first part, participants were required to complete the sentence with an appropriate ending word (e.g. “When you go to bed turn off the...*LIGHT*”; “In the first space enter your...*NAME*”). In the second part, participants were required to complete the sentence with a nonsense ending word (and inhibit an appropriate one) (e.g. Most cats see very well at...*CHOCOLATE*”; “The dog chased our cat up the...*MOVIE*”).

The sentences and the training followed the original Hayling sentence completion task. The only difference was that in the present study the task was presented using a computer program, thus the sentences were audio played and the RTs recorded by the program while in the original test the examiner recorded response time with a stopwatch. The approach taken here is more sensitive than the one used in the original study. RTs under 300 milliseconds (ms) were not registered. Between trials, a fixation point (a white dot) was displayed for 2 seconds.

*Letter-memory task*

In the letter-memory task, only capitalised consonant letters were used. On each trial, a string of 6 or 8 series of consonants was presented and they were displayed in the centre of the computer screen one at the time. Each letter was displayed for 3 seconds. In a string of letters, the same consonant was not repeated twice and the consonants displayed on a string had to be at least two letters apart from each other in the alphabet.

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The consonants that were chosen were C, F, H, J, K, L, N, P, R, S, T, V, X, Z<sup>3</sup>. The numbers of letters presented were randomised across trials (the letters presented were randomised using a Latin square such that each string of letters was just displayed once for each participant. The same string of letters was not repeated twice for the same participant. The word “recall” was paired with the last letter from the string, and acted as a cue informing the participants that once they included the last letter in their update they would have to press the space bar for their answer to be validated. Between trials, there was a fixation point, a white dot against a black background which was displayed for 1500ms. The consonants were white displayed against a black background.

After pre-testing with strings of 5, 6, 7 and 8 letters it was decided that strings of 5 letters were far too easy and did not represented any challenge So a string of 6 letters were chosen as the less difficult and thus less stressful condition and strings of 8 letters were chosen as the more difficult and thus more stressful condition.

### *Design*

Participants were requested to perform three different tasks, a switching task, the Hayling sentence completion test and a letter memory test. The order of presentation of the tasks was randomised across participants.

In the switching task, a 2x2 design was followed with repetitive vs. task switching as a within subjects condition and anxiety group (high vs. low-anxious group) as a between subjects condition. In the switching task, participants performed in total 4 blocks of arithmetical problems (additions and/or subtractions). Each block had 12 trials

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<sup>3</sup> Y and Q were removed after pre-testing, as they were considered to make the trials more difficult; initials from famous brands or companies were also excluded.

in total, so participants performed 48 trials. Participants performed 2 repetitive blocks as the control condition (one of additions and other of subtractions) and 2 task switching blocks (alternating between addition and subtraction). The presentation order of the blocks was also randomised. Training consisted of 4 repetitive trials (2 for addition and 2 for subtraction), and 4 task switching trials.

In the Hayling sentence completion test, a 2x2 design was followed with response initiation versus response inhibition as a within subjects condition and anxiety group as a between subjects condition. There were 2 blocks in total, 1 block of 15 sentences for prepotent response (part A) and another block of 15 sentences for prepotent response inhibition (part B). Training consisted in a total of 4 sentences, 2 for part A and 2 for part B.

In the letter-memory task, a 2x2 design was used with length (short vs. long) x anxiety group. In the short length condition, a total of 6 consonants were displayed while in the long length condition 8 consonants were used. A total of 3 blocks of 12 trials each was used, in total participants performed 36 trials, 18 trials of short letters strings condition (6 letters) and 18 trials of long letters strings condition (8 letters). The blocks had mixed trials of 6 and 8 letters strings randomly distributed, such that each block had half of its trials with 8 letters strings and half with 6 letters strings. Training was performed until the participant clearly understood the task.

*Experimental conditions:*

*Plus-minus task*

*Task-type (repetitive vs. switching) condition-* the participants were asked to switch between addition and subtraction in half of the experimental blocks (2 blocks), in

the other half the task was repetitive (control condition). Participants had to perform a repetitive block of addition and another of subtraction.

#### *Hayling task*

*Response type (Prepotent response vs. inhibition of prepotent response) condition-* In the prepotent response condition, the participants were asked to complete sentences that had the last word missing with an obvious word (control condition). In the inhibition of prepotent response condition, participants were asked to complete sentences which had the last word missing, but with a word not related with the sentence context, a no-sense word.

#### *Letter-memory task*

*Length condition (short vs. long strings)-* In the short length condition, a total of 6 letters was displayed 2 letters updates were required (less stressful condition). In the long length condition, 8 letters were displayed 4 letters updates were required. In both conditions participants had to recall the last 4 letters of the string (more stressful condition).

### **Procedure**

At the beginning of each session, participants were asked to read the information sheet and sign the consent form. Participants were then asked to complete the self reported measures, the trait form of the STAI and the ACS. Participants were tested one at the time and after completing the consent form they were asked to sit in front of the computer. The instructions for each of the tasks were always displayed in the computer; in addition, the experimenter also explained the task. When the participants had no doubts about the instructions, the task training phase started. After participants had done

the training and clearly understood the task, the main experiment was then conducted. This procedure was followed for all of the three tasks used in this study.

In the switching task, participants were instructed to perform additions and/or subtractions, and informed that in some parts of the experiment they had to alternate between addition and subtractions, starting with addition. They were informed that before each block the instructions would be displayed and that no arithmetical sign would be displayed between the numbers. They were told to pay attention to the instruction given before each group of problems and that they should answer as accurately and quickly as possible. In order for them to answer, they had to give the result out loud and press the space bar simultaneously for their answer to be validated.

In part A of the Hayling sentence completion test (prepotent response) (Burgess & Shallice, 1996), the participants were instructed that the computer was going to play a series of sentences, each of which had the last word missing from it. They were asked to listen carefully to each sentence and when the sentence finished their task was to say out loud a word which completed the sentence. They were asked to answer as quickly as they could – “the faster the better”. They were told that in order for their answer to be validated they had to press the space bar simultaneously as they answered.

In the letter-memory task, participants were instructed to rehearse aloud the last 4 letters by mentally adding the most recent letter and dropping the fifth letter back, and then saying the new string of 4 letters out loud. For example, if the letters presented were **T, H, G, B, S, K**, the participant should say **T, TH, THG, THGB, HGBS, GBSK**. In addition, they were instructed that the last letter of each string (in this case **K**) was always paired with the word **recall**, and that as soon as their update included the

last letter they had to press the space bar for their answer to be validated (which allowed RTs to be recorded followed by the initiation of the next trial).

The participants were informed that in total the study would take around 50 minutes, varying from participant to participant. During all the experiment, the experimenter was seated behind the participant.

### *Statistical analysis*

Only correct trials were included in the analysis for all the three different experiments. Practice trials were not included in any analysis.

The SPSS statistical program was used for all the data analysis. P-values of less than 0.05 were taken to indicate statistically significant differences.

To deal with the outliers, a cut-off of 3 standard deviations from the mean was used in all the 3 experiments.

### *Plus-minus*

RT-means were computed for each participant in each block (addition, subtraction, and task switching). The repetitive block consisted of the means of the addition plus subtraction blocks computed together.

For correction of the outliers, responses more than 3 standard deviations from the participant's mean were excluded (Ratcliff, 1993). The average percentage of error was 10.82%, and outliers were 0.01%, this data was removed from the main analysis. After the data was screened for multivariate outliers using Mahalanobis distance, no multivariate outliers were identified, ( $M=1.94$ ,  $SD = 1.59$  high-anxious group;  $M = 1.94$ ,  $SD = 1.61$  low-anxious group).

All variables were normally distributed according to Kolmogorov-Smirnoff tests.

Switching cost was calculated using the following formula (RTs mean in the switch block – RTs mean in the repetitive block) x number of trials in a block / (number of trials in a block -1).

*Hayling sentence completion test*

In this task, two participants were not included in the final data because they continuously pressed the space Key (which recorded RTs) before saying the answer out loud or forgot to press space Key, which greatly affected their response time. In addition, another participant was excluded due to malfunction of the equipment. The mean RT was computed for each participant in each block (response initiation and response inhibition). For correction of the outliers, responses 3 standard deviations of the subject's mean were excluded (Ratcliff, 1993). The average percentage of outliers was 0.02%, this data was removed from the main analysis. The data was screened for multivariate outliers using Mahalanobis distance, no multivariate outliers were identified, ( $M = .97$ ,  $SD = 1.20$  high-anxious group;  $M = .97$ ,  $SD = 1.27$  low-anxious group). All variables were normally distributed according to Kolmogorov-Smirnoff tests.

*Letter-memory task*

In this task, three participants were not included in the final data, due to very high error rate, above 50% in both short and long length strings conditions. Only correct responses, i.e., trials on which participants updated correctly the strings of letters were included in the reaction time (RT) data analysis.

RT means were computed for each participant and for each block (short and long length letters strings blocks). For the correction of outliers, scores exceeding 3 standard deviations from the participant's mean were excluded (Ratcliff, 1993). The average percentage of error was 33.10%, and outliers was 0.01%, this data was removed



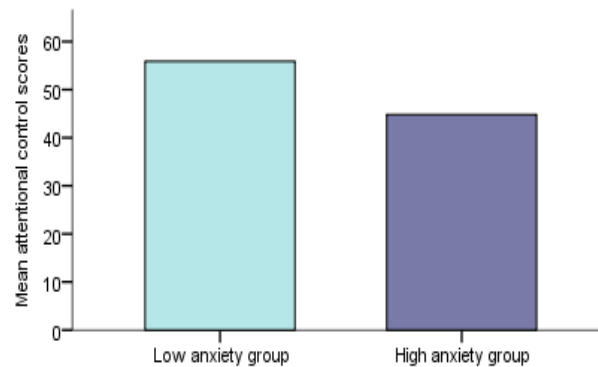
from the main analysis. The data was screened for multivariate outliers using Mahalanobis distance, no multivariate outliers were identified, ( $M = .97$ ,  $SD = 1.20$  high-anxious group;  $M = .97$ ,  $SD = 1.27$  low-anxious group). All variables were normally distributed according to Kolmogorov-Smirnov tests. For all the three different tasks mixed measures ANOVA analyses and independent t tests were conducted to look for group differences in performance. A subsequent mixed measures ANCOVA was performed with attentional control as a control variable.

## Results

### *Trait Anxiety and Attentional Control Measures*

Participants were divided into two groups, a high-anxiety group ( $M = 54.78$ ,  $SD = 6.51$ ) and a low-anxiety group ( $M = 29.74$ ,  $SD = 3.28$ ) based on their self-report scores on trait anxiety.

A one-way ANOVA showed a significant effect of anxiety group on the levels of attentional control (ACS) [ $F(1, 62) = 47.70$ ;  $p < .001$ , partial  $\eta^2 = .439$ ], with the low-anxious group ( $M = 55.87$ ,  $SD = 6.49$ ) scoring higher in the ACS and showing a better attentional control than the high-anxious group ( $M = 44.81$ ,  $SD = 6.22$ ). These results are in accordance with ACT, which states that anxiety negatively affects attentional control.



**Figure 1:** Mean attentional control scores as revealed by the ACS in function of the group.

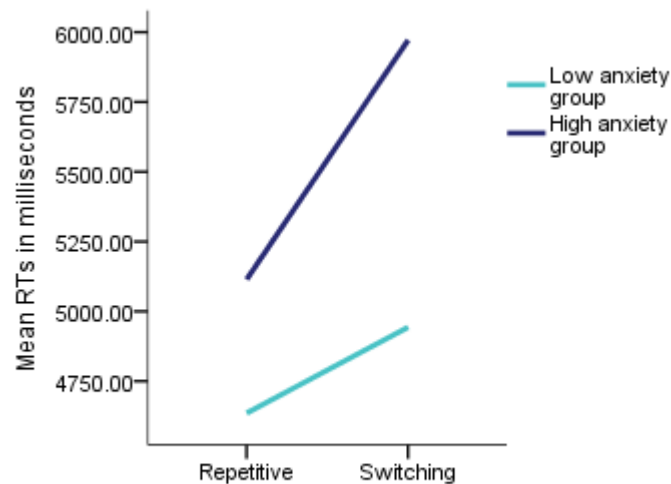
### **Task switching (plus-minus task)**

A 2x2 mixed model analysis of variance (ANOVA) was performed on the reaction time (RT) data, with task type (repetitive vs. switching) as within subject condition and anxiety group as between subject factor design.

A main effect of the task type was found [ $F(1, 61) = 23.73, p < .001$ , partial  $\eta^2 = .280$ ], such that participants in general had longer RTs on the switching task ( $M = 5465.65\text{ms}$ ,  $SD = 1823.14$ ) than the repetitive task ( $M = 4878.61\text{ms}$ ,  $SD = 1698.33$ ). There was a tendency for a main effect of the group [ $F(1, 61) = 3.23, p = .077$ , partial  $\eta^2 = .050$ ] with the high-anxious having longer RTs ( $M = 5542.66\text{ms}$ ,  $SD = 1944.21$ ) than the low-anxious ( $M = 4789.65\text{ms}$ ,  $SD = 1309.14$ ).

There was a significant interaction between task type and anxiety group [ $F(1, 61) = 5.28, p = .025$ , partial  $\eta^2 = .080$ ] as predicted by hypothesis 1. To investigate the difference between groups further, an independent  $t$ -Test (2-tailed) was performed. When the task was repetitive, both anxiety groups had equivalent response times [ $t(61)$

= 1.12,  $p < ns.$ ]. However, in the switching task, the high-anxious group was significantly slower ( $M = 5971.46\text{ms}$ ,  $SD = 2091.88$ ) than the low-anxious group ( $M = 4943.53\text{ms}$ ,  $SD = 1338.99$ ) [ $t(61) = 2.32$ ,  $p < .024$ ], confirming hypothesis 1.



**Figure 2:** Mean reaction times in milliseconds for the switching and the repetitive tasks as a function of anxiety group.

Subsequently, a mixed measures *ANCOVA* was carried out on response times, with the following variables; task type as a within subject condition and anxiety group as a between subjects factor. Attentional control was used as a covariate.

When the attentional control variable was controlled, the interaction between anxiety and task-type had a decrease in effect size [ $F(1, 60) = 535$ ,  $p = .467$ , partial  $\eta^2 = .009$ ] and this interaction was no longer significant (see main *ANOVA* p.154).

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### *Switch cost*

A univariate analysis of variance was performed on the switch cost data, with switch cost as within subject and anxiety group as between subjects factor design.

The results revealed that there was a significant main effect of the anxiety group [ $F(1, 62) = 7.21, p = .009, \text{partial } \eta^2 = .753$ ], such that the high-anxious group had significantly longer RTs ( $M = 1251.87\text{ms}, SD = 1562.37$ ) than the low-anxious ( $M = 329.54\text{ms}, SD = 1120.43$ ) in terms of switch cost.

### *Error rate*

There was no significant relation between error rate and response time in general ( $r = .207, p = .\text{ns}$ ). Between groups there was also no significant interaction between response time and error rate (high-anxious group  $r = .316, p = .\text{ns}$ ; low-anxious group  $r = .299, p = .\text{ns}$ ). Thus, the results cannot be explained in terms of speed-accuracy trade-off.

A 2x2 mixed model analysis of variance (ANOVA) was performed on accuracy, with task type (repetitive vs. switching) as the within subjects condition and anxiety group as the between subjects condition. The results revealed a main effect of task type [ $F(1, 61) = 17.83, p < .001, \text{partial } \eta^2 = .226$ ], such that participants had fewer errors on the repetitive task ( $M = 8.14\%; SD = 6.88\%$ ) than on the switching task ( $M = 13.49\%; SD = 6.88\%$ ). There was also a marginal main effect of the group [ $F(1, 61) = 3.79, p = .056, \text{partial } \eta^2 = .058$ ], such that overall there was a tendency for the low-anxious group to have more errors ( $M = 12.64\%; SD = 10.01\%$ ) than the high-anxious ( $M = 9.05, SD = 7.12\%$ ). No interaction between task type and anxiety were found for the error-rate data ( $F(1, 61) = 1.58, p = \text{ns}$ ).

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### **Hayling sentence completion test**

A 2x2 mixed model analysis of variance (*ANOVA*) was performed on the reaction time (RT) data, with response type (prepotent response vs. inhibition of prepotent response) as within subject condition and anxiety group as between subject factor design.

The results revealed a main effect of response type [ $F(1, 58) = 42.32, p < .001$ , partial  $\eta^2 = .422$ ], such that the participants had shorter RTs on the response initiation ( $M = 602.66\text{ms}$ ,  $SD = 209.24$ ) than on response inhibition ( $M = 1349.39\text{ms}$ ,  $SD = 932.74$ ). No significant main effect of the anxiety group [ $F(1, 58) = 1.05, p = \text{ns}$ ] or interaction was found [ $F(1, 58) = .095, p = \text{ns}$ ].

### ***Error rate***

A one-way *ANOVA* was performed on error rate of inhibition of prepotent responses x anxiety group. The results revealed that response inhibition was not significantly affected by the group [ $F(1, 58) = .66, p = \text{ns}$ ]. The total error score was not high  $M = 2.56$ ;  $SD = 2.23$  (out of a maximum possible error score of 45).

