AN EXAMINATION OF ATTENTIONAL CONTROL THEORY, PERCEPTUAL ANTICIPATION AND DUAL TASK PARADIGMS

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Abstract

Skilled perceptual anticipation, the capability of anticipating the actions of others and processing information under severe time- and task-constraints, is a critical component in many dynamic real-world activities and cognitive tasks, particularly in elite sporting performance. Attention Control Theory was developed, from Processing Efficiency Theory, to further explore the relationship between anxiety and its effects on performance and has specifically investigated perceptual anticipation skill. Attentional Control Theory holds that the three functions listed above are the main functions of the central executive. Accordingly, Attentional Control Theory holds that anxiety impairs attentional control; therefore, anxiety has adverse effects on the central executive (inhibition, shifting and updating functions) due to their involving attentional control. This study would attempt to explore this relationship in a more conclusive and encapsulating manner by investigating all three functions of the central executive together, while also testing perceptual anticipation in a tennis-based dual task paradigm. Multiple hypotheses were established for the following study and multiple measures were examined to examine any significant effects in attentional control and perceptual anticipation skill in low and high anxiety groups. It was predicted that anxiety would impair all functions of the central executive and perceptual anticipation skill. The results from this study offer partial support for the assumptions of Attentional Control Theory.

Introduction

The role of attentional control in sport performance has been widely researched in sport performance, particularly with regards to perceptual anticipation skill, however it has not been examined to its full capacity. Skilled perceptual anticipation, the capability of anticipating the actions of others and processing information under severe time- and task-constraints, is a critical component in many dynamic real-world activities and cognitive tasks, particularly in elite sporting performance (Rowe and McKenna, 2001; Vickers and Lewinski, 2012; Cocks, Jackson, Bishop and Williams, 2016). Sporting events can instigate increased levels of anxiety due to their capacity to pose as potentially threatening evaluative situations (Englert and Bertrams, 2012). Consequently, the execution of cognitive tasks are often hindered, leading to decrements in an individual's performance levels (Nibbeling, Daanen, Gerritsma, Hofland and Oudejans, 2012). Accordingly, the influence that anxiety exerts on an individual's sporting performance, has been one of the most fundamentally studied phenomena in social and sport psychology (Cocks, Jackson, Bishop and Williams, 2016).

To gain a better understanding of how certain cognitive actions are hindered, the entity that is anxiety must be defined along with the theories that offer a detailed explanation as to how anxiety impairs performance. Anxiety is a multidimensional entity, recognised as an aversive emotional and motivational state that occurs in situations where levels of perceived threat are high (Derakshan and Eysenck, 2009). State anxiety (the current level of anxiety experienced at a given point) is interactively reliant on the trait anxiety-situational stress relationship (Eysenck, 1992; Derakshan and Eysenck, 2009). It is habitually perceived as a state in which an individual is unable to prompt a clear behavioural response to eliminate or modify an event, object or interpretation that poses as a direct threat to a current goal (Power and Dalgleish, 1997). Individuals who exhibit high levels of anxiety often worry about this threat to a current goal, and therefore will employ a strategy to lower their levels of anxiety in an attempt to achieve that goal (Derakshan and Eysenck, 2009). Consequently, anxiety is often associated with adverse effects on the performance of cognitive tasks (see Eysenck, 1992).

The following segment of this paper will focus on the theoretical predictions of anxiety on cognitive tasks, particularly those placing significant demands on cognitive resources. There are several theories that have been proposed over the last 20 years toward explaining this process, though only two are of importance to this paper: Processing Efficiency Theory (PET; Eysenck and Calvo, 1992) and the more recent, yet major extension of Processing Efficiency Theory, Attentional Control Theory (ACT; Eysenck, Derakshan, Santos and Calvo, 2007). These theories will be explored, specifically in the domain of sport, as competitive sport offers a dynamic environment in which to test the applications of both PET and ACT, where rapid decisions are required, with concurrently high demands on perception, action and cognition (Cocks, Jackson, Bishop and Williams, 2016). Finally, the evidence relating to ACT's major hypotheses will be evaluated prior to the declaration of this study's own hypotheses.