### **Letter-memory task**

A 2x2 mixed model analysis of variance (*ANOVA*) was performed on the RT data, with length (short vs. long) as the within subjects condition and anxiety group as the between subjects condition.

The results revealed a main effect of length [ $F(1, 58) = 43.34, p < .001$ , partial  $\eta^2 = .428$ ], such that participants were in general slower with the long strings of letters ( $M = 3774.50\text{ms}$ ;  $SD = 1630.89$ ) than with the short strings ( $M = 3118.30\text{ms}$ ,  $SD = 1228.44$ ). There was no significant main effect of anxiety group [ $F(1, 58) = .14, p = \text{ns}$ ] nor an interaction between length and group [ $F(1, 58) = .39, p = \text{ns}$ ].

***Error rate***

A 2x2 mixed model analysis of variance (*ANOVA*) was performed on the error rate data, with length (short vs. long) as within subject condition and anxiety group as between subject factor design.

The results revealed a significant main effect of length [ $F(1, 58) = 321.72, p < .001, \text{partial } \eta^2 = .847$ ], such that participants had more errors in the long strings of letters ( $M = 47.96\%; SD = 22.10\%$ ) than in the short strings of letters ( $M = 16.20\%, SD = 12.06\%$ ). There was a non-significant main effect of anxiety group [ $F(1, 58) = .80, p = .ns$ ] and a non-significant interaction between length and anxiety group [ $F(1, 58) = 1.99, p = .ns$ ]

### Discussion

The present study aimed to investigate the effects of individual differences in anxiety on three central executive functions: inhibition, shifting, and updating. According to ACT, anxiety impairs attentional control of the shifting and the inhibition functions of the central executive; however, it is expected that anxiety will have a smaller effect on the updating function as it is more related with short-term memory. For that purpose, three different tasks were used: the plus-minus task which involves task switching was used to study the shifting function as task switching as been associated with the shifting function (Miyake et al., 2000); the Hayling completion test (Burgess & Shallice, 1996) was used to study the inhibition function as it involves inhibition of obvious or prepotent responses; the letter-memory task (Miyake et al., 2000) was used to study the updating function as it involves the capacity to update information in short-term memory.

The results from the plus-minus task revealed that when task switching was required the high-anxious group had significantly longer switch cost than the low-anxious group as revealed by a significant main effect of the group (in accordance with hypothesis 1). In addition, during task switching response times increased significantly for the high-anxious group compared with the low-anxious, while when the task was repetitive both groups had similar performance. These results seem to suggest that the shifting function was impaired by anxiety in support of ACT. Accordingly, there was also a significant increase in switch cost (the time it takes to change between mental sets) by the high-anxious group compared with the low-anxious. However, it is important to have in consideration that while in previous studies (chapter 2 and 3) there were no significant differences in performance effectiveness between groups, as

measured by task error rate, in the present study there was a marginally significant main effect of the group. The high-anxious group had generally less task errors than the low-anxious group. These results difficult the interpretation in terms of processing efficiency as the assessment of efficiency involves the relation between the processing resources used (as measured by reaction times) and the task result (measured by error rate). Reaction times are an indirect measure of processing efficiency and it is necessary to have relatively stable error rate between groups in order to make correct interpretations in terms of efficiency. In the present study anxiety was found to impair task switching, a measure of the shifting function. In accordance with the above findings, a few studies have also found that anxiety impairs the shifting function. For example, Derakshan et al., (2009b) investigated the effects of state anxiety on the shifting function. For that purpose, they used an arithmetical switching task under 2 conditions: high versus low complexity and cue present versus absent. They found that participants high in state anxiety had significantly slower responses during the switching task than low-anxious participants when the task complexity was high.

Ansari, Derakshan & Richards (2008) used a mixed saccade paradigm, whereas participants randomly completed anti- and pro-saccade trials in the switching task and only anti- or pro-saccades in the single task. Differences between the high- and low-anxious groups were found in switching costs with the low-anxious showing a common paradoxical improvement in saccade latency while the high-anxious group did not.

In the plus-minus task, differences between groups were found in terms of response time and switch cost, but regarding the error rate there was only a marginal effect of the group, which showed a tendency for the high-anxious to give less errors than the low-anxious. As mentioned before this difference between groups in error rate



can difficult the interpretation of the results in terms of processing efficiency, however, having in consideration that the difference between groups was only marginally significant it will be considered that the findings are broadly in accordance with hypothesis 4.

In addition, when attention control as measured by the ACS self reported measure (Derryberry & Reed, 2002) was controlled, the findings showed that the interaction between anxiety and task-type had a large decrease in effect size, and the interaction was no longer significant. Thus, when attentional control was covariate the interaction between anxiety and task-type was weakened, suggesting that attentional control could account for the findings, suggesting that they can be at least partially explained in terms of individual differences in attentional control. These findings are also in accordance with the ACT, as anxiety impairs attentional control, one of the central functions of the central executive. In support of this prediction the findings also showed that the high- and low-anxious groups differed significantly in terms of attentional control with the high-anxious having less attentional control than the high-anxious.

The results from the letter-memory task used to investigate the effects of anxiety on the updating function revealed that there were no significant differences in response time between the high and low anxiety groups. In addition, there were also no interactions between the anxiety groups and the length of the string of letters presented (6 or 8 letters). In terms of the error rate, there were also no significant differences between the groups. These results do not seem to be in accordance with the initial hypothesis (hypothesis 3). However, anxiety was expected to affect the updating function to a much lesser extent than the shifting or inhibition functions (and then only

under stressful conditions). Overall, the letter memory task revealed that participants were significantly slower when they had to do 4 letter updates (long strings) and gave significantly more errors compared to when they had to do only 2 letters updates.

The results revealed that anxiety did not seem to impair the updating function, as no significant effects were found between the high and low anxiety groups in terms of processing efficiency or performance effectiveness. These results support the attentional control assumption that anxiety affects the updating function to a much lesser extent as it is more related with short-term memory than with attention.

The updating function involves updating and monitoring current information in the working memory (Miyake, 2000 et al., p.56). According with ACT, anxiety affects processing efficiency by impairing attentional control, the main role of the central executive. Based on this assumption the theory predicts that the inhibition and the shifting functions should be the most affected as they involve using attention control in a negative way to inhibit the task irrelevant stimuli (inhibition function) and to use attention in a positive way to direct attention from task to task as the task requires. However, it was still expected that anxiety would affect the updating function to some extent on the more demanding task (8 letters strings) as it would impose considerable demands on the central executive.

According to ACT the adverse effects of anxiety affect the updating function only when state anxiety increases due to a stressful situation. However, in this experiment stress was not directly manipulated. The manipulation was in terms of demands on the central executive, which are known to impair efficiency of the high-anxious. It was expected that the long strings of letters anxiety would be demanding and affect mostly the updating function. However, this assumption was not confirmed.

The results from the Hayling sentence completion test (Burgess & Shallice, 1996) used to investigate the effects of anxiety on the inhibition function did not reveal significant differences in response time between the high- and the low-anxious groups. In addition, no significant interaction was found between the anxiety group and the test (response vs. response inhibition). These results are not in accordance with ACT and with hypothesis 2 which predicted that when the task required inhibition of the obvious response (response inhibition) to give a no-sense word to complete the sentence, the high-anxious would increase significantly the response time compared to the low-anxious.

One possible explanation is that the Hayling task did not impose enough demands on the central executive, and thus efficiency of the inhibition function was not affected. The present results are in accordance with the second study (chapter 3) results, in which there were no significant differences between groups in distractor inhibition, while in the first study (chapter 2) differences between groups were found only when the distractor was present during task switching, requiring both inhibition and the shifting function. It is important to note that distractors can impair someone's performance either because individuals have poor inhibitory control or because there is a strong automatic activation of distractors and so an unusually great amount of inhibitory control is needed.

A potential problem related to the Hayling task is that participants develop simple strategies for dealing with the inhibition of prepotent response conditions. For example, they can plan ahead which non-sense word they will say in the next trial. The use of solid blocks of non-sense trials could have facilitated the use of such strategies. This is a limitation of the Hayling task. A way to go around this in future research is by

using mixed blocks of sense and no-sense trials (mixed part A and part B). The main finding of this study was that anxiety impairs the shifting function, as anxiety slowed more the high-anxious individuals during task switching than the low-anxious. This result is in accordance with the findings on chapter 2 and 3.

Another important finding is that anxiety did not seem to significantly impair the updating function. This is in accordance with ACT which states that the updating is impaired to a lesser extent than the shifting and inhibition functions. The updating function was only expected to affect performance on high stressful and demanding conditions. As referred above, in this study stress was not manipulated, only the overall task demands on the central executive were manipulated. However, as the task got more difficult and more updates were required, still no significant effects of anxiety were found.

Overall, the present study supports the attentional control prediction that anxiety affects attentional control of the shifting function. However, there was no support for the prediction that anxiety affects the inhibition function. No significant differences between the high and low-anxious groups were found in the capacity to inhibit dominant or prepotent responses, which involved controlling the response to avoid the obvious response and give a no-sense word instead. This finding is not in accordance with ACT assumption that both the shifting and the inhibition function are the most impaired by anxiety during cognitive performance as they are the ones most related with attentional control. However, the inhibition task was not very demanding and it is possible that the participants had enough processing resources to easily cope with the effects of anxiety.

In addition, the results regarding the updating function were not significantly affected by anxiety and thus are somewhat inconclusive.

## **Chapter Five**

# **The effects of anxiety in cognitive performance: a single versus dual-task study**

The present study investigates the effects of anxiety as a personality trait on cognitive performance of two concurrent tasks. In the previous chapters the effects of anxiety on the central executive functions shifting, inhibition and updating were investigated. These three executive functions were identified by Miyake et al. (2000), on basis of empirical research, and latter this approach to the central executive was adopted by the ACT. Several functions have been attributed to the central executive (e.g., Baddeley, 1996, Smith & Jonides, 1999; Barrett, Tugade, & Eagle, 2004; Miyake, et al., 2000; Fournier-Vicent et al., 2008) but researchers have not agreed about the number or role of these functions. In the present chapter the capacity to coordinate two different tasks is investigated as it has been identified as a possible executive function by several authors and it is important to investigate if anxiety also impairs this capacity.

The capacity to co-ordinate two different tasks has also been associated with the central executive. For example, Baddeley, (1996) in a study that attempted to identify the central executive functions reviewed several dual-task studies and concluded that the capacity to co-ordinate two different tasks was one of the important functions of the central executive (see also Sala, Baddeley, Papagno & Spinnler, 1995). D'Esposito, Detre, Alsop, Shin, Atlas and Grossman (1995) developed a neuroimaging study that used a dual-task versus single task paradigm to investigate the central executive. fMRI results revealed that during dual-task performance (but not in the single task) there was activation of the dorsal lateral prefrontal cortex (DLPFC) (see also Szameitat, Schubert, Müller & von Cramon, 2002). The DLPFC has been associated with a top-down attentional system (Bishop, 2007); this attentional system is more goal-driven while the bottom-up system is more stimulus-driven (Corbetta & Shulman, 2002).

Collette, Olivier, Van der Linden, Laureys, Delfiore, Luxen, and Salmon, (2005) found that when single tasks' performance was compared with that of the dual-tasks', there was increased activity not only in the dorsolateral prefrontal cortex, but in a larger cerebral area that included the prefrontal cortex and parietal areas. These have been associated with the executive functions, inhibition, shifting and updating, and with manipulation of information (see Collette, Hogge, Salmon & Van der Linden, 2006, for a review). The studies above suggest that dual-task coordination might be one of the central executive functions as it activates areas related with the other central executive functions including the DLPFC which is associated with top-down (goal-driven) attentional control.

Collette et al. (2006), explored neural substrates of dual-task coordination, and the executive functions identified by Miyake et al. (2000, i.e., inhibition, shifting, and updating). They found that, although separable, they all shared prefrontal areas, supporting the commonality and independence of the executive functions found by Miyake, et al. (2000) and Miyake and Friedman (2004).

Regarding the effects of anxiety on the central executive functions, it is important to investigate if dual-task co-ordination is impaired by anxiety. First, because Miyake et al. (2000) suggested that dual-task coordination might be an independent executive function, thus it could be considered as fourth executive function. Second, because Collette et al. (2005, 2006) found that dual-task coordination activates neural areas that have been related with functioning of the central executive including top-down (goal-driven) attentional control areas (DLPFC). Also, ACT states that anxiety impairs efficiency of attentional control (see Derakshan & Eysenck 2009 for a review).



Anxiety impairs attentional control efficiency because it alters the balance between the top-down (goal-driven) and the bottom-up (stimulus-driven) attentional systems, which leads to a more stimulus-driven than goal-driven attentional control (Eysenck, et al., 2007; Derakshan & Eysenck 2009).

A pure dual-task paradigm involves two single tasks (A and B) and these tasks are either performed as single tasks or concurrently. The “costs” of dual-task performance are assessed by comparing performance on tasks A and B when performed as single tasks versus when they are performed simultaneously (e.g. Esposito et al., 1995). However, research that investigated the effects of anxiety during performance of two simultaneous tasks has not used a pure dual-task paradigm; a loading paradigm has been used instead. In a loading paradigm, the emphasis is on performance of the primary task and the demands of the secondary task are manipulated. For example, Macleod and Donellan (1993) investigated the effects of anxiety on the working memory using a loading paradigm that included a verbal reasoning task (primary task) and a memory load task with different levels of difficulty (high load - retaining in memory 6 random numbers vs. low load - retaining 6 zeros) as a secondary task. They found that when performing these two tasks simultaneously the high-anxious group had longer response times on the reasoning task (primary task) when the memory load (secondary task) was difficult than the low-anxious group. Part of the limitation of the loading paradigm as a way of looking at dual-task effects is that retaining 6 zeroes is such an easy task that it is inconceivable that anxiety could have any effects on performance. Thus, among other things, what is required is the use of two tasks that do not suffer from ceiling or floor effects.

Inspired by the above study, Derakshan and Eysenck, (1998) used the same dual-tasks but they restricted the time available to respond to increase anxiety. They divided the participants into four groups high-anxious (that score high on trait and low on defensiveness), defensive high-anxious groups (individuals that score high on trait anxiety and high on defensiveness) and low-anxious (that score low on anxiety and on defensiveness) and repressors (individuals that score low on trait anxiety but high on defensiveness measures). Repressors can contaminate the low-anxious groups, which can compromise the results in research that involves high and low-anxious groups as they feel the need to deceive others by reporting low anxiety levels and hiding their true anxiety levels (see Eysenck, 1992). Derakshan and Eysenck, (1998) findings were similar to the ones found by Macleod and Donellan (1993), with the high-anxious and defensive high-anxious having longer response times on the reasoning task with high load memory. These two studies found that the adverse effects of anxiety on cognitive performance increased as the task demands increased in agreement with the attentional control prediction.

However, both these studies used a loading paradigm in which performance on task A was compared under low and high difficulty load (task B conditions). Thus, these studies only give a measure of the effects of anxiety on performance on a task under two different levels of difficulty/memory load. However, there was no measure of the effects of anxiety when the tasks were performed singly compared to when they were performed concurrently. Using the load paradigm provides a less accurate measure of dual-task coordination, but a good measure of the effects of increasing demands or task difficulty on the central executive. A single versus dual-task performance provides a purer measure of dual-task performance, because performance in both tasks can be

compared with the single task acting like a control condition. Also, a single versus dual-task paradigm provides a good measure of dual-task coordination but so far this paradigm has not been used to investigate the effects of anxiety on coordination of two different tasks.

The present study investigates how anxiety affects the capacity to co-ordinate two concurrent tasks and is inspired by the tasks used by Macleod and Donellan (1993) and Derakshan and Eysenck, (1998) and by the single vs. dual-task paradigm used by D'Esposito, et al. (1995). A single task should impose fewer demands on the central executive than a dual-task condition. Thus, the negative anxiety effects on cognitive performance should increase as the task demands on the central executive increase, impairing processing efficiency in the more demanding task (dual-task condition). This ACT assumption generally found support from studies that manipulated the demands on the central executive by using different levels of task difficulty or the load paradigm (e.g. Derakshan & Eysenck, 1998).

Anxiety affects performance because it impairs attentional control, which is the main role of the central executive (Eysenck et al., 2007). As for the negative effects of anxiety on attentional control, high-anxious individuals make use of extra processing resources and effort in order to achieve satisfactory performance. However, as more and more effort and resources are required as the task becomes more demanding, performance efficiency is affected even if performance effectiveness is not (Eysenck, et al., 2007). Thus, anxiety should impair processing efficiency (relation between resources used and task result) during dual-task performance but not performance effectiveness (result of the performance measured in terms of accuracy).

In the current study, a reasoning task and a visual memory task were used as single tasks and both tasks were also used concurrently in dual-task conditions. The reasoning task used was very similar to the one used by Derakshan and Eysenck, (1998) and by Macleod and Donellan (1993), but the memory task differed from the one used in Derakshan and Eysenck (1998). Instead of presenting a string of digits as a memory task, framed pictures of faces with neutral expressions were presented.

There were two main reasons for this decision. First, both tasks had to be performed as a single-task as well as concurrently in the dual-task condition. Although the reasoning task could stand as a single task, the digit memory task which involved memory of random 6 digits was too easy as a single task. Second, the problem with using digits was that in both tasks (reasoning and memory), participants had to focus on the order of strings of letters or strings of numbers, both were verbal tasks and both involved order. In this case the findings could state only that anxiety impairs performance of two demanding verbal tasks concurrently. In addition, it could be argued that the effects were due to anxiety impairing verbal processing instead of dual-task co-ordination, and it was important to have two separate tasks, as the dual-task cost could be due to the use of the same specific resources (see Klingberg, 1998). In essence, it is not possible with the earlier research to decide whether the adverse effects of anxiety reflected general processing limitations or specific processing limitations relating to similarities in the stimuli and processes required on the two tasks.

To address the above limitation of the Derakshan and Eysenck study (1998), pictures of faces with neutral expression were used for the memory task. Instead of presenting strings of digits it was decided to present a picture of a framed face with neutral expression. In the dual-task a picture of a face was presented for a brief moment

followed by the reasoning task followed by a second picture of a face which could be the same or different from the first face displayed. This face memory task was chosen as it is a totally separate task from the reasoning task and is unlikely to use the same specific resources, and so the adverse effects of anxiety cannot be related with processing limitations due to similarities in the stimuli and processes required on the two tasks.

The reasoning task involved sentence verification while the memory task involves storage of visual information regarding the face. Thus, while the reasoning task was more related with the central executive the face memory task was more related with short-term visual memory. ACT states that anxiety impairs processing efficiency by affecting attentional control, which is an important function of the central executive. In accordance with that theory, Derryberry and Reed (2002) found that attentional control was negatively correlated with trait anxiety. They developed a self-report measure of attentional control (Attentional Control Scale - ACS) and found that individuals high in trait anxiety had significantly lower attentional control than the low-anxious. In the present study, this self-report measure of attentional control was used to investigate its relation with trait anxiety, since the effects of anxiety on attentional control are central to ACT.

The central prediction in this experiment is that anxiety will impair performance more in the dual-task condition than in the single-task conditions. This would indicate that anxiety impairs the ability to co-ordinate the performance of two concurrent tasks. To the best of my knowledge, this prediction has never been tested directly. If successful, the experiment could lead to a development and extension of ACT, as it

would suggest that the executive processes involved in co-ordinating performance of two concurrent tasks are less efficient in high-anxious individuals.

In summary, the present study involved a face memory task, and a grammatical reasoning task, performed either as single task or concurrently as dual-tasks. Response reaction times were measured as well as the accuracy, in order to test the following predictions:

1. First, an interaction between anxiety and dual-task vs. single task was predicted for the reasoning task. In this interaction, the high-anxious group would have a larger increase in response times than the low-anxious group when the reasoning task was performed concurrently with face memory task than when the reasoning task was performed singly.
2. Second, an interaction was predicted between anxiety and dual-task vs. single task for the face memory task. In this interaction, the high-anxious group would have a larger increase in response times than the low-anxious group when the face memory task was performed concurrently with the reasoning task than when the face memory task was performed singly.
3. Third, it was predicted that differences between the high and the low-anxious groups should be greater in terms of response times than in terms of accuracy, because in accordance with ACT anxiety affects processing efficiency to a greater extent than performance effectiveness.

## Method

### Participants

A total of 82 undergraduate students at Royal Holloway University of London participated in this study, 56 were female and 26 were male. The mean age of the participants was 20.52 ( $SD = 3.48$ ). The participants received credits or were paid 5 pounds in exchange for their participation. Participants were selected to participate in this study based on their score, on the Trait form of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene 1970). On the basis of the trait anxiety level reported, the students were divided into a high (scoring  $\geq 45$ ) and a low anxiety (scoring  $\leq 34$ ) groups. These cut-off values correspond to the upper and lower quartile of the sample of university students at Royal Holloway, as it was found in the first study of the present thesis. Half of the selected participants were in the high anxiety group and the other half in the low anxiety group.<sup>4</sup> In the low-anxiety group 26 of the participants were female and 15 were male and the mean age in this group was 20.49 ( $SD = 3.06$ ). In the high-anxiety group 30 of the participants were female and 11 were male and the mean age in this group was 20.56 ( $SD = 3.89$ ).

### Measures

As described in chapter 2 (p.72)

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<sup>4</sup> All of the studies conducted in Royal Holloway as part of this thesis were based on the same cutoffs (upper and lower quartiles) for the high and low anxiety groups as the first study.

**Apparatus**

Visual basic 6 programming language was used to program the task. The program registered reaction times and accuracy. The participants sat in front of an IBM computer that was used to present the stimuli and to record their reaction times.

**Stimuli**

Two different categories of stimuli were presented in this experiment, a letter pair and black and white pictures of faces with neutral expressions (non-emotional) retrieved from the NYMH database.

In the reasoning task, the stimuli displayed in the centre of a white computer screen were the letter-pair X and Y, which could appear in 2 possible spatial orders (XY or YX). The letter-pair was presented jointly with a sentence possibly describing the letter pair's spatial relationship on the screen. A total of 8 stimuli were used in the experiment, the sentence could be presented in the affirmative or in the negative grammatical form. Half of the letters pairs had sentences that correctly described the spatial relationship between the letter pair on the screen, and the other half sentences that did not describe the letters' spatial relationship (see table 1).

The letter pair was black displayed in a white screen jointly with the sentence regarding the letter-pair position, these stimuli were displayed for a maximum time of 5500 milliseconds (ms). In this time, participants were expected to give an answer by pressing the true key or the false key. The spatial order of the presentation of the letter-pair was randomised.



Table 1. The total set of 8 stimuli used in the reasoning task

|                                |                                |
|--------------------------------|--------------------------------|
| <b>XY</b><br>X is before Y     | <b>YX</b><br>X is before Y     |
| <b>YX</b><br>Y is before X     | <b>XY</b><br>Y is before X     |
| <b>YX</b><br>X is not before Y | <b>XY</b><br>X is not before Y |
| <b>XY</b><br>Y is not before X | <b>YX</b><br>Y is not before X |

The stimuli displayed in the memory task were pictures of emotional neutral faces. In total 24 different pictures of emotional neutral faces were displayed. Half of the pictures were female faces and the other half were male faces. The faces were presented in black and white colour and with an oval white frame. In each trial each picture was displayed for a 1000ms time, after 5500ms of a white screen the same or a different picture was displayed for a maximum of 5500ms, which was the participant's time limit for responding. The participants' task was to recall if the first face that they saw was the same as the second face. The participants answered by pressing one of the two keys (true key – it is the same face or false key – it is a different face). If the participant did not answer during the time limit the program would move to the next trial. In 50% of the trials, the picture displayed was the same as the one presented in the beginning and in the other 50% it was different. Female pictures were always followed by female pictures and male pictures always followed by male pictures. The stimuli presented were randomised from trial to trial. Only Caucasian faces were used in the main experiment.

### **Design**

The design consisted of a 2x2 model, memory (single vs. dual-task) x anxiety group and another 2x2 model reasoning (single vs. dual-task)

In the reasoning single task, the letter pair X and Y was displayed in the screen jointly with a sentence describing one of the two possible spatial positions of the letter pair (e.g. X is before Y). Participants had to decide if the sentence was true or false by pressing the respective key. Reaction times were registered as well as the accuracy of the answer. Participants performed 2 blocks of 16 trials each in this single task.

In the memory single task, a framed face was displayed followed by a white screen and then a second face was displayed, which could be the same face or not. In total participants performed 2 blocks of 16 trials each during the single task.

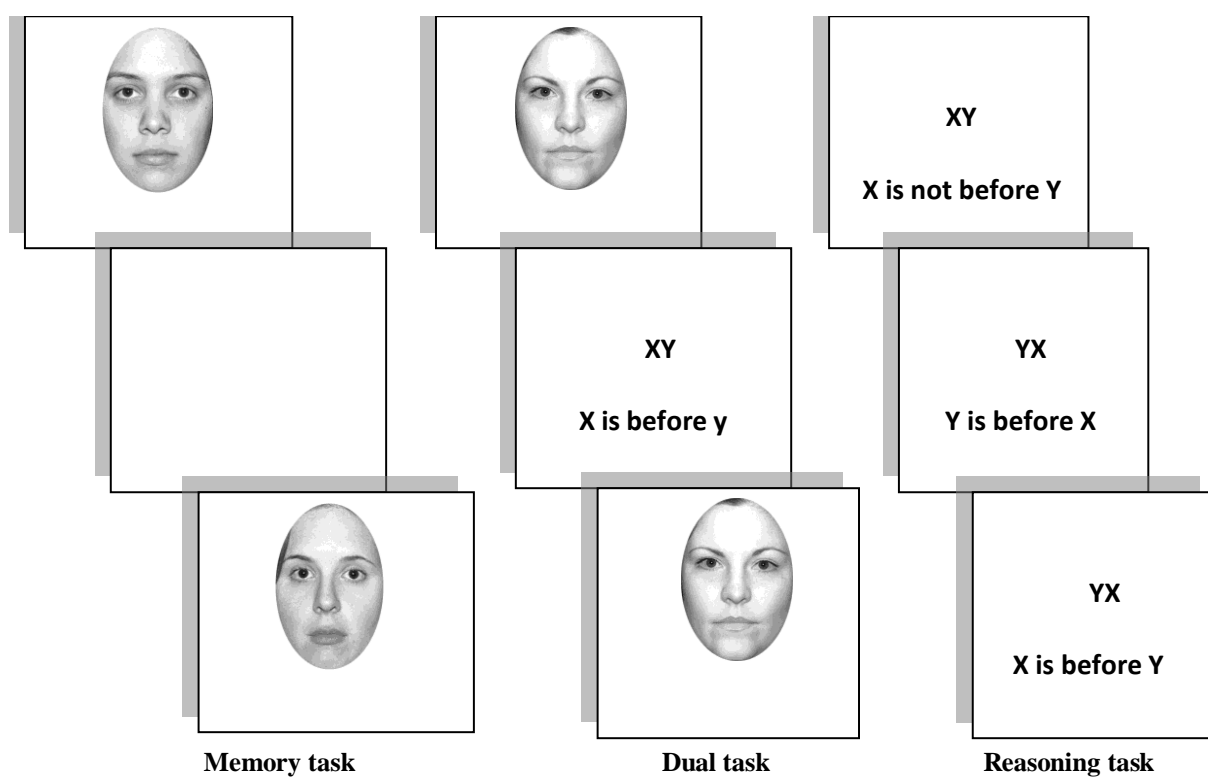
In the dual-task condition, a face was displayed, followed by the reasoning task (the pair of letters Y and X, and the sentence about their spatial position). Participants had a total of 5500ms to answer. Participants had to retain the face displayed in the beginning of the dual-task and maintain it in their memory while on the reasoning task, because reasoning task was followed by another face which could either be the same as or different from the face displayed in the beginning. In the dual-task, participants performed four blocks of 16 trials each. In total, 64 trials were presented in the dual-task. Thus, in total in the single task participants performed 2 blocks of memory and also 2 blocks of reasoning. In the dual-task, participants performed 4 blocks, each block contained 16 trails, in total participants performed 128 trails.

### ***Experimental Conditions***

*Face memory (single vs. dual-task) condition.* In the single task condition, participants had to perform only the memory task. A face was displayed for a brief time

followed by a white screen and then a second face was displayed. Participants had to answer if the face before the whole screen was the same or not as the face displayed after. However, in the dual-task condition, participants were asked to concurrently do a memory task and a reasoning task. Thus, instead of a white screen displayed in the single task, in the dual-task a pair of letters and a sentence representing a possible spatial relation between the pair of letters on the screen were displayed (reasoning task). After performing the reasoning task a second face was displayed. Participants had to recall if the face they saw before the reasoning task was the same or a different face from the one displayed after the reasoning task.

*Reasoning (single vs. dual-task) condition.* In the single task condition, participants performed a reasoning task that consisted of a letter pair and a sentence that described a possible spatial relationship between the letter pair. Participants had to answer if the sentence was true (represented the pair of letters spatial position in the screen) or false (did not represent the position of the pair of letters on the screen). However, in the dual-task, the reasoning task was displayed after a face was presented (memory task), which participants were asked to retain in their memory while performing the reasoning task.



**Figure 1:** Schematic representation of a typical trial of a single memory task, a dual-task and a single reasoning task.

### **Procedure**

Participants were tested in a quiet room. First, participants read the information sheet and signed the consent form, and then they were asked to fill the trait scale of the STAI-trait and the attentional control scale. The participants were then asked to sit in front of the computer screen; the instructions were displayed in the screen as follows:

“In this experiment you will be evaluated in two different single tasks and one dual-task. As a single task you will be required to perform a reasoning task and a memory task. In the reasoning task a pair of letters will be displayed in the screen for a short time, and then it will be replaced by a sentence. Your task is to decide if the sentence describes accurately or not the pair of letters displayed. Press true key if the sentence is accurate or false key if the sentence does not describe the letter pair accurately.

In the memory task a picture of a face will be displayed in the screen for a short period of time followed by a white screen the white screen is then replaced by a picture of a face. Your task is to remember if the face presented initially is the same presented after the white screen. Press true key if the same face is presented or false key if a different face is presented.

The dual-task involves the reasoning task and the memory task. Thus, a picture of a face will be displayed first. Pay attention to the face because later you will be asked to identify the face. After the presentation of the picture, a pair of letters will be displayed, followed by a sentence that describes the letter pair. Your task is to decide if the sentence describes accurately the letter pair or not, press true key if it does, or false if not. After it, a picture of a face is presented, and your task is to remember if the face

presented is the same as the face that was presented before the reasoning task. Press true key if is the same or false if is a different face.

Accuracy is very important. Some trials are more difficult than others. Please make sure that you give the correct answer. To give the correct response is very important in the memory task and in the reasoning task single tasks as in the dual-task. These instructions were based in the instructions given in the Derakshan and Eysenck (1998) study.

After the instruction participants, were asked to perform a total of 16 practice trials with 4 practice trials for the reasoning task, 4 practice trials for the memory digit task and 8 practice dual-task trials. When participants showed that they understood the task, the experiment started. In the middle of experiment participants were told that if they wanted to rest for a little bit they could do so.

The order of presentation of the tasks was randomized as the trials inside each block. In total participants performed 128 trials.

Participants were tested individually and the experiment took in total approximately 30 minutes long.

### **Statistical analysis**

Only correct responses were included in the reaction time (RT) data analysis. RT means were computed for each participant, each block (single and dual) and for each task (reasoning and memory). For correction of the outliers, responses over 3 standard deviations away from the subjects mean were excluded (Ratcliff, 1993). The average percentage of error was 8.91%, and outliers was 0.01%, this data was removed from the main analysis. The data was screened for multivariate outliers using Mahalanobis distance, no multivariate outliers were identified, ( $M = .98$ ,  $SD = 1.37$

high-anxious group;  $M = .98$ ,  $SD = 1.33$  low-anxious group). All variables were normally distributed according to Kolmogorov-Smirnoff tests. The SPSS statistical program was used for all the data analysis. P-values of less than 0.05 were taken to indicate statistically significant differences.

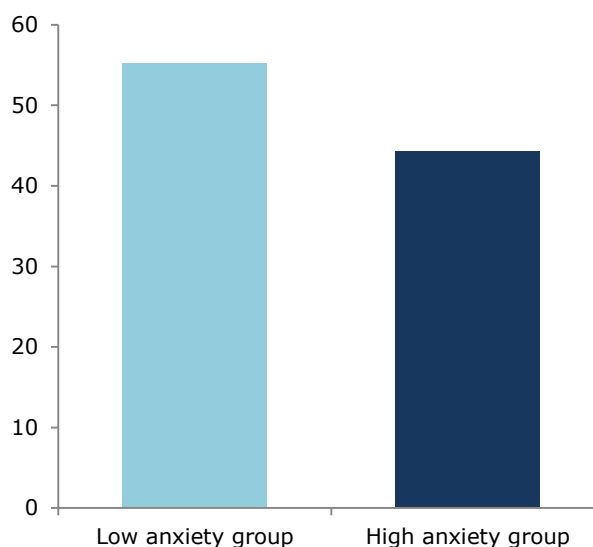
Mixed measures *ANOVA* analyses and independent *t*-Tests (2-tailed) were conducted to look for group differences in performance. A subsequent analyse mixed measures *ANCOVA* was performed with ACS as a control variable.

## Results

### *Trait anxiety and attentional control measures*

Participants were divided in two groups, a high anxiety group ( $M = 56.32$ ,  $SD = 5.85$ ) and a low anxiety group ( $M = 29.29$ ,  $SD = 3.34$ ) based on their self-reported measures of trait anxiety.