Processing Efficiency Theory (PET)

Before exploring ACT, PET must be explored to identify the foundations that led to the development of Eysenck, Derakshan, Santos and Calvo's new theory. PET, developed by Eysenck and Calvo (1992), offered the earliest explanation towards depicting anxiety as an aversive emotional state occurring as a result of threat, consequently diverting an individual's attention toward distracting or irrelevant stimuli. The fundamental distinction in PET is between performance effectiveness and processing efficiency (Eysenck, Derakshan, Santos and Calvo, 2007). Derakshan and Eysenck (2009) define performance effectiveness as the quality of task performance (generally, response accuracy of performance), whereas processing efficiency is defined as the relationship between the performance effectiveness and the effort or resources spent in task performance. It is habitually observed that processing efficiency decreases as more resources are invested to attain a given performance level (Derakshan and Eysenck, 2009). Furthermore, Eysenck, Derakshan, Santos and Calvo (2007) predict negative effects of anxiety to have a significantly greater impact on processing efficiency compared to performance effectiveness.

Assumptions

PET is built upon two major assumptions. The first assumption is that worry is the underlying component of state anxiety responsible for the effects of anxiety impairing performance effectiveness and processing efficiency (Eysenck, Derakshan, Santos and Calvo, 2007). Worrisome thoughts use up attentional resources necessary for cognitive task demands, leaving fewer resources available for concurrent task processing (Derakshan and Eysenck, 2009). However, "… a critical assumption is that task-irrelevant processing does not necessarily have adverse effects on performance effectiveness" (Derakshan and Eysenck, 2009, pp. 169). Therefore, worrisome thoughts are assumed to enhance motivation in individuals high in anxiety to minimise the adverse effects of anxiety. Consequently, anxious individuals will enhance their efforts in an attempt to compensate for the adverse effects of anxiety on processing efficiency by utilising additional auxiliary processing resources (Eysenck, Derakshan, Santos and Calvo, 2007). If these auxiliary processing resources are available, anxiety will typically impair processing efficiency more so than performance effectiveness, however if these resources are unavailable, then performance effectiveness will be impaired (Eysenck, Derakshan, Santos and Calvo, 2007).

The second assumption of PET concerns the adverse effects of anxiety on the mechanisms and components of working memory. PET is primarily based on Baddeley's Tripartite Working Memory Model (1986), which has since expanded into a four-component model (see Baddeley, 2001). The original model dictates that the limited-capacity working memory system consists of three components: a) a modality-free central executive involved in information processing that comprises self-regulatory functions (e.g. performance monitoring, planning, and strategy selection); b) a phonological loop for the rehearsal and transient storage of verbal information; and c) a visuospatial sketchpad for the processing and transient storage of visual and spatial information. The latter two are also known as 'slave systems (Derakshan and Eysenck, 2009).

It is assumed that the main effects of worry (more generally of anxiety) are predominantly on the central executive (Eysenck, Derakshan, Santos and Calvo, 2007). Consequently, adverse effects of anxiety on performance effectiveness and processing efficiency should be greater on tasks imposing substantial demands on the processing and storage capacity of working memory (particularly the central executive). The central executive is primarily affected, yet there is a small adverse effect on the functioning of the phonological loop. Consequently, anxious individuals should exhibit impaired performance in dual task situations, where the simultaneous demands of the two tasks on the central executive are high (Derakshan and Eysenck, 2009).

There is a wide array of literature that supports these assumptions (for a review, see Eysenck *et al.,* 2007). Eysenck, Payne and Derakshan (2005) reported relatively direct evidence in their study, in which high and low trait anxious individuals performed a primary complex visuospatial task while simultaneously performing a secondary task that involved the central executive, the visuospatial sketchpad, or the phonological loop. When individuals performed the primary visuospatial task alongside a secondary task that demanded the use of the central executive, the high anxious group performed significantly worse than the low anxious group. It is important to note that Eysenck, Payne and Derakshan (2005) observed significant adverse effects of anxiety on performance *only* when the secondary task demanded the central executive. Consequently, anxiety impaired performance on both the primary and secondary tasks under this condition, meaning that the adverse effects of anxiety on primary task performance when compared to the secondary task involving the central executive cannot be accredited to strategic changes (due to anxiety) in which primary task priorities are reduced. Thus, the overall pattern of their findings suggests that anxiety reduces the central executive's available capacity; however, the phonological loop and visuospatial sketchpad are marginally affected.

Rapee (1993) reported earlier relevant evidence when exploring the effects of several tasks that varied in their demands on the central executive on worry-related thoughts. Rapee used random letter generation as a task, due to its ability to overload the central executive and use up attentional resources. The random letter generation task reduced worry-related thoughts. These results are consistent with PET, in that worry-related thoughts and the random letter generation task competed for use of the limited-capacity central executive resources. Additionally, tasks requiring minimal central executive involvement (word repetition; fixed-or-finder- key presses) failed to reduce worry-related thoughts.

Theoretical Limitations

While PET provides an early framework for explaining how anxiety impairs attentional control, processing efficiency and performance effectiveness, some of the theoretical assumptions it offers come with little explanatory power and/or precision, causing the scope of this theory to be questionable. These theoretical assumptions of PET concern the effects of distracting stimuli on anxious individuals (see Calvo and Eysenck, 1996), threat-related stimuli adversely affecting anxious and nonanxious individuals' performance rather than neutral stimuli (see Eysenck and Byrne, 1992), and anxious individuals outperforming nonanxious individuals (see Byrne and Eysenck, 1995). However, the fundamental theoretical assumption that creates the most concern is that anxiety impairs the efficiency of the central executive. This assumption is relatively imprecise. The central executive fulfils several functions that include switching attention between tasks, inhibition and selective attention (i.e. focusing attention on relevant information and processes whilst attempting to inhibit irrelevant ones), updating and checking the contents of the working memory, and coding representations in working memory for time and place of appearance (see Smith and Jonides, 1999). What PET fails to specify is if some or all of these functions are affected (Eysenck, Derakshan, Santos and Calvo, 2007). Thus, Derakshan and Eysenck (2009) deemed it necessary to extend and develop this theory further.

Attentional Control Theory (ACT)

Eysenck, Derakshan, Santos and Calvo's (2007) developed ACT as a major development of PET to build on its strengths and to address its limitations. It provides a solid framework in explaining the effects of anxiety on attention and cognitive task performance in a more systematic manner. The development of ACT has had many influences from ideas put forward (e.g. Fox, Russo and Dutton, 2002; Derryberry and Reed, 2002). These influences have strongly supported the most general assumption within ACT: that the effects of anxiety on attentional processes are of fundamental importance to an understanding of how anxiety adversely affects performance (Eysenck, Derakshan, Santos and Calvo, 2007). Power and

Dalgleish (1997) assumed that an individual experiences anxiety when a current goal is under threat, a general assumption consistent with plentiful empirical evidence. This threat to a current goal causes attention to be allocated to detecting the source of the threat and then deciding on the most appropriate response. ACT holds the assumption that attention allocated to threat-related stimuli is increased through the effects of anxiety, depicting that anxiety typically reduces attentional focus on a current task (unless it involves threat-related stimuli; Eysenck, Derakshan, Santos and Calvo, 2007). More specifically, anxiety impairs attentional control, a fundamental function of the central executive. Anxious individuals are thought to favourably allocate attentional resources to threat-related stimuli whether internal (e.g. worrisome thoughts) or external (threat-related stimuli).

Elevated levels of worry are often associated with decreased performance levels, though there are several studies in which high anxious individuals reported significantly more worry than low anxious individuals yet have performed at the same level as the low anxious individuals (e.g. Calvo and Ramos, 1989; Calvo, Alamo and Ramos, 1990). According to ACT, this pattern occurs due to worry impairing processing efficiency more so than performance effectiveness (Eysenck, Derakshan, Santos and Calvo, 2007). The only argument about this revelation is that worry is seldom manipulated explicitly yet is often only retrospectively assessed and the relationship between worry and attention has not been investigated systematically.