*Attentional control measure:* The analysis of the ACS revealed significant differences between the high-anxious group and the low-anxious group [ $F(1, 80) = 42.99$ ,  $p < .001$ , partial  $\eta^2 = .350$ ] with the low-anxious group ( $M = 55.20$ ,  $SD = 6.98$ ) scoring higher in the ACS and showing greater attentional control than the high-anxious group ( $M = 44.29$ ,  $SD = 8.04$ ) (see figure 1). These results are in accordance with ACT, which states that anxiety negatively affects attentional control.



**Figure 2:** Mean scores for the self reported ACS measure for both high and low anxiety groups.

### ***Reaction time Data***

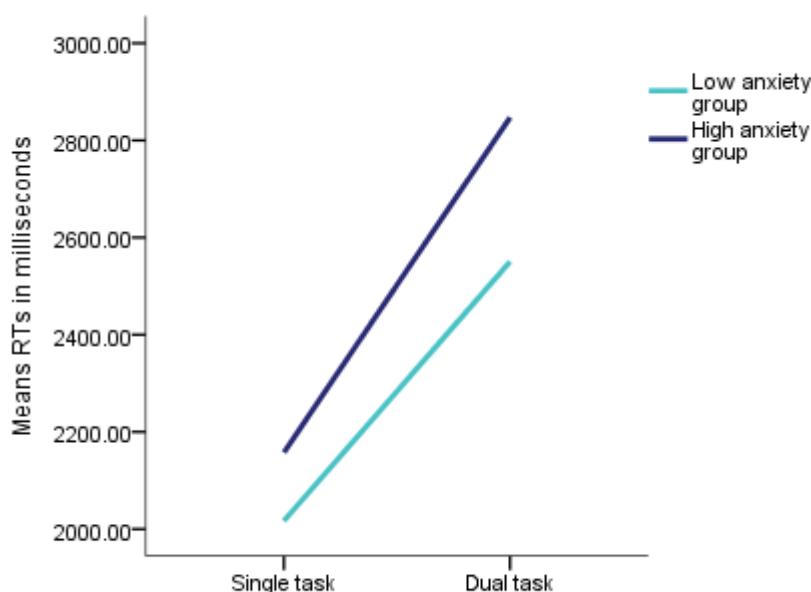
#### *Verbal reasoning task*

A 2x2 mixed model analysis of variance (*ANOVA*) was performed on the reasoning task reaction times (RTs), with single vs. dual-task as a within subjects factor and anxiety group as a between subjects factor.

There was a significant main effect of anxiety group [ $F(1, 80) = 4.88, p = .030$ , partial  $\eta^2 = .058$ ]. The high-anxious group had slower RTs ( $M = 2620.79$  ms,  $SD = 436.39$ ) than the low-anxious group ( $M = 2374.69$  ms,  $SD = 455.86$ ). A main effect of the task (single vs. dual-task) was also found [ $F(1, 80) = 492.22, p < .001$ , partial  $\eta^2 = .860$ ], such that participants had faster RTs in the reasoning task when performed on its own ( $M = 2087.33$  ms,  $SD = 2698.85$ ) than in the dual-task ( $M = 2698.85$ ms,  $SD = 471.41$ ) where the verbal reasoning task was performed concurrently with the face memory task.



In the reasoning task, the results revealed an interaction between the task (single vs. dual) and the anxiety group [ $F(1, 80) = 8.00, p = .006, \text{partial } \eta^2 = .091$ ] in accordance with hypothesis 1 (see figure 2). To further investigate the differences between groups an independent (2-tailed)  $t$ -Test was performed (2-tailed). The high-anxious group had significantly longer RTs ( $M = 2847.23 \text{ ms}, SD = 455.55$ ) than the low-anxious ( $M = 2550.46 \text{ ms}, SD = 444.24$ ) when they had to perform the reasoning task concurrently with the face memory task (dual-task) [ $t(80) = 2.99, p = .004$ ]. Reasoning during single task performance did not reveal significant differences between the high and the low-anxious group [ $t(80) = 1.33, p = \text{ns}$ ].



**Figure 3:** Mean RTs for the grammatical reasoning task in the single versus dual-task performance for the high and low-anxious groups.

Subsequently, a mixed measures *ANCOVA* was carried out, on verbal reasoning with the following variables single task vs. dual-task as a within subject condition and anxiety group as a between subjects factor. Attentional control was used as a covariate.

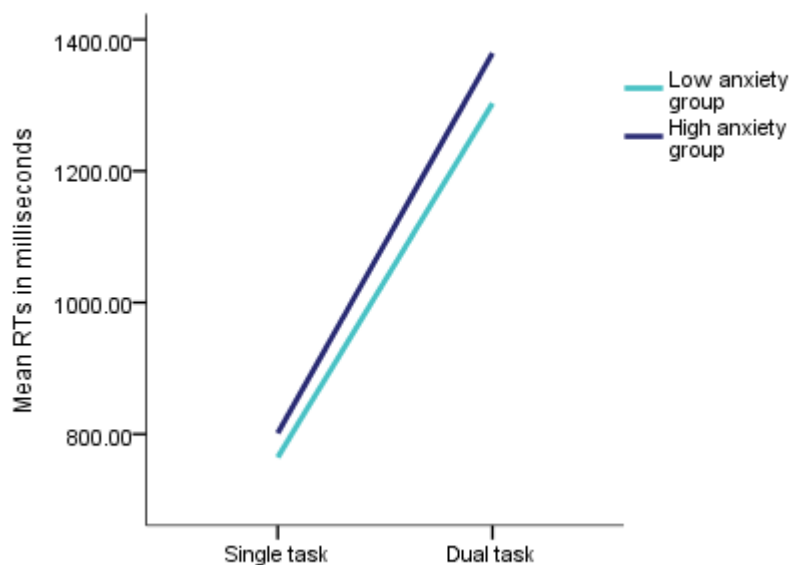
The results revealed that when attentional control was controlled the interaction between task (single vs. dual) and the anxiety group was strengthened [ $F(1, 79) = 8.61, p < .004, \text{partial } \eta^2 = .098$ ] (see main ANOVA p.184).

#### *Face memory task*

A 2x2 mixed model analysis of variance (ANOVA) was performed on the face memory task reaction times (RTs) data, with single vs. dual-task as a within subjects factor and anxiety group as a between subjects factor.

The results revealed a significant main effect of condition (single vs. dual) with participants having longer RTs when the memory task was performed concurrently with the reasoning task as a dual-task ( $M = 1341.05\text{ms}, SD = 174.74$ ) than when the memory task was performed as a single task ( $M = 783.10\text{ms}, SD = 158.13$ ), [ $F(1, 80) = 2685.55, p < .001, \text{partial } \eta^2 = .971$ ]. The results did not show a main effect of group [ $F(1, 80) = 2.63, p = \text{ns}$ ].

There was a tendency for an interaction between the task (single vs. dual) and the anxiety group but it did not reach significance [ $F(1, 80) = 3.35, p = .071, \text{partial } \eta^2 = .040$ ] (see figure 3). The high-anxious group had significantly longer RTs ( $M = 1379.10\text{ms}; SD = 158.10$ ) in the dual-memory task compared with the low-anxious ( $M = 1302.99\text{ms}, SD = 184.02$ ) [ $t(80) = 2.01, p = .048$ ], but no significant differences between groups were found in the single memory task [ $t(80) = 1.05, p = \text{ns}$ ] as predicted in the second hypothesis.



**Figure 4:** Mean RTs for the face memory task in the single versus dual-task performance for the high and low-anxious groups.

Subsequently, a mixed measures *ANCOVA* was carried out, on face memory with the following variables: single task vs. dual-task as a within subjects factor and anxiety group as a between subjects factor. Attentional control was used as a covariate.

The results showed that when attentional control was covariate the interaction between task (single vs. dual) and the anxiety group [ $F(1, 80) = 1.37, p = ns$ , partial  $\eta^2 = .017$ ] was weakened, showed by a decrease in effect size and in addition the interaction was no longer close to significance levels (see main *ANOVA* p.186).

### ***Error rate***

The error rates were not significantly correlated with mean RTs ( $r = -.114, p = ns$ ). In addition error rates were not significantly correlated with mean RTs for the high-anxious group ( $r = -.112, p = ns$ ) or for the low-anxious group ( $r = -.039, p = ns$ ),

suggesting that RTs differences cannot be explained in terms of speed-accuracy trade off.

A 2x2 mixed model analysis of variance (*ANOVA*) was performed on the face memory task error rate with single task vs. dual-task as a within subjects factor, and anxiety group as a between subjects factor.

There was a significant main effect of the condition (single vs. dual) [ $F(1, 80) = 48.54, p < .001, \text{partial } \eta^2 = .378$ ] such that participants had higher error rate when the task was performed concurrently with the reasoning task ( $M = .14, SD = .07$ ) than when performing only the memory task ( $M = .09, SD = .06$ ). There was also a significant main effect of group [ $F(1, 80) = 6.51, p = .013, \text{partial } \eta^2 = .075$ ] with the high-anxious group having fewer errors ( $M = .10, SD = 0.06$ ) than the low-anxious ( $M = .13, SD = .07$ ). No significant interaction was found between anxiety group and memory task (single vs. dual). The results are in accordance with the third hypothesis.

A 2x2 mixed model analysis of variance (*ANOVA*) was performed on the verbal reasoning task error rate with single task vs. dual-task as a within subjects factor, and anxiety group as a between subjects factor.

There was a significant main effect of condition (single vs. dual) [ $F(1, 80) = 9.83, p = .002, \text{partial } \eta^2 = .109$ ] such that the participants had more errors when the task was performed concurrently with the face memory task ( $M = .05, SD = .05$ ) than when only the reasoning task was performed ( $M = .07, SD = .08$ ). No interaction was found between the anxiety group and the reasoning task [ $F(1, 80) = .03, p = .ns$ ]. The results are in accordance with the third hypothesis.

### Discussion

ACT states that anxiety affects the central executive functions concerned with attentional control, inhibition and shifting. However, Miyake et al. (2000) suggested that dual-task coordination might be an independent executive function, as it was not related to the shifting, inhibition and updating functions. In addition, there is evidence that the prefrontal and parietal areas associated with executive functioning and top-down (goal-driven) attentional control are activated during dual-task performance (see Collect, et al; 2005; 2006, D'Esposito et al., 1995). Based on the above findings, the aim of the present study was to investigate the effects of trait anxiety on the capacity to co-ordinate the performance of two concurrent tasks, which is required during dual-task performance. For that purpose, a single task vs. dual-task paradigm was used.

The results revealed that participants had longer response times during dual-task when compared with single task performance. Thus, during the verbal reasoning task participants were slower when they had to perform the reasoning task concurrently with the face memory task (dual-task), than when the reasoning task was performed singly. Similarly, in the face memory task participants were also slower during dual-task compared to single task conditions. The results revealed a time cost associated with dual-task performance. In a similar fashion, Szameitat, Schubert, Muller & von Cramon, (2002) used a single versus dual-task paradigm and also found that there was a decrease in performance during dual-task, when compared with single task.

Regarding the effects of anxiety on the capacity to coordinate two tasks it was found a significant interaction in the reasoning task between anxiety group and dual-task vs. single task, as predicted in the first hypothesis. The high-anxious group had significantly slower response times than the low-anxious group during dual-task

conditions when the reasoning task was performed concurrently with the face memory task but not when the reasoning task was performed singly. In the face memory task, there was an almost significant interaction between anxiety group and dual-task performance, such that the high-anxious group response times were significantly slower when compared to the low-anxious group in dual-task. However, the same did not happen in the single task, which is as predicted by the second hypothesis.

The present findings are of great theoretical importance as they suggest that anxiety affects the capacity to co-ordinate two concurrent tasks, as shown by significantly slower response times for the high than for the low-anxious groups, only during dual-task performance. These findings suggest that dual-task co-ordination is an executive function that is impaired by anxiety. Based on these findings ACT should be updated and dual-task co-ordination added as one of the central executive functions most impaired by anxiety in conjunction with shifting and inhibition.

ACT states that anxiety impairs the executive functions most related with attentional control, because anxiety disturbs the balance between the top-down (goal-driven) and bottom-up (stimulus-driven) attentional control systems increasing the influence of stimulus-driven attentional control. The present results suggest that anxiety impaired attentional efficiency of dual-task coordination as differences between groups were only found during dual-task and not during single task performance.

It is important to note that in the present study the effects of anxiety were higher on the verbal reasoning task than on the face memory task; as revealed by a highly significant interaction with anxiety group in the reasoning task while in the face memory task there was a tendency for an interaction but did not reach significance. Markham and Darke (1991) found that anxiety affected performance in a verbal

reasoning task only on the most difficult items. One possible explanation for the present findings is that the reasoning task was more difficult than the face memory task requiring more processing resources.

According with ACT, it was predicted (third hypothesis) that anxiety would impair performance efficiency to a greater extent than performance effectiveness. As predicted in the third hypothesis, anxiety affected response time which is an approximate measure of processing efficiency to a greater extent than accuracy a measure of performance effectiveness. No interaction between anxiety and task accuracy was found in the reasoning task or in the face memory task. A considerable amount of research has consistently found that anxiety affects processing efficiency to a great extent than performance effectiveness (Derakshan & Eysenck, 1998; Derakshan et al., 2009; Ansari Derakshan & Richards, 2008; Ansari & Derakshan, 2010, 2011a, 2011b; Eysenck & Derakshan, 2009; for a review see Eysenck & Derakshan, 2011).

However, a main effect of group was found in the face memory task, with the high-anxious group having significantly fewer errors than the low-anxious group. These results suggested that the high-anxious group could compensate for the effects of anxiety by using extra resources and effort that affected performance efficiency to some extent but improved performance effectiveness significantly (quality of the performance in terms of response accuracy). This in turn suggested that the high-anxious group was more motivated to achieve a satisfactory performance than the low-anxious.

In accordance, Eysenck and Derakshan, (2011, see Eysenck et al., 2007) stated that anxiety affects the attentional systems which become less goal-driven and more stimuli-driven. However, this influence of the stimulus-driven can be overcome with increased effort and extra use of processing resources, provided that the task is

demanding and the goal is clear. Until now, the loading paradigm has been consistently used to investigate the effects of anxiety during two concurrent tasks. The focus of these studies is on a primary task while secondary task demands are manipulated.

Performance on the primary task is then compared under high vs. low load. For example Derakshan and Eysenck, (1998; see also MacLeod & Donnellan, 1993) used the loading paradigm and found that when the verbal reasoning task was performed simultaneously with a difficult memory load task (secondary task) the high-anxious group had longer response times compared with the low-anxious.

To investigate the capacity to co-ordinate two concurrent tasks, the paradigm used in the present study is more appropriate, because performance in single task can be compared with performance in dual-task conditions (which require capacity to coordinate two concurrent tasks). The present results are of potential theoretical importance because they indicate that dual-task coordination is indeed affected by anxiety as shown by longer response times for the high-anxious group. In future studies, dual-task coordination should be investigated using a single vs. dual-task paradigm instead of a loading paradigm.

The analysis of the self-report measure of attentional control ACS (Derryberry & Reed, 2002), revealed that the high-anxious group had lower attentional control when compared with the low-anxious group which is in accordance with ACT assumption that anxiety impairs attentional control (Eysenck et, al., 2007). When the self-report measure of attentional control was used as a covariate variable it was found that the interaction between anxiety and the reasoning task was strengthened; however, it had the opposite effect on the interaction between anxiety and memory, weakening the interaction. This suggests that attentional control affected the differences between



groups on the memory task but not on the reasoning. It is important to note that the interaction between anxiety and the memory did not reach significance levels.

Overall, the findings suggest that anxiety impairs the capacity to co-ordinate two concurrent tasks, longer response times were found for the high-anxious group than for the low-anxious group when the verbal reasoning task and face memory task were performed concurrently (dual-task) compared to when they were performed singly. These findings suggest a development and an extension of ACT to include dual-task coordination as one of the central executive functions most affected by anxiety during cognitive performance. In addition Miyake et al. (2000) should consider including dual-task coordination as an additional executive function.

## **Chapter Six**

# **Effects of goal-setting on performance of high-anxious versus low-anxious individuals**

In the previous chapters (2, 3, 4 and 5) the effects of anxiety on the central executive functions was investigated, having as a basis ACT's assumption that anxiety affects the central executive functions related with attentional control the most. In this study, the focus is not only on the effects of anxiety on cognitive performance but also on how goal setting (assigning different levels of goal difficulty) can affect performance. Goals, either self set or assigned, are considered to be an indirect measure of motivation. High difficulty and clear goals have been associated with increased motivation and thus improve task performance, while easy or unclear goals have been associated with low motivation and poor task performance (e.g. Locke & Latham 2002). Both ACT and its predecessor (Eysenck & Calvo, 1992; Eysenck, et al., 2007) have suggested a relation between cognitive performance, anxiety and motivation. The former theory suggested that high-anxious individuals' worries about performance would increase effort and motivation in order to overcome the adverse effects of anxiety. The more recent ACT (Eysenck et al., 2007) agrees with this assumption, suggesting that high-anxious individuals generally use compensatory measures such as the use of extra processing resources to achieve a satisfying quality of performance (performance effectiveness). This means that high-anxious individuals will make an extra effort and will be more motivated to achieve a good level of performance effectiveness. However, this will come at a cost as performance efficiency will be impaired by the use of extra resources and effort.