A further assumption that ACT holds is that attentional control is impaired by anxiety when threat-related, task-irrelevant stimuli are not present (Eysenck, Derakshan, Santos and Calvo, 2007). If an individual perceives him- or herself to be under threat and subsequently experiences anxiety, it is potentially dangerous to maintain very high attentional control to a specific stimulus. The optimal strategy would be to allocate attentional resources widely, thereby reducing attentional control with respect to an ongoing task (Eysenck, Derakshan, Santos and Calvo, 2007).

Like PET, ACT portrays a major distinction between processing efficiency and performance effectiveness, yet the central point of this new theory predicts anxiety to affect the performance of cognitive tasks via its adverse effects on attentional control, one of the central executive's major functions. It is important to understand the term 'attentional control' due to its numerous definitions. In their recent journal in which they reported new developments in ACT, Derakshan and Eysenck (2009) adopted Yantis's (1998) definition, in which there is a fundamental distinction between top-down goal-driven processes and bottom-up stimulus-driven processes.

Moving forward from Yantis's definition of attentional control, Corbetta and Shulman (2002) proclaimed that there are two attentional systems: the top-down goal-driven system (influenced by an individual's current goals, knowledge, and expectations) and the stimulus-driven system, which is influenced by salient stimuli (adopted from Yantis's definition). The top-down goal-driven system, centred in the prefrontal cortex, is involved in the top-down regulation of attention and closely resembles the cognitive control system proposed by Miller and Cohen (2001). The stimulus-driven system, which closely resembles the posterior attentional system proposed by Posner and Petersen (1990), comprises the temporo-parietal and ventral frontal cortex. As stated by Corbetta and Shulman (2002), the stimulus-driven system is recruited when 'behaviourally relevant sensory events' are detected, particularly when these events are salient. Both of these systems are assumed to interact with one another regularly (see Pashler, Johnston and Ruthruff, 2001, for a review).

ACT posits that anxiety disrupts the balance between these two attentional systems by enhancing the influence of stimulus driven bottom-up processes over the efficient top-down goal-driven processes (Derakshan and Eysenck, 2009). This involves bidirectional influences of each system on the other, for example, there is a reduced influence of the top-down goal-driven attentional system when anxiety affects the stimulus-driven attentional system through the automatic processing of threat-related stimuli (see Fox, Russo and Georgiou, 2005 for a review). Additionally, a reduced influence of goal direction on attentional processes dictates that such processes are significantly more affected by salient stimuli (Eysenck, Derakshan, Santos and Calvo, 2007). All of these effects of anxiety should be significantly greater when anxiety levels are remarkably high (e.g. under stressful conditions).

Accordingly, there is plentiful evidence demonstrating that anxiety is associated with an attentional bias for threat-related information as well as an enhanced distractibility in the presence of task-irrelevant, particularly threatening information. Additionally, there is a strong association with a failure to disengage from the processing of threat-related information (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg and Van Ijzendoorn, 2007). The assumption that anxiety increases attention to task-irrelevant stimuli, particularly threat-related) is a strong indicator that attentional focus on concurrent task demands is typically reduced by the detrimental effects of anxiety (Derakshan and Eysenck, 2009). Put simply, anxiety affects attentional control, a key function of the central executive.

Functions of the Central Executive

While anxiety affects attentional control, a fundamental function of the central executive component of the working memory, there was originally no consensus regarding the number and nature of functions of the central executive that are adversely affected (Derakshan and

Eysenck, 2009). The approach adopted by Miyake, Friedman, Emerson, Witzki, Howerter and Wager (2000) and Friedman and Miyake (2004) used latent-variable analysis (using many tasks generally regarded as using the central executive) to identify the basic control functions of the central executive. They identified three functions: inhibition, shifting and updating. Firstly, the inhibition function (also known as negative attentional control) involves the use of attentional control to resist disruption or interference from task-irrelevant stimuli (Eysenck, Derakshan, Santos and Calvo, 2007). Secondly, the shifting function (also known as positive attentional control) involves the use of attentional control to shift attention flexibly between tasks in an attempt to ensure that it remains focused on task-relevant stimuli. Lastly, the updating function involves the "… updating and monitoring of working memory representations" (Miyake *et al.*, 2000, pp. 56). This function is primarily involved with the transient storage of information, though it involves short-term memory rather than attentional control. Derakshan and Eysenck (2009) regard it as a measure of basic attentional or short-term capacity.

ACT holds that the three functions listed above are the main functions of the central executive (Eysenck, Derakshan, Santos and Calvo, 2007). Accordingly, ACT holds that anxiety impairs attentional control; therefore, anxiety has adverse effects on these functions due to their involving attentional control. The updating function is not directly affected by anxiety as it involves short-term memory more than attention. However, the other two functions are both directly involved with attentional control: inhibition uses attentional control to restrain attention from being directed to task-irrelevant stimuli, while shifting uses attentional control in a positive way to respond optimally to changing task demands (Derakshan and Eysenck, 2009). Thus, the most noteworthy assumption of ACT is that anxiety impairs the efficiency of the inhibition and shifting functions. It is worth noting that the brain areas most associated with the inhibition and shifting functions of the central executive are similar to those associated with Miller and Cohen's goal-directed attentional system (2001).

To summarise, the inhibition, shifting and updating functions are partially separable, though they are also partially interdependent in their functioning. This suggests that they all rely to some extent on the resources of the central executive or top-down goal-driven system; therefore, demands on any one function may reduce the processing resources of the central executive available for the other functions (Eysenck, Derakshan, Santos and Calvo, 2007).

Wilson (2008) has demonstrated that both PET and ACT are applicable to sporting performance. Individuals use the same attentional systems regardless of task or situation, however there are numerous fundamental differences between the research literature on the effects of anxiety on cognitive processing and performance and that on the effects of pressure on sporting performance (Groome and Eysenck, 2016). These differences must be addressed before moving towards Attentional Control Theory: Sport (ACTS).

There are two major factors that are much more apparent in sport performance research as compared to cognitive performance research (Groome and Eysenck, 2016). The first factor is a major emphasis on the effects of pressure (high vs low) on performance. This is fundamental because individual's anxiety and motivational levels are strongly influenced by pressure. The second factor is that sport performance research often compares that of experts and novices. This is fundamental because experts have developed 'automatic' response patterns and behaviours of reducing anxiety under pressure (Groome and Eysenck, 2016).

Effects of Pressure

In sport research, it is habitually assumed that performers' anxiety will be greater in high-pressure situations compared to low-pressure ones (Groome and Eysenck, 2016). Thus, a theory of sport performance needs to consider factors within individual sportspersons determining the extent to which high pressure situations create anxiety. In contrast, the emphasis in research on cognitive performance has been on between-participants' differences in trait anxiety levels (Groome and Eysenck, 2016).

Sport performance success and failure are frequently more apparent and important in high pressure, competitive sport situations as compared to cognitive tasks (Groome and Eysenck, 2016). In many sport situations, failure is immediately recognisable (e.g. a dart misses the winning double; a short putt is missed;). Additionally, sport performance failure can have fundamental importance (e.g. thwarting a professional sportspersons' lifelong ambition). Thus, an emphasis on reactions to success and failure is of greater importance to a sport performance theory as compared to a cognitive performance theory (Groome and Eysenck, 2016).

Manipulating situational pressure in sport performance research has direct implications for motivation on the plausible assumption that high pressure situations typically produce greater motivation in sportspersons than low pressure situations. However, ACT typically considers indirect effects of motivation (e.g. poor sporting performance habitually leads to minimal effort).

Expert vs Novice Performance

The emphasis in sport performance research on comparing experts and novices has various implications (Groome and Eysenck, 2016). Experts typically possess various motor skills that can be performed on demand. Consequently, expert sporting performance is often affected much less than that of novices by manipulations targeted at reducing the available resources of the central executive. Additionally, many experts have devoted thousands of hours to developing their motor skills for their respective sports (Baker and Young, 2014). Such prolonged practice (and competition experience) characteristically translates to finely developed cognitive processes and strategies, specifically designed to facilitate optimal sport performance levels. Groome and Eysenck (2016) expect the effects of heightened anxiety on these individuals to be considerably different from what typical participants experience in mainstream anxiety research (i.e. individuals high in trait anxiety).