Recently, in an update to ACT, Eysenck and Derakshan (2011) suggested two different stages in the use of compensatory measures by anxious individuals, which are deeply related with task/goal difficulty and motivation. When facing unclear or low difficulty goals high-anxious individuals believe that attentional control isn't really

required, and so put less effort and feel less motivated to achieve a good task performance. Thus, in accordance with ACT, unclear /low difficulty task goals are associated with low motivation in high-anxious, and consequently with poor task performance. On the other hand, when the task goal is difficult and clear, high-anxious individuals will use extra processing resources and effort as compensatory measures, feeling more motivated to achieve the goal of the task satisfactorily (Eysenck & Derakshan, 2011).

It is of great importance to test this assumption of ACT in order to find empirical support or revise the theory. Above all, it would bring a greater understanding to the role of goal setting and motivation in high and low-anxious individuals, since there is almost no research undertaken in this field, despite being a central assumption of the theory. Only indirect support has been found for this ACT prediction. For example, Hayes, Macleod and Hammond (2009) used a category learning task and the findings revealed that performance of high-anxious participants was impaired only in incidental learning (unclear goal) but not when the task goal was clear (intentional learning).

In accordance with ACT goal setting and motivation are related. This is in line with the goal setting theory of work motivation, as task goals are central in both approaches. The goal setting theory is one of the most important theoretical explanations in the field of work motivation, and it was first put forward in 1968 by Locke and since then it has been updated several times (e.g. Locke, Shawn, Saari, & Latham, 1981; Locke & Latham, 1990; Locke, 2001; Latham et al. 2002). The basic assumption is that in certain conditions, specific and difficult goals can improve performance considerably when compared to easy and unclear goals (Locke & Latham, 1990). In line with this

concept, Eysenck and Derakshan (2011), in their update to ACT, suggested that unclear or low difficulty task goals generally lead to low motivation and inefficient recruitment of processing resources by high-anxious individuals. On the other hand, a clear and difficult goal generally leads to high levels of motivation that are associated with the extra use of effort and processing resources by high-anxious individuals, although not in a very efficient way (Eysenck & Derakshan 2011).

Crucial to work motivation is goal commitment, which is the individual's determination to achieve a goal (see Locke, Latham & Erez, 1988; Locke & Latham 1990; Klein, Wesson, Hollenback, & Alge, 1999; Hollenback & Klein 1987; Hollenback, Klein, O'Leary & Wright, 1989; Klein, Wesson, Hollenback, Wright, & DeShon, 2001). Commitment "is most important and relevant when the goal is difficult" (Klein et al., 2001 as cited in Latham & Pinder, 2005, p497). Goal commitment is a moderator variable between goal difficulty and performance and it is important to measure commitment to the goal when studying the effects of motivation on performance.

According to Locke, Latham & Eres, (1988), performance improves when both goal difficulty and the individual's goal commitment are high. However, if the individual perceives the goal as impossible to achieve, incentives can lower motivation instead of increasing it (Lee et al., 1997). Locke's theory has often not been supported when the task is spread over several weeks or months, suggesting that the theory works best when the task lasts only for a short period of time.

Based on the assumptions of ACT (Eysenck et al. 2007, Eysenck & Derakshan, 2011) and on goal setting theory of work motivation (Locke & Latham, 1990) it is important, when studying the effects of goal setting and consequently of task

motivation, to develop a task with clear goals (Eysenck & Derakshan, 2011). These goals should be perceived as achievable (Lee et al. 1997) and different levels of goal difficulty (low and high difficulty) will lead to different levels of goal commitment, which is related with motivation and task performance (Locke, Lathan & Eres, 1988; Locke & Latham, 1990). Different levels of task goal difficulty will produce different levels of task motivation and consequently of performance. There are other ways of manipulating motivation as by use of incentives (e.g. monetary rewards), however, in this study the goal setting theory approach is followed and different levels of goal difficulty are used to manipulate motivation.

In order to study the effects of goal setting on performance of high and low-anxious individuals, it is important to use a task on which high-anxious individuals are unlikely to show performance deficits due to processing inefficiency, as this could confuse the effects of goals (and therefore motivation) on performance. Thus, if the task was complex, processing efficiency would probably be affected due to the effects of anxiety on the central executive. It would be difficult to separate the effects of anxiety on processing efficiency from the effects of the goals. Based on this condition it was decided to use an easy task presented under different goals conditions.

The digit symbol substitution test, which is part of the Wechsler Adult Intelligence Scale III, was chosen. This test only involves copying symbols, and it is not expected to impose demands on the central executive. This test looked adequate because it is relatively easy to have specific goals with this test, and is therefore susceptible to motivational manipulations while diminishing individual's differences in efficiency as it is an easy and straightforward task. The same easy task is presented but under different goal conditions. A slightly modified version was developed in order to

have different goal difficulty conditions. Two levels of goal difficulty were set up (high difficulty goal and low difficulty goal) as well as a no goal condition (“do your best”). The only constraints about this task were the practice effects that have been reportedly high (see Hinton-Bayre & Geffen, 2005). In order to mitigate those constraints, several measures were taken. Participants were asked to do a block of training trials, and the presentation of the different trial blocks was randomised using a Latin Square for both groups. Also, each sequence of block presentation had the same number of participants for each group, so that the learning effect was equally distributed.

In general, it is expected that in instances where a clear, difficult and achievable goal is present, commitment to achieve the goal will increase and consequently so will performance and task motivation. As a result, performance improves for both groups, but high-anxious individuals should have made an extra effort.

Goal commitment was assessed in the conditions involving a goal. Hollenbeck, Klein, O’Leary and Wright, (1989) have previously found that there is no consensus about time measuring point of goal commitment with some studies having measured it at the beginning of the task, others at the end and some at both stages. The measuring point can deeply affect the results of the goal commitment measures. When measured before the task participants do not know if they are going to achieve the goal, whereas when measured after the task participants know if the goal was achievable or not. When measured both before and after the task, goal participants might try to be consistent (Hollenbeck, Klein, O’Leary & Wright, 1989).

It was decided to measure goal commitment in the beginning of each goal as it seems to reflect the participants’ expectancies, and it would reflect how committed they

were initially to achieve each goal. In addition, it would allow a clearer way to compare differences in commitment between the two anxiety groups.

In the current study, the focus is on the effects of motivation on trait anxiety rather than state anxiety. There are two reasons for this. First, because ACT (Eysenck, et al. 2007) focuses more on the effects of anxiety on cognitive performance as a personality trait (trait anxiety) than on anxiety as a reaction to a situation/stimuli (state anxiety), since most of the studies reviewed within the theory have centred on the effects of trait anxiety rather than state anxiety (see Eysenck et al. 2007 for a review). Second, because the focus in this study is on the habitual ways of processing information rather than transient ones.

However, state anxiety was assessed before the start of the experiment and at the end of the experiment, in order to compare the participant's state anxiety levels before and after the experiment, and also to separate the effects of trait anxiety on motivation from state anxiety. State anxiety is an emotional response to stimuli or situation perceived as threatening (Rachman, 2004), and in this context it was used as a control measure to investigate if the experimental task increased the participant's levels of anxiety. State anxiety was assessed before the task, as it was important that processing efficiency would not be impaired by anxiety as it could confuse the effects of different goals and consequently of motivation on performance, this being the main reason why state anxiety was assessed in this experiment but not in all the previous. The task used in the current study was easy and was not expected to increase state anxiety considerably. However, both trait and state anxiety are highly correlated, and individuals who have high trait anxiety do tend to experience more frequent and intense state anxiety levels (Rachman, 2004).



As previously mentioned, this study aimed to test the effects of goal setting on the performance of high-anxious individuals on a simple task, in which the goals were manipulated by having two different levels of goal difficulty (low and high) and “do your best” as a no goal condition. The effects of goal setting were analysed by measuring the response times to complete the task under the conditions stated above.

Specific hypotheses included:

1. That an interaction between anxiety group and goal difficulty, (low versus high goal difficulty) would be found. The high-anxious group should have a greater improvement in terms of time taken to finish the task, when going from the low difficulty goal condition to the high difficulty goal condition.
2. That an interaction between anxiety group and “do your best” versus high goal difficulty would be found. The high-anxious group should have a greater improvement in terms of time taken to finish the task, when going from “do your best” (no goal) condition to the high difficulty goal condition.
3. That an interaction is expected between anxiety group and goal difficulty in terms of goal commitment, the high anxiety group is expected to have a greater increase in goal commitment when the goal difficulty is higher.

## Method

### *Participants*

Eighty-four undergraduate students at ISCTE-Lisbon University Institute participated in this study, of whom 61 were female and 23 male. The mean age of the participants was 22.42 ( $SD = 5.44$ ). Students were first contacted to fill in the Portuguese version of the Trait form of the State-Trait Anxiety Inventory (STAI, Spielberger, Gorsuch, & Lushene, 1970; Silva & Spielberger, 2007), while they were waiting for the class to start. They were informed that completing the questionnaire did not mean that they would necessarily participate in the study, as only some of them would be contacted to actually take part in it. Students were also informed that by participating in the study they would enter into a challenge in which 5 vouchers of 20 Euros and 1 of 50 Euros would be randomly awarded among the participants. Students were then selected to participate in the study based on their score on the Trait form of the STAI. According to the trait anxiety level reported, participants were divided into the upper and lower quartile of the sample being selected, with the high trait anxiety group scoring 45 or higher and a low trait anxiety group scoring 35 or lower. In the low-anxiety group 27 of the participants were female and 15 were male and the mean age in this group was 22.12 ( $SD = 5.03$ ). In the high-anxiety group 34 of the participants were female and 8 were male and the mean age in this group was 22.71 ( $SD = 5.86$ ).

### *Measures*

The participants were asked to complete three questionnaires; the Portuguese version of the trait form of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970; Silva & Spielberger, 2007) and the Portuguese version of

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the STAI-State Short-Form scale (Marteau & Bekker, 1992) and the Hollenbeck, Williams, and Klein (1989) scale which was translated into Portuguese. The trait form of the STAI and the STAI-State Short-Form scale are described in chapter 2 (p.72).

The Hollenbeck, Williams, and Klein (1989) scale is a self-report measure of goal commitment. This scale is generally known as the HWK scale, and it has a total of 9 items (e.g. item 1 - it's hard to take this goal seriously; item 5 - I am strongly committed to pursuing this goal). However, the authors recommend the use of a 7-item scale to assess goal commitment when it is central to research; the 7-item scale was used in the present study, with each item ranked from 1(I totally disagree) to 5 (I totally agree). A low score means low goal commitment and a high score high goal commitment. The alpha coefficient for the 7-item version of the scale is .80 (Hollenbeck, Klein, O'Leary & Wright, 1989). This scale was translated to Portuguese, and reviewed by independent researchers and a professional translator.

### *Stimuli*

The stimuli used in this experiment belong to the digit symbol substitution test that is part of the Wechsler Adult Intelligence Scale (WAIS-III); it consists of 9 different digit-symbol pairs (e.g. 1 / - ; 2 / ⊥ ... 7 / Λ; 8 / X; 9 / =). In the original test sheet, there are a total of 133 boxes with numbers to be completed. Each number box has an empty box under it where the participant should write down the corresponding symbol and the original digit symbol test coding sheet from WAIS-III was used.

In some parts of the experiment, participants were asked to complete the 133 trials of the test coding sheet. In other parts they were asked to complete only 93 trials, a bold mark on the ninety-third trial signalled up to where participants had to complete.

In the conditions with a goal, the digit symbol sheets had a green mark and blue mark to indicate approximately in which trial participants should be when 1 minute had passed (green mark) and when 2 minutes had passed (blue mark) in order to complete the trials in the 3 minutes time limit. The digit symbol pairs used in this experiment were the same as the ones in the original test. The only manipulation was in terms of instructions, the number of trials and the time to complete. Participants completed a training of 50 trials before starting the main experiment.

#### *Experimental Conditions*

*“do your best” vs. high difficulty goal* - There were two levels in this condition: A “Do your best” (no goal), in which participants were asked to do their best to fill the 133 digit symbol of the WAIS-III. There was no specific goal, and participants were not informed about any time limit (3 minutes) to complete the task. And a high difficulty goal in which participants were told that their goal was to fill the 133 trials of digit symbol (WAIS-III) in 3 minutes which was the same as in the “do your best” condition.

*Level of goal difficulty* - There were two levels of goal difficulty conditions; low difficulty goal condition (in this condition participants were told that their goal was to fill a total of 93 digit symbol of WAIS-III in 3 minutes), and a high difficulty goal condition as described above.

#### *Design*

To study goal setting, a modified version of the WAIS-III digit substitution test was used. In this modified version of the digit substitution test, there were three different conditions. Two 2x2 designs were used, one that analysed anxiety group as the between subjects’ variables versus level of goal difficulty as the within subjects

conditions (low goal vs. high goal difficulty), and another 2x2 design that analysed anxiety group versus high difficulty goal vs. “*do your best*”.

In total, participants performed 1 block for each condition (“*do your best*”, low difficulty goal, high difficulty goal), thus a total of 3 blocks was performed by each participant. The presentation of the 3 blocks was randomised using a Latin square design. The two anxiety groups had exactly the same number of participants with the same order of blocks presented to them, so that the learning effect would affect each condition equally.

### ***Procedure***

At the start of each session, the participant was invited to seat at a desk, the desk had a smooth drawing surface and on the desk there was only a pencil with no rubber (following the instructions on WAIS-III). A monitor in the desk displayed a countdown stopwatch (only in the blocks where there was a time limit). Only one participant was tested in each session.

First, the participants were presented with the information sheet and consent form. Participants were then asked to complete the Portuguese version of the STAI-State Short-Form scale (Marteau & Bekker, 1992). After that, participants performed 50 trials of training, which were taken from the original, digit symbol sheet (WAIS- III).

Participants were told that the task consisted in copying some symbols. They were told to look at the boxes in the sheet, and then it was explained that each box had a number in the upper part and a symbol in the lower part and that each number had its own symbol. The participant was asked to fill each of the empty squares with the corresponding symbol. First, the examiner showed how it was done three times and then asked the participants to complete the remaining 50 trials.

In the main experiment, instructions were given to the participants before each block. The presentation of the blocks was randomised, but for the present purposes the procedure is explained following the following order: do your best, low goal, and high goal.

In the “do your best” blocks the participants were instructed that their task was to copy the symbols to the empty boxes under each number. They were told to start when the examiner said the word “start” and to stop at the word “stop”. The examiner then asked the participants to do their best and at the word “start” the experiment started. Although there was a 3-minute time limit in this condition, participants were not informed of any time limit.

In the low difficulty goal blocks, participants were told that their goal was to copy 93 symbols into the empty boxes under each number within 3 minutes. Although the original digit symbol sheet was given to participants (133 trials), it had a mark on the 93 trial and they were advised to stop when they had reached that mark. In the high goal difficulty condition, participants were told that their goal was to fill all the empty boxes under each number in that sheet, a total of 133 symbols in 3 minutes.

In the low difficulty goal condition and in the high difficulty goal condition, there were a blue and a green mark on certain trials. Participants were informed that these marks were a reference point to inform them of approximately where they should be when 1 minute had passed and when 2 minutes had passed, so they could see if they were on target to finish the task within 3 minutes. In the low goal and the high goal conditions after the instructions participants were then asked to fill the HWK self-report measure of goal commitment (Hollenbeck, et al., 1989). In these two conditions, a

countdown stopwatch was displayed on the computer screen, programmed for a 3 minutes countdown. At the word “start” the examiner started the countdown stopwatch.

The participant’s response time was recorded by a stopwatch held by the examiner. Because of the nature of the task, the participants could get tired, so participants were given 2 minutes to rest from writing after each block. At the end of the experiment, participants completed the Portuguese version of the STAI-State Short-Form scale (Marteanu & Bekker, 1992). In total, the study did not take longer than 25 minutes.

### *Statistical analysis*

Two low-anxious participants were excluded because they misunderstood the low goal task and continued beyond the point where they should have stopped. Two more participants were recruited to replace the ones excluded, and performed exactly the same order of block presentation as the ones who were excluded. This was done so that in both anxiety groups the same number of participants had performed the same sequence of block order, for the learning effect to be equally distributed.

To calculate the average response time in the digit symbol tests for the “do your best”, low goal difficulty, and high goal difficulty conditions, the time each participant took to complete each of the conditions was divided by the number of trials completed in that condition, for simplicity the result will be called response time. Only correct trials were included in the analysis. Practice trials were not included in any analysis. The error rate was very low (less than 1%).

The SPSS statistical program was used for all the data analysis. P-values of less than 0.05 were taken to indicate statistically significant differences.

The variables were examined separately for the low-anxious group and the high-anxious group. The data was screened for univariate outliers using boxplots for both groups separately. 2 outlier cases were found in the “do your best” variable for the low-anxious group and 3 outlier cases for the high-anxious group. In the high difficulty goal variable 3 outlier cases were found for the low-anxious group and 2 for the high-anxious group. These outlier case scores were changed to one unit larger or smaller than the next most extreme score (see Tabachnick & Fidell, 2007). This method to remove outliers was selected for this experiment as it was impossible to use the 3 standard deviations generally used in reaction times data (which was used in the previous experiments). In this experiment there was only a single time measurement per participant per goal type condition. The data was screened for multivariate outliers using Mahalanobis distance, no multivariate outliers were identified, ( $M=1.95$ ,  $SD = 1.69$  high-anxious group;  $M = 1.95$ ,  $SD = 1.39$  low-anxious group). All variables were normally distributed according to Kolmogorov-Smirnoff tests.

Mixed measures *ANOVA* analyses and paired *t*-Tests (2-tailed) were conducted to look for group differences in performance (between the high-anxious and low-anxious groups). A subsequent mixed measures *ANCOVA* analysis was performed with state anxiety as a control variable, with the level of goal difficulty (high vs. low) as within subject and anxiety group as a between subject factor design.

## Results

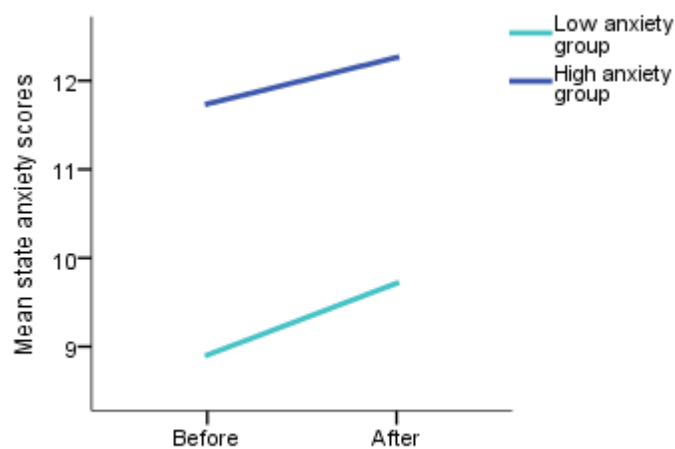
### *Trait and state anxiety measures*

Participants were divided into two groups, a high anxiety group ( $M = 51.52$ ,  $SD = 6.56$ ) and a low anxiety group ( $M = 30.33$ ,  $SD = 3.08$ ), based on their self-reported



measures of trait anxiety. State anxiety was assessed before the experiment started and after the experiment.

A 2 (high vs. low trait anxious group) X 2 (state anxiety before vs. after the experiment) mixed *ANOVA* has shown a main effect of trait anxiety, with the high-anxious group showing significantly higher state anxiety throughout the experiment than the low-anxious group [ $F(1, 82) = 26.66, p < .001, \text{partial } \eta^2 = .245$ ]. There was also a main effect of the state anxiety measurement point [ $F(1, 82) = 9.85, p = .002, \text{partial } \eta^2 = .107$ ]. The experiment significantly increased the participants levels of state anxiety (before vs. after) [ $t(83) = 3.148, p = .002$ ](see figure1). The interaction between anxiety group and state anxiety measurement point was not significant [ $F(2, 68) = .452, p = .ns$ ].



**Figure 1:** Mean state anxiety scores measured before and after the experiment for both anxiety groups.

### ***Goal Commitment measure***

A 2x2 mixed *ANOVA* was performed on the goal commitment (measured before both the low difficulty and high difficulty goals) as within subjects and anxiety group as between subjects design, with no significant results being found. There was no main

effect of goal commitment [ $F(1, 82) = 1.70., p = ns$ ] or any significant interactions, the results are unable to prove hypothesis 3 (see table 1).

*Table 1 Goal commitment means for the high and the low difficulty goal conditions in function of the group*

|                      | Anxiety group | Goal commitment |                |
|----------------------|---------------|-----------------|----------------|
|                      |               | Mean            | Std. Deviation |
| High difficulty goal | low anxiety   | 19.62           | 1.74           |
|                      | high anxiety  | 19.86           | 2.64           |
|                      | Total         | 19.74           | 2.22           |
| Low difficulty goal  | low anxiety   | 19.26           | 1.93           |
|                      | high anxiety  | 19.62           | 1.86           |
|                      | Total         | 19.44           | 1.89           |

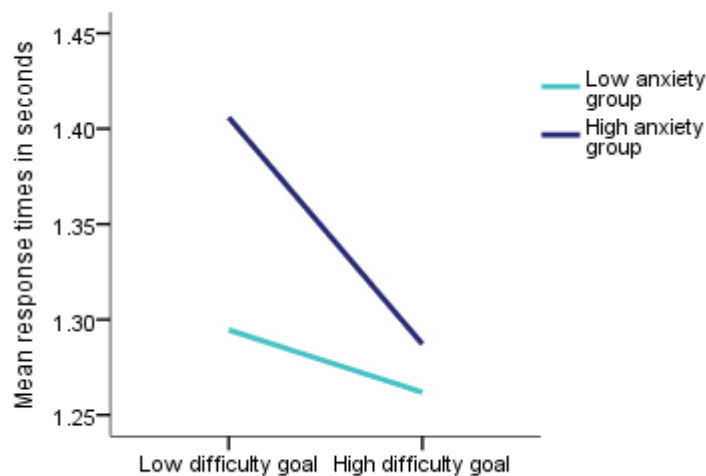
### ***Response time***

A 2x2 mixed model analysis of variance (ANOVA) was conducted on response time data, with level of goal difficulty (low difficulty goal vs. high difficulty goal) as a within subject condition and anxiety group (high vs. low anxiety) as a between subject design.

A significant main effect of the level of goal difficulty was found [ $F(1, 82) = 26.26, p < .001, \text{partial } \eta^2 = .243$ ]. In general participants' response time was slower on the low difficulty goal ( $M = 1.35s, SD = .20$ ) when compared with the high difficulty goal ( $M = 1.27s, SD = .15$ ). A marginal main effect of the anxiety group [ $F(1, 82) =$

3.84,  $p = .053$ , partial  $\eta^2 = .045$ ] was also found, the high-anxious group was in general slower ( $M = 1.35s$ ,  $SD = .16$ ) than the low-anxious group ( $M = 1.28s$ ,  $SD = .17$ ).

A significant interaction between level of goal difficulty and anxiety group was found [ $F(1, 82) = 8.48$ ,  $p = .005$ , partial  $\eta^2 = .094$ ]. To further investigate the differences between groups, a paired  $t$ -Test was performed. It was found that the high-anxious group improved response time significantly from the low difficulty goal task ( $M = 1.41s$ ,  $SD = .20$ ) to the high difficulty goal task ( $M = 1.29s$ ,  $SD = .14$ ), [ $t(41) = 5.29$ ,  $p < .001$ ] while the low-anxious group did not show a significant improvement in terms of response time from the low difficulty goal to the high difficulty goal [ $t(41) = 1.70$ ,  $p = ns$ ] in accordance with the hypothesis 1.



**Figure 2** Mean response times in seconds in the low difficulty goal and in the high difficulty goal in function of the group.

A 2x2 mixed model analysis of variance (ANOVA) was conducted on response time data, with high difficulty goal vs. “do your best” condition, as a within subject condition and anxiety group (high vs. low anxiety) as a between subject design.

However, no significant main effect of the “do your best” vs. high difficulty goal was found [ $F(1, 82) = .29$ ,  $p = ns$ ]. There was also no significant main effect of the

group [ $F(1, 82) = 1.91, p = ns$ ]. Also, no significant interaction was found between anxiety group and “do your best” vs. high difficulty goal condition, [ $F(1, 82) = 1.21, p = ns$ ] the results are unable to prove hypothesis 2.

*Table 2 Mean response times for all the conditions.*

|                      | Anxiety group | Mean (s) | Std. Deviation |
|----------------------|---------------|----------|----------------|
| “do your best”       | low anxiety   | 1.25     | .16            |
|                      | high anxiety  | 1.31     | .18            |
| Low difficulty goal  | low anxiety   | 1.29     | .18            |
|                      | high anxiety  | 1.41     | .20            |
| High difficulty goal | low anxiety   | 1.26     | .17            |
|                      | high anxiety  | 1.29     | .14            |

Subsequently, mixed measures *ANCOVA* was carried out, with the following variables; high goal difficulty and low goal difficulty as within-subject design, anxiety group as between subject factor design and state anxiety measured before and after the experiment as a covariate, in order to separate the effects of trait anxiety from state anxiety on goal setting.

The level of goal difficulty (high vs. low goal) x trait anxiety group was significant, [ $F(1, 80) = 7.84, p < .006, \text{partial } \eta^2 = .089$ ], indicating that the level of goal difficulty affected both trait anxiety groups differently. In contrast, state anxiety measured before and after the experiment did not significantly interact with level of goal difficulty ([ $F(1, 80) = 1.02, p = ns$ ] and [ $F(1, 80) = .317, p = ns$ ] respectively). Thus the covariate variable (state anxiety) cannot account for the results found.

***Error rate***

Overall the total error rate was very low, less than 1%.

There was no significant relation between error rate and response time in general ( $r = .138, p = .ns$ ). Between groups there were also no significant interaction between response time and error rate (high-anxious group  $r = .244, p = .ns$ ; low-anxious group  $r = .177, p = .ns$ ). Thus speed accuracy trade off did not affect the results.

### Discussion

The current study aimed to investigate how individual differences in anxiety and motivation affect performance, testing the assumption that to overcome the adverse effects of anxiety, high-anxious individuals exert extra effort on the task at hand, feeling more motivated to accomplish a satisfying performance. This assumption is central to both processing efficiency theory and ACT (Eysenck & Calvo, 1992; Eysenck et al., 2007).

Additionally, Eysenck and Derakshan, (2011) suggested that when the task goal is easy or no clear goal is present, the high-anxious individuals feel less motivated than when the task goals are clear and difficult. This assumption is related to the goal-setting theory of work motivation (Locke, Latham & Erez, 1988, Locke & Latham, 1990), which states that goals determine the level of task motivation. The theory predicts that high difficulty goals increase goal commitment and performance motivation while the opposite is expected in presence of low difficulty goals.

The most relevant result of the present study is that high-anxious individuals' response time significantly decreased from the low difficulty goal to the high difficulty goal, while the low-anxious group did not show a significant decrease. These results are in accordance with hypothesis 1 supporting the two-stage process suggested by Eysenck and Derakshan (2011), in which low difficulty goal tasks lead to minimal use of processing resources as motivation is minimal, while difficult/clear goal tasks lead to extra use of processing resources as motivation is high to overcome the negative effects of anxiety and achieve a reasonable performance. The results revealed that when the goal difficulty is high and the goal is clear and achievable the high-anxious group puts an extra effort to achieve the goal, as shown by a decrease on reaction times. This might

suggest that they feel more motivated than the low-anxious group to achieve the goal, putting an extra effort on the task at hand. Thus, provided that the task remains simple, and motivation is manipulated in terms of having clear and challenging goals, high-anxious individuals are likely to improve performance as they put more effort than the low-anxious. In addition, when state anxiety was covariate, it was found that state anxiety could not account for the results, eliminating the role of state anxiety in producing the results.

The goal setting theory suggests that having no clear goal or having an easy goal leads to low goal commitment and consequently low motivation, while high difficulty goals increase goal commitment and consequently motivation. However, the participants' response times did not reveal significant differences in terms of goal commitment between the high and the low difficulty goals. In addition, no significant differences were found in goal commitment between the low-anxious and high-anxious groups and were therefore unable to confirm hypothesis 3. The results might be explained by the fact that individuals can resist change, and might have resisted to change from one goal to the other, it is also possible that commitment might have affected performance but that participants were not able to report it accurately, which can be a problem when using self-reported measures as pointed out by Locke, Latham and Erez (1988). In general, goal commitment was slightly below average and it almost did not change from low goal to high goal. Since there were no differences in goal commitment in the present study, the results regarding motivation must be taken carefully as goal commitment is a component of motivation, and a determinant of performance (Meyer, Vandenberghe & Becker, 2004).

In terms of the effects of anxiety on processing efficiency, differences between the two anxiety groups were only found when the task goal difficulty was low, such that the high-anxious group had longer response times than the low-anxious group. However, when goals were manipulated by increasing goal difficulty, which has been related with increased motivation, such significant differences between groups were no longer present. These findings are in accordance with the two-stage process (Eysenck & Derakshan, 2011) and also with previous research findings. For example, Hayes, Macleod and Hammond (2009) found that during incidental learning conditions, trait anxiety had an adverse effect on performance that was no longer present during intentional learning conditions (more motivational condition). This suggests an increase in motivation with the effort increasing when a clear and difficult goal was set, compared to when the task was incidental and thus less motivational (see also Tohill & Holyoak, 2000). The findings are in accordance with the present study, which revealed that the high-anxious group increased effort when the goal difficulty was high compared to when it was low.

The participants' response time did not improve significantly from when they were asked to do their best (with no time limit or goal) to when the goal difficulty was high, and in addition, no differences between groups were found. Therefore, these findings are unable to confirm hypothesis 2. The results did not confirm the assumption that no goal or unclear task goal will lead to less task motivation and poor performance, as suggested by Eysenck and Derakshan, (2011) and by the goal setting theory (Locke & Latham 1990). The participants' response time suggest that they put a considerable effort when asked to their best. Winters and Latham (1996) found that, when asking



people to do their best in a complex task, performance improved more than setting a specific high performance goal.

In the present study, it was found that there were no significant differences between asking participants to do their best and setting a difficult goal in a simple task. Although speculative, perhaps the use of a within-participants design led participants to understand that the major emphasis was on response speed. They might have interpreted “do your best” as perform as rapidly as you possibly can, which could account for the similar performance found in both conditions (high difficulty and “do your best”).

In the present study, participants were assigned to the low or high-anxious group based on their trait anxiety scores, but the two groups also differed in terms of state anxiety. This was not unexpected since both trait and state anxiety correlate highly with each other. The task used was a very easy task, in order to minimize the effects of anxiety on processing efficiency, which could confuse the effects of goal setting on performance and it was not expected that it would increase greatly the levels of state anxiety. State anxiety significantly increased from before to the end of the experiment for the low-anxious group and marginally increased for the high-anxious. To investigate whether the differences in task performance were due to effects of anxiety trait or state, state anxiety was controlled. The results revealed that the differences shown in performance were due to trait anxiety, suggesting that it reflects a strategy to cope with the effects of anxiety as a vulnerability related with a trait dimension, rather than a reactive outcome to a stimuli or situation (state anxiety). In addition, the results are in accordance with ACT, which has focused more on the effects of trait anxiety on cognitive performance rather than state anxiety (Eysenck et al. 2007).

A limitation of the present study was the learning effect associated with the task used the digit symbol (WAIS III), measures were taken to equally distribute the learning effect. However, in future studies tasks that involve less learning effect should be used, such as the Raven progressive matrices (1938). An adaptation of this task using the easiest items could be an option.

In the present study, a within-subjects design was used due to constraints related with the large number of participants required for a between-subject design. Even though interesting findings regarding the relation between goal difficulty and task effort/motivation were revealed in this study, future studies would improve by using a between-subjects design, as it is probably the best approach to study goal setting/motivation. Each participant would perform only one of the tasks with no need to change between 3 different goals, which can generate some confusion. This might account for the fact that there were no differences in goal commitment. In addition, due to the use of within-subjects design, it is possible that in the present study participants have interpreted that major emphasis was on response speed. That would explain the similar results in the high difficulty goal and in the “do your best” conditions if participants interpreted it as perform as fast as you can. The self reported measure used to assess goal commitment was not validated for the Portuguese sample but simply translated to Portuguese from the English version, this might also have accounted for the present results. By validating a questionnaire, bias and misinterpretations are reduced as result the comparability is increased (Suri & Verma, 2010).

Overall, the results revealed that the high-anxious group improved performance significantly from the easy goal to the difficult goal condition by reducing response

time, while the low-anxious group did not show such significant improvement. That is in support of both main theories in the field of anxiety and cognitive performance, processing efficiency theory (Eysenck & Calvo, 1992) and ACT (Eysenck et al., 2007; Eysenck & Derakshan, 2011). The high-anxious group greater improvement from the low difficulty to the high difficulty goal suggests an increase in effort which might be interpreted as an increase in task motivation. However, as significant differences in goal commitment were not found, future research is needed to clarify the results. In future research a task motivation questionnaire should be included as an additional and more direct measure of motivation.

Research on anxiety and cognitive performance generally manipulates task difficulty (using a complex task) to study the effects of anxiety on performance. Results in general reveal that high-anxious individuals' performance decrease as the task complexity increases (e.g. Darke, 1988; Richard et al., 2000; Ashcraft & Kirk 2001, Experiment 3; Derakshan et al., 2009b). Difficult tasks put higher demands on the central executive and to overcome the negative effects of anxiety on performance, the high-anxious need to use extra processing resources of the central executive in order to achieve a satisfactory performance (Eysenck, et al., 2007).

In this study, the task itself remained simple but motivation was manipulated by using a no goal (*do your best*) condition, an easy goal condition or a difficult goal condition. The results suggest that, when high-anxious individuals face a difficult goal, they increase effort more than the low-anxious group, as they are likely to feel more motivated in order to achieve a good result. However, this means a use of extra resources of the central executive. So, how high-anxious individuals' performance will

be affected depends on the relative importance of effort and the executive capacity in the more difficult condition.

It is worth emphasising that the focus of most studies on anxiety and cognitive performance has been on relatively difficult tasks involving the central executive. In future, it is probably worth focusing more on easy tasks that may more readily reveal motivational differences between low- and high-anxious individuals.

# **Chapter Seven**

## **General Discussion**

This thesis aimed to investigate the effects of trait anxiety during cognitive performance having as its basis ACT's assumptions. Research literature in this area was limited in many ways and had failed to consider some of these assumptions in detail. More specifically, there had been almost no previous research on the effects of anxiety on the shifting function and the updating function. In addition, the motivational effects associated with high trait anxiety have rarely been tested experimentally. Finally, the potential impact of trait anxiety on dual-task performance has rarely been investigated systematically.

The main focus of research was on the effects of anxiety on the central executive functions, inhibition, shifting and updating. It tested the attentional control predictions that the inhibition function and the shifting functions are the ones most impaired during cognitive performance (see chapter 2, 3 and 4) as their main role is attentional control and anxiety affects attentional control efficiency (Eysenck et al., 2007). The updating function was expected to be less affected by anxiety as it is more related with short-term memory (see chapter 4). Dual-task coordination has been suggested as a possible executive function that might be involved in attentional control (Collette et al., 2005, 2006), and as such the effects of anxiety on the capacity to coordinate two different tasks concurrently were also investigated (see chapter 5). In the last empirical chapter (chapter 6) the effects of goal setting were investigated based on the ACT assumption that high-anxious individuals are more likely to feel motivated and put an extra effort to overcome the adverse effects of anxiety when the task goal is difficult compared to when the task goal is easy (Eysenck & Derakshan, 2011).

*Findings that support attentional control theory*

According to ACT, anxiety impairs the shifting function; this assumption was investigated in three different studies using a task switching paradigm (see chapter, 2, 3 and 4). In all these studies, an interaction was obtained between anxiety and task type (switching vs. repetitive). In addition, when task switching was performed the high-anxious group had consistently longer switch cost than the low-anxious. Task switching is considered a direct measure of the shifting function (Miyake et al., 2000). This task involves a cost, the cost of moving attention from one task to the other (Monsell, 2003). As predicted by ACT, high-anxious individuals were significantly slower than the low-anxious during task switching. These results are of great theoretical importance as they suggest that anxiety impairs attentional efficiency of the shifting function. This attentional control assumption has rarely been tested as research in this field has mostly focused on the effects of anxiety on the inhibition function and overlooked the effects of anxiety on the shifting function.

The present sets of results are in agreement with the few studies designed to investigate the shifting function. For example, Derakshan, Smith, and Eysenck (2009b), who investigated the effects of state anxiety on an arithmetical task switching, found that the high-anxious group had significantly longer response times on task switching than the low-anxious when task complexity was high. Ansari, Derakshan, and Richards (2008) used a mixed anti and prosaccade paradigm to investigate the effects of trait anxiety on the shifting function, and found that during task switching the low-anxious group had faster correct antisaccade latencies in task switching than in the repetitive task, while the high-anxious group did not show such improvement.

Orem, Petrac and Bedwell (2008) used the comprehensive trial-making test (CTMT) which included trials 3 and 5 (these trials have been associated with set shifting). The results revealed that participants with high stress levels were slower than participants with low stress on trial 5; suggesting that high stress affected participants in a task that required the shifting function.

Another important finding was that anxiety slowed the capacity to switch between tasks to a greater extent when the task complexity increased as only the high-anxious group significantly increased switch cost when the task complexity increased (chapter 2). Derakshan, Smith and Eysenck (2009b), had also found that anxiety slowed task switching performance only when complexity was high. This in accordance with the ACT prediction that anxiety adverse effects on efficiency of the central executive will be greater as the demands on the central executive increase (Eysenck, et al., 2007). There are numerous findings that support this assumption (e.g. Derakshan, Smith, & Eysenck, 2009b; Ashcraft & Kirk, 2001, experiment 3; for a review see Eysenck, et al., 2007).

The findings from the studies above suggest that anxiety impairs the shifting function, which is in accordance with the set of results found in the three different studies developed in this thesis. It is important to note that in all the three different studies a task switching paradigm was used to investigate the effects of anxiety on the shifting function (chapter, 2, 3 and 4). Monsell (2003) has called attention for the fact that switch cost (the cost to change from one task to another) can be affected by multiple factors, as an example it has been found that to switch from the *stronger* task (for example more practiced task) results in larger switch cost as it is more difficult to inhibit the stronger task than to inhibit the *weakest* (see Alport, et al., 1994). Task



preparation, age and many other factors also affect task switching. Overall, there are several factors that influence performance differences between task-switching and non-task-switching conditions (Monsell, 2003). It should not be assumed that task switching is a “pure process” to assess the shifting function, and it would be important to know which processes are exactly involved in the switch cost and which of those are affected by anxiety. It is for future research to explore these complexities. However, it seems reasonable to conclude that the single most important reason why performance in task-switching conditions is slower than in non-task-switching conditions is because the former involves far greater use of the shifting function than does the latter

It is important to note that two different types of task switching were used in chapter 3, an alternation task switching based in Jersild (1927) method, and an unpredictable task switching. These two task involved different task switching preparation. In accordance with Monsell (2003) in the alternation blocks participants were told before the task start that they have to alternate between “task A and B”. This imposes a considerable working memory load as participants need to keep track of the task, the author also suggests that it can also promote greater effort. Unpredictable task switching, involves the use of a cue to signal which task to perform. In the present case (chapter 3) the cue was presented simultaneously with the stimuli. The cue was the position in which the task stimuli (rows of numbers) were displayed in the screen. As the cue was presented simultaneously with the stimuli there was no cue-stimulus interval to allow for preparation. This task was considered to cause more arousal due to the unpredictable switch trails, and to the fact that the cue was presented simultaneously not allowing time to prepare.

Anxiety affected both task switching paradigms (alternating and unpredictable) (see chapter 3). These results are both interesting and new, to the best of my knowledge the effects of anxiety have not been investigated on unpredictable task switching. With predictable switching it could be argued that high-anxious individuals have their mental set for alternating tasks less strongly represented than those low in trait anxiety. However, this explanation cannot account for the high-anxious slower performance during unpredictable task switching as it is not possible to have a clear-cut pre-programmed strategy.

It would be interesting to test what would happen if during unpredictable task switching participants were given information about the upcoming task and had time to prepare for it. For example, if a cue-stimuli interval was used, would the effects of anxiety still slow performance of the high-anxious more than the low-anxious? Future research could investigate if having time to prepare before the task would decrease the effects of anxiety on efficiency of the shifting function.

There is a great need to design research to investigate the effects of anxiety on the shifting function as only a few studies in this area have been carried out. The present findings bring important information about the effects of anxiety on the capacity to shift attention, and as well providing support for the ACT.

Another finding of great theoretical importance is that anxiety was found to impair the shifting and inhibition functions when they were required simultaneously, measured by task switching in presence of the distractor. When task switching was required and the distractor was present the switch cost increased more for the high-anxious than for the low-anxious (only in chapter 2, in chapter 3 there was no significant effect of the distractor).

There have been a great number of studies that have found that the high-anxious individuals are more prone to distraction or more affected by task-irrelevant stimuli than the low-anxious (see Bar-Haim et al, 2007; Cisler & Koster, 2010 for a review). ACT explains the high-anxious individual's distractibility as an adverse effect of anxiety on attentional control. The goal-driven and the stimuli-driven attentional system interact with each other continually (see Yantis 1998, Corbetta & Shulman, 2002; Pashler, Johnston, & Ruthroff, 2001). However, anxiety disturbs the balance of this interaction, increasing the influence of the stimuli-driven over the goal-driven. Thus, it was expected that the distractor would have a greater effect on the high-anxious, especially when task switching was required because it involves a great use of attentional control to perform the task imposing considerable demands on the shifting and inhibition functions.

The present results support ACT's assumption that anxiety impairs the executive functions of shifting and inhibition, but support was only found when both executive functions were required simultaneously. It is important to note that the inhibition function, either measured by distractor inhibition (chapter 2 and 3) or by inhibition of prepotent responses (chapter 4), was not found to significantly interact with anxiety by itself (see explanation under findings that do not support ACT).

Anxiety impaired efficiency of the inhibition and shifting function when they were required together, slowing the high-anxious individuals responses more than that of the low-anxious. This confirms what was discussed above that the inhibition and shifting functions share some common processes. If these two executive functions were totally independent then it would be expected different anxiety effects on each one. These results are in accordance with several studies that found that shifting and

inhibition are separate constructs that also share some common executive processes (e.g. Miyake et al., 2000). Also it has been found that the inhibition and shifting functions activate common neural regions, but have also their preferential regions (Hedden & Gabrieli, 2010). Friedman and Miyake (2004) found that response distractor inhibition and task switching were related, such that task switching involved the capacity to select the relevant task set and use it to filter out or inhibit distraction.

These findings also indicate that high anxiety mostly has an adverse effect when the *total demands* on executive processes are high. This would be more likely to happen when inhibition and shifting are both required than when only inhibition is required. Participants had to both use attentional control in a positive way (shifting attention from one task to the other) and in a negative way (inhibiting distracting stimuli) (see Derakshan & Eysenck, 2009). However, there are a great number of studies that have found that anxiety increased distractibility in tasks that did not involve task switching as mentioned above.

Most of the research developed has either investigated the inhibition or the shifting function, the studies developed in chapter 2 and 3 were the firsts to be deliberately designed to test both functions simultaneously.

A study by Ansari, Derakshan, and Richards (2008) that aimed to study the effects of anxiety on the shifting function used mixed and single blocks of pro and/or antisaccade. Antisaccade was identified by (Miyake et al., 2000) as a good measure of the inhibition function. The differences between anxiety groups were only found in terms of a switch benefit found in the low-anxious group in the antisaccade that was not found in the high-anxious group. Their results are not as clear or strong as the results

found in chapter 2, in which a large significant increase in switch cost was found when the distractor was present for the high-anxious group but not for the low-anxious.

Anxiety was not found to impair the updating function (see chapter 4) in a letter memory task that involved constant update of strings of letters. There was no significant interaction between anxiety and the letter memory task, either on the 6 letters string or on the 8 letters strings.

ACT predicts that the updating function is affected by anxiety to a lesser extent than the inhibition and shifting functions. In accordance with the theory, the updating function is only impaired under stressful conditions (when the task is demanding) as it increases the processing demands on the central executive impairing processing efficiency and possibly processing effectiveness (quality or result of the performance) of the updating function (Eysenck et al., 2007).

The stress levels were not manipulated directly for this task as it sought to measure the effect of anxiety on the updating function by varying the level of demand on this function's resources.

The non-significant findings suggest that the updating function was not significantly impaired by anxiety. This was true both in terms of efficiency, as a consequence of extra processing resources to overcome the effects of anxiety not being needed, and of performance effectiveness, which was also not significantly affected.

The non-significant results regarding the effects of anxiety on the updating function are not completely unexpected as research on the effects of anxiety on the updating function has not provided clear results. For example, there have been several studies that have investigated the effects of anxiety using reading span memory tasks that did not find significant effects of anxiety, suggesting that anxiety does not affect

significantly the updating function (e.g. Calvo & Eysenck, 1996, see Eysenck et al., 2007 for a review). More recently, Fales, Becerril, Luking and Barch (2010) used a task that involved the updating function and measured neural activity. The results revealed that anxiety did not significantly affect neural activity or performance.

It is important to note that ACT predicts that anxiety affects the updating function to a lesser extent than the inhibition and shifting functions, because the updating function is less concerned with attentional control and more with short-term memory (Eysenck, et al. 2007). According with Miyake et al. (2000, p.56), the updating function involves monitoring and updating the working memory information by replacing old information with new and more useful information.

ACT predicts that anxiety affects the updating function only in stressful conditions. This assumption was not able to be confirmed in Chapter 4. In future, to study the updating function, stressful situations should be considered. For example, the use of scenarios that increase stress, like academic assessment, may be employed.

Another important finding regards the effects of anxiety on dual-task co-ordination. The effects of anxiety on dual-task co-ordination were investigated in chapter 5 using a single versus dual-task paradigm, and it was found that anxiety impaired dual-task co-ordination.

Dual-task co-ordination has been suggested as a possible executive function as research has found that the prefrontal and parietal areas associated with executive functioning and top-down (goal-driven) attentional control are activated during dual-task performance (see Collette, et al; 2005; 2006; Esposito et al., 1995).

Johnson and Zatorre (2006) found that it was only under dual-task conditions that there was activation of dorsolateral prefrontal cortex (this area has been associated

with executive functioning and attentional control), which suggests that that area is involved in task coordination. In addition, it was found that dual-task coordination is not associated with inhibition, shifting or updating functions, suggesting that it might be an independent executive function (Miyake, et al. 2000). Miyake et al. (2000) did not include dual-task coordination as one of the central executives functions (inhibition, shifting and updating) because dual-task and the shifting function involve similar processes, as they both involve shifting rapidly between tasks (see Duncan, 1995). The authors predicted that shifting and dual-task would be related and that dual-task would be a measure of the shifting function to some extent. However, as mentioned above dual-task was not related with any of the executive functions identified in their study.

In this thesis, dual-task coordination was investigated using a single versus dual-task paradigm (chapter 5), and it was found that anxiety impaired dual-task coordination. Anxiety significantly slowed performance of a reasoning task when performed concurrently with a face memory task. In addition, anxiety did not slow performance of the reasoning task or memory task when they were performed singly. The results found in Chapter 5 suggest that dual-task coordination is indeed a central executive function which is affected by anxiety during cognitive performance. This indicates that this executive function is involved in attentional control, which is required to co-ordinate two tasks simultaneously.

These findings suggest a development and an extension of ACT to include dual-task coordination as one of the central executive functions most affected by anxiety during cognitive performance. In addition, Miyake et al. (2000) should consider including dual-task coordination as a fourth central executive function. Dual-task versus single task paradigm brings advantages as it clearly allows us to compare performance

of the same task when performed singly to when performed concurrently with different task. This is a more accurate measure of dual-task performance than the loading paradigm which has been consistently used and just compares performance of two concurrent tasks under different demanding levels.

On the basis of the general theoretical assumptions incorporated within ACT, it seems reasonable to predict that high-anxious individuals should have an impaired ability to engage in task co-ordination within the dual-task paradigm. In that context, it is surprising that so little previous research has made use of the dual-task paradigm. In future research it would be very useful to try to identify the role played by the shifting function within the dual-task paradigm. More specifically, successful dual-task performance requires optimal switching of attention and processing resources between the two tasks as well as overall co-ordination of resources.

Another important finding regards the effects of goal setting on the performance of high-anxious individuals. Goal setting is related with task motivation, and motivation is an important component of ACT and yet explicit motivational manipulations have very rarely been used in research designed to test the ACT or its predecessor processing efficiency theory. Both theories have emphasised the use of effort and motivation as compensatory strategy used in an attempt to overcome the adverse effects of anxiety.

Goal setting was studied in chapter 6 using a simple task and different task goal levels (easy/difficult goals and no goal). The results revealed that the high-anxious group improved performance, suggesting that they were more motivated than the low-anxious group only when the task goal was difficult and clear than compared to when the goal was easy. This was shown by an improvement in response time from the easy task to the high goal difficulty task.



This suggests that when high-anxious individuals face a difficult goal they are likely to feel more motivated, increasing the effort more than the low-anxious in order to achieve a satisfactory result. However, difficult goals require extra use of processing resources; so in the end, how high-anxious individuals' performance will be affected depending on effort and processing resources available during high difficulty goals.

The results found are in accordance with the attentional control, as recently Eysenck and Derakshan, (2011) in an update to ACT suggested that when the task is undemanding or no clear goal is present the high-anxious individuals feel less motivated than when the task goal is difficult and clear. This assumption is related with the goal-setting theory of motivation (Locke, Latham & Erez, 1988, Locke & Latham, 1990) which states that goals determine the level of motivation.

In accordance, Hayes et al. (2009) found that anxiety affected performance in an incidental learning condition but not in the intentional learning condition. This suggests an increase in motivation with the effort increasing when a clear and difficult goal was set (intentional learning) compared to when the task was incidental and thus less motivational as there was no clear goal (see also Tohill & Holyoak, 2000).

It is important to note that research on anxiety and cognitive performance has mostly used difficult tasks that impose demands on the central executive (see Eysenck, et al 2007 for a review). However, to study the effects of goal setting and motivation it is probably worth focusing more in the future on easy tasks that may more readily reveal motivational differences between low and high-anxious individuals.

Overall, the results from five different studies consistently revealed that anxiety affected response time to a greater extent than accuracy, suggesting that processing efficiency was affected to a greater extent than performance effectiveness. Processing

efficiency is the relationship between the effort or resources used and the task result, and an approximate measure of processing efficiency is reaction times. On the other hand performance effectiveness is the result or quality of the performance generally measured in terms of task accuracy.

Processing efficiency is believed to decrease when more processing resources are needed in order to achieve a good task result (performance effectiveness). The effects of anxiety on processing efficiency show that the anxious individuals try to compensate the adverse effects of anxiety by putting an extra effort and using extra resources to achieve a satisfactory task performance. As the use of processing resources increase processing efficiency decrease but performance effectiveness or the result of the performance is not affected (basically at the cost of efficiency) (Eysenck, et al., 2007; Eysenck & Derakshan, 2011).

ACT followed processing efficiency theory's assumption that anxiety affects efficiency to a greater extent than effectiveness (Eysenck & Calvo, 1992), and added that processing efficiency of the shifting and inhibition functions would be most affected by anxiety (Eysenck, et al., 2007).

This thesis revealed that anxiety impaired processing efficiency of the shifting function and dual-task coordination (a possible executive function) to a greater extent than performance effectiveness. However, efficiency of the inhibition function was only affected by anxiety when the shifting function was also required, on its own the inhibition function was not found to be significantly affected by anxiety and so ACT's assumption was only partially supported (see next section on findings that do not support ACT). Anxiety did not significantly affect the updating function; however,

ACT predicts that anxiety has a lesser effect on the updating function as it is more related with short-term memory.

In accordance with the findings of this thesis, research in general has found evidence for the attentional control prediction that anxiety impairs processing efficiency more than performance effectiveness (Derakshan, Ansari, Hansard, Shoker & Eysenck, 2009; Ansari Derakshan & Richards 2008; Ansari & Derakshan 2010, 2011a, 2011b; Derakshan & Eysenck, 2009 see Eysenck & Calvo, 1992; Eysenck et al., 2007; Eysenck & Derakshan, 2011, for reviews). Much of the evidence found comes from studies that have used behavioural measures, and have assessed response times/response latencies and accuracy, as the studies developed in this thesis. It is important to note that response times are only an indirect measure of processing efficiency as they involve the relation between the effort put into to the task, the amount of processing resources used and the task result or accuracy.

A purer way of investigating the effects of anxiety on processing efficiency of the executive functions is by analysing neural activity (e.g. ERPs; fMRI) while the task is performed. Recently research has been developed based on this approach and the results generally revealed that anxiety increased brain activity while performing demanding executive tasks, while such increase was not found for the low-anxious. In addition, this increase in neural activity was found even when significant difference in response times and accuracy were not reported (e.g. Bishop, 2009; Fales et al., 2008).

In a study that investigated the attentional control prediction that high-anxious individuals use an extra effort in an attempt to compensate the negative effects of anxiety on cognitive performance, Ansari & Derakshan (2011b) used a mixed antisaccade task and found that when the interval between cue and target was medium

the antisaccade latencies improved compared to when it was short. However, during medium intervals the high-anxious group showed a greater increase in levels of contingent negative variation (CNV) on frontal sites than the low-anxious. This increase in neural activation suggested that more resources were used by to overcome the negative effects of anxiety.

Overall, in this thesis the response times do suggest that processing efficiency was affected to a greater extent than performance effectiveness (task accuracy). However, these results must be taken carefully, as response time is just an indirect measure of efficiency. Future studies analysing the adverse effects of anxiety on processing efficiency versus performance effectiveness should be addressed by measuring neural activity as it is a more pure measure of efficiency. The increase of neural activity clearly represents an increase in effort by using extra processing resources, plus it allows observing the areas more activated, given further information about the resources used.

### *Findings that do not support ACT*

The inhibition function was assessed in three different studies (chapters 2, 3 and 4) and the results have consistently shown no interactions between anxiety and distraction (chapter 2 and 3) or between anxiety and inhibition of prepotent responses (chapter 4), which is not in accordance with ACT.

When the inhibition function was assessed on its own, (measured by the capacity to inhibit the distractor) in chapters 2 and 3, anxiety was not found to impair response times significantly. These findings were unexpected, and do not support the attentional control assumption that the inhibition function is impaired by anxiety. However, there is a large amount of research that has investigated the effects of

distraction on high-anxious individuals and consistently found that distractors or task-irrelevant stimuli affect the high-anxious more than the low-anxious individuals (e.g. Hopko et al., 1998; Pacheco-Unguetti, et al., 2010; Calvo, Gutiérrez & Fernandez-Martin, 2012; see Eysenck et al., 2007, Cisler & Koster, 2010).

It is important to note that in both studies an auditory distractor was used. Research that has addressed inhibition by means of a visual distractor is very abundant, while considerable less research is found on auditory distractors. It would be interesting to investigate if anxiety has less effect on auditory distractors compared to visual.

Another possible explanation for the non-significant differences between groups found on distraction is the possibility that the high-anxious group had enough processing resources to resist distraction interference when the distractor was on its own (repetitive blocks with distractor). When the distraction was assessed during task switching anxiety was found to impair efficiency of both the inhibition and of the shifting functions.

The effects of anxiety on inhibition of prepotent responses were investigated in chapter 4 using the Hayling task (Burgess & Shallice, 1996). This task involves inhibition of prepotent responses; however the results did not reveal differences between the two anxiety groups in inhibition efficiency. As suggested above a possible explanation is also that the task did not impose enough demands on the central executive and that the high-anxious individuals had enough processing resources to cope with the adverse effects of anxiety on the inhibition. Another possible explanation is related with strategies used during the Hayling task (no-sense word condition) for example planning what word to say in the next trial. It is possible that the high-anxious

have prepared more than the low-anxious, although this is not possible to observe from the data

When the inhibition function was assessed on its own, for example when the task required to inhibit a distractor (chapter 2 and 3), or when the task involved inhibition of prepotent responses, differences were not found between the anxiety groups in efficiency of the inhibition function.

Friedman and Miyake (2004) have pointed out that there is a problem when assessing the inhibition function, as inhibition is always inhibition of something, every task that assesses this function also involves other processes. This may account to some extent for the result. To study the inhibition function, researchers have used distractor (Hopko et al., 1998), antisaccade (e.g. Derakshan, Tahereh, Hansard, Shoker & Eysenck, 2009) or Stroop paradigms (e.g. Reinholdt-Dunne, Mogg, & Bradley 2009), and research generally has found that anxiety affects the ability to inhibit task irrelevant stimuli or prepotent responses. Miyake and co-workers (2000) suggested that the antisaccade task was a good measure of the inhibition function. It is possible that the antisaccade task represents a more “pure process” task to investigate the inhibition function than the ones used in this thesis and future research should consider using this task to investigate the inhibition function.

### *Limitations*

Overall there are a few limitations that can be identified. First, the anxiety groups were only characterised based on self reported measures of trait anxiety (STAI), attentional control, gender and age, no additional measures were include to control, for example, for depression which has been largely associated with anxiety or for repressors that have been found to easily contaminate low anxiety groups. For these

reasons in future research a self reported measure of depression should be used as well as the Marlowe-Crowne social desirability scale (Crowne & Marlowe 1960), to detect repressors. Repressors can experiment the same anxiety levels as the high-anxious but they report low levels of anxiety in other words they feel the need to deceive others by not showing their true anxiety levels so they can easily contaminate the low-anxious groups. In addition, in the three studies that involved mental calculation (chapter 2, 3 and 4) a simple questionnaire to measure arithmetic ability and mental calculation could have been used as it would be interesting to know if there were differences between groups in this ability.

Second, anxiety is a continuous variable, however in order to study the effects of anxiety this variable was dichotomized into high and low anxiety groups by selecting the upper and lower quartile of the sample. This dichotomization of continuous variables as been criticised because is an artificial dichotomizing of variable that is continuous. Consequences could be loss of information about personal differences as well as generalisation and misinterpretation of the relationships between variables (Maccallum, Zhang, Preacher & Rucker, 2002).

Third, neutral stimuli were used in all the studies; however ACT predicts that both threat related and neutral stimuli can impair processing efficiency of the attention control functions. It would be interesting to investigate the effects of anxiety on the inhibition function using threat related task irrelevant stimuli on the arithmetical tasks used in chapter 2, 3 and 4. According with the theory, the capacity to inhibit task irrelevant stimuli should be greater when the stimuli are threat related than when they neutral, as long as the task demands are high. High-anxious individuals have a selective attention to threat as consequence they have more difficulty in inhibit threat related task

irrelevant stimuli because attention is captured automatically and becomes stimuli-driven impairing attentional efficiency of the inhibition function (Eysenck, et a., 2007). Thus, threatening stimuli impair performance of high-anxious individuals because the attentional resources are allocated to threat, unless the main task involves threat related stimuli (Eysenck, et al. 2007).

### *Wider implications of the current results*

Overall, the results suggest that anxiety affects the capacity to switch attention between tasks when the task is demanding. In addition the negative effects of anxiety are greater when participants are required to switch attention between tasks in presence of distractors. This suggests that, when the tasks are difficult, constant switching of attention between tasks is required and there are task distractors present, the high-anxious individuals have greater difficulty in coping with the adverse effects of anxiety on attention control. These findings can have interesting applications. For example in workplace, managers should allocate tasks that require less task switching to high-anxious individuals as they will perform repetitive tasks better, managers should also choose a more quiet desk for the high-anxious as they tend to have difficulty in coping with distraction. Managers should avoid giving tasks that require rapid and constant task switching in noisy work places as they will be especially be difficult for high-anxious to cope with.

The results also suggest that high-anxious perform better when the task goal is difficult/challenging and very clear. Managers should take this in consideration when allocating tasks to high-anxious individuals and always make sure the task goals are very clear and challenging enough to increase motivation.



*Future directions*

Three important future directions for research are suggested.

First, the emphasis in the literature has been too much on the inhibition and shifting functions and not enough on the updating function or on the possible involvement of other functions (e.g., dual-task coordination). For example, there are a considerable number of studies that have investigated the inhibition function using different paradigms and neutral or emotional stimuli. However, regarding the effects of the shifting function there is considerably less research. This thesis makes a good contribution in this field with three different task switching studies that consistently found that anxiety impaired the shifting function. In all three studies, arithmetical tasks were used. It would be important in future research to use tasks of a different nature, to investigate if the effects of anxiety would also be present in non arithmetical tasks. There is some evidence that this might be true as Ansari, Derakshan, and Richards (2008) found that anxiety affected efficiency of the shifting function in a mixed antisaccade task.

There is not enough research on the updating function and recent research has not tried to manipulate situational stress to directly test ACT's assumption that anxiety affects the updating function only on stressful situations. The updating function was investigated in this thesis; however, the results were non-significant. Thus, further research is needed to test ACT's assumptions on the updating function.

The potential involvement of other functions on the central executive should be investigated as well as the effects of anxiety on such functions. This thesis made an important contribution investigating dual-task coordination which has been purposed as a possible executive function. In accordance it was found that anxiety impaired

efficiency of dual-task coordination. It is important to clearly distinguish between dual-task coordination and the shifting function, since both functions are operative when two tasks need to be performed during the same period of time. Further research is needed to clarify which abilities or processes belong to dual-task coordination and to the shifting function and which are independent, in order to identify which executive processes are more affected by anxiety.

Second, there is a need for more research to test the relation between motivation and anxiety. Motivation is central to both processing efficiency and ACT, both of which suggest that motivation is used by the high-anxious individuals as a strategy to maintain a good task performance. Although motivation is a component of the ACT it has been disregarded by researchers, and rarely been manipulated in research designs to test the theory. This thesis makes a useful start on the relation between goal setting and anxiety as difficult and clear goals have been associated with motivation. However, there is a huge amount that remains to be discovered about the relationship between anxiety and motivation. Motivation is a complex concept and there are numerous ways in which one might attempt to manipulate motivation. High-anxious individuals may be especially motivated by various forms of ego threat (e.g., failure feedback). To understand the relation between motivation, anxiety and performance would have great practical benefits.

Third, most of the literature on the effects of anxiety on cognitive performance has focused on trait anxiety rather than on state anxiety. It is important to clearly understand how these two types of anxiety affect cognitive performance, it would be important to detach the effects of trait anxiety on performance from those of state anxiety. It could be argued that trait anxiety as a personality dimension relates to

habitual ways in which the cognitive system deals with numerous situations, whereas state anxiety is more situational and relates more to the immediate processing of threats.

Pacheco-Unguetti, Acosta, Callejas and Lupianez (2010), who investigated the effects of trait and state anxiety, found that trait anxiety seems to have more effect on the executive system when processing non-emotional/affective information. As state anxiety is situation-related it affects the attentional networks more related with vigilance or context sensitivity. The focus of ACT is on trait anxiety but there are real questions concerning the precise role of state anxiety in mediating the effects of trait anxiety on performance. Studies in which stress is manipulated are required to clearly define the difference between the roles of each.

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# Appendix

## Self Reported measures used in the study

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 Attentional Control Scale - ACS (Derryberry & Reed, 2002)

| <b>ACS</b>   |                     |
|--|---------------------|
| <b>Instructions: put a circle around the answer that characterise you more</b>   |                     |
| <b>It's very hard for me to concentrate on a difficult task when there are noises around.</b>                          | <b>almost never</b> |
|  | <b>sometimes</b>    |
|  | <b>often</b>        |
|  | <b>always</b>       |
| <b>When I need to concentrate and solve a problem, I have trouble focusing my attention.</b>                           | <b>almost never</b> |
|  | <b>sometimes</b>    |
|  | <b>often</b>        |
|  | <b>always</b>       |
| <b>When I am working hard on something, I still get distracted by events around me.</b>                                | <b>almost never</b> |
|  | <b>sometimes</b>    |
|  | <b>often</b>        |
|  | <b>always</b>       |
| <b>My concentration is good even if there is music in the room around me.</b>  | <b>almost never</b> |
|  | <b>sometimes</b>    |
|  | <b>often</b>        |
|  | <b>always</b>       |
| <b>When concentrating, I can focus my attention so that I become unaware of what's going on in the room around me.</b> | <b>almost never</b> |
|  | <b>sometimes</b>    |
|  | <b>often</b>        |
|  | <b>always</b>       |
| <b>When I am reading or studying, I am easily distracted if there are people talking in the same room.</b>             | <b>almost never</b> |
|  | <b>sometimes</b>    |
|  | <b>often</b>        |
|  | <b>always</b>       |

|   |              |
|---|--------------|
| When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.                            | almost never |
|   | sometimes    |
|   | often        |
|   | always       |
| I have a hard time concentrating when I'm excited about something.  | almost never |
|   | sometimes    |
|   | often        |
|   | always       |
| When concentrating I ignore feelings or hunger or thirst.   | almost never |
|   | sometimes    |
|   | often        |
|   | always       |
| I can quickly switch from one task to another.  | almost never |
|   | sometimes    |
|   | often        |
|   | always       |
| It takes me a while to get really involved in a new task.   | almost never |
|   | sometimes    |
|   | often        |
|   | always       |
| It is difficult for me to coordinate my attention between the listening and writing required when taking notes during lectures. | almost never |
|   | sometimes    |
|   | often        |
|   | always       |
| I can become interested in a new topic very quickly when I need to.   | almost never |
|   | sometimes    |
|   | often        |
|   | always       |

|   |              |
|---|--------------|
| It is easy for me to read or write while I'm also talking on the phone.                                       | almost never |
|   | sometimes    |
|   | often        |
|   | always       |
| I have trouble carrying two conversations at once.  | almost never |
|   | sometimes    |
|   | often        |
|   | always       |
| I have a hard time coming up with new ideas quickly.  | almost never |
|   | sometimes    |
|   | often        |
|   | always       |
| After being interrupted or distracted, I can easily shift my attention back to what I was doing before.       | almost never |
|   | sometimes    |
|   | often        |
|   | always       |
| When a distracting thought comes to mind, it is easy for me to shift my attention away from it.               | almost never |
|   | sometimes    |
|   | often        |
|   | always       |
| It is easy for me to alternate between two different tasks  | almost never |
|   | sometimes    |
|   | often        |
|   | always       |
| It is hard for me to break from one way of thinking about something and look at it from another point of view | almost never |
|   | sometimes    |
|   | often        |
|   | always       |

## STAI-State Short-Form scale (Marteau &amp; Bekker, 1992)

**Self- evaluation questionnaire (Y-6 item)**

Name

.....Date.....

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the most appropriate number to the right of the statement to indicate how you fell right now, at this moment.

There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

|                          | <b>Not at all</b> | <b>Somewhat</b> | <b>Moderately</b> | <b>Very much</b> |
|--------------------------|-------------------|-----------------|-------------------|------------------|
| <b>1. I feel calm</b>    | <b>1</b>          | <b>2</b>        | <b>3</b>          | <b>4</b>         |
| <b>2. I am tense</b>     | <b>1</b>          | <b>2</b>        | <b>3</b>          | <b>4</b>         |
| <b>3. I feel upset</b>   | <b>1</b>          | <b>2</b>        | <b>3</b>          | <b>4</b>         |
| <b>4. I am relaxed</b>   | <b>1</b>          | <b>2</b>        | <b>3</b>          | <b>4</b>         |
| <b>5. I feel content</b> | <b>1</b>          | <b>2</b>        | <b>3</b>          | <b>4</b>         |
| <b>6. I am worried</b>   | <b>1</b>          | <b>2</b>        | <b>3</b>          | <b>4</b>         |

The Portuguese version of this scale was used in (chapter 6)