Attentional Control Theory: Sport (ACTS)

There are two central issues that must be addressed with any adequate theory of pressure and sport performance (Groome and Eysenck, 2016). Firstly, there is the issue of how pressure influences the individual's levels of anxiety and motivation. Second is the issue of how those levels of anxiety and motivation influence performance. Typically, ACT focuses primarily on the latter issue, whereas ACTS focuses equally on both issues.

There are three key theoretical assumptions of ACT (mentioned above) that relate to the effects of anxiety on performance and are directly applicable to ACTS (Groome and Eysenck, 2016). It is assumed that anxiety impairs processing efficiency more than performance effectiveness, that anxiety reduces the efficiency of the inhibition function, and the efficiency of the shifting function also.

ACT and ACTS emphasise the important role that attentional control holds in outstanding performance (Groome and Eysenck, 2016). Typically, experts should have more efficient attentional control as compared to novices (of a specific sport). For example, Gegenfurtner, Lehtinen and Säljö (2011) compared eye movements of experts and novices in several domains (medicine, transportation and specifically sport). They found that in all domains, experts had faster first fixations on task-relevant information and fewer fixations on task-irrelevant visual areas, suggesting that experts displayed more efficient attentional control as compared to novices.

Processing Efficiency vs Performance Effectiveness

According to ACTS, adverse effects of competitive pressure will be habitually be greater on processing efficiency as compared to performance effectiveness (Groome and Eysenck, 2016). In sport performance research, processing efficiency has sporadically been assessed by relating performance effectiveness to self-reported effort. Canal-Bruland, Pijpers and Oudejans (2010) previously examined novice dart players throwing darts as a target under both low and high anxiety conditions. There were no adverse effects from anxiety on performance accuracy, however participants reported much greater mental effort under high anxiety conditions. These findings support the notion that anxiety impairs processing efficiency more so than performance effectiveness. Self-report measures are simple to use, though they can provide distorted evidence (Groome and Eysenck, 2016). Thus, it is important to examine other factors and measures such as movement kinematics and muscular activity in future studies.

ACTS represents an extension of ACT, making it more directly relevant to sport performance under pressure. These theories overlap substantially in their accounts of the adverse effects of anxiety on performance. The key distinction is that ACTS focuses much more on the factors jointly determining an individual's anxiety level in pressured situations as compared to ACT.

Though not a fully developed theory, there is a high recommendation to test the theory more thoroughly (for a full review, see Groome and Eysenck, 2016).

Attentional Control Theory Research

Circling back to ACT (some relevance to ACTS), the following section will explore previous research that has been devoted to the three functions of the attentional control.

Inhibition Function

As mentioned above, Friedman and Miyake (2004) extended the scope of the inhibition function using latent-variable analysis. They found that inhibition resists distracting interference in addition to inhibiting pre-potent responses, suggesting that this function is directly involved in maintaining task goals when confronted with environmental task-irrelevant stimuli. This function is identified as a general one involving executive control (Eysenck, Derakshan, Santos and Calvo, 2007). Other approaches have identified several different inhibition processes. Nigg (2000) identified four types of effortful inhibition: cognitive inhibition (suppression of irrelevant information from working memory); behavioural inhibition (suppression of pre-potent responses); oculomotor inhibition (suppression of reflexive saccades); and interference control (interference due to resource or stimulus competition). While these inhibition processes may be theoretically separate, Miyake *et al.* (2000) and Friedman and Miyake (2004) identified that interference control, behavioural inhibition and oculomotor inhibition appear to involve the same underlying inhibition function. This evidence postulates that the inhibition involves attentional control in a restrictive manner, preventing attentional resources from being allocated to task-irrelevant stimuli. This is of direct relevance to ACT, though it remains to be determined whether the same inhibition function is involved in other forms of inhibition.

Inhibition has been a thoroughly researched function of ACT (for a review of previous research, see Eysenck, Derakshan, Santos and Calvo, 2007), with more studies seeking to investigate the capability of this function in the domain of sport. In a recent study looking at the effects of anxiety on anticipation and visual search in dynamic, time-constrained situations, Vater, Roca and Williams (2016) expected the inhibition function would be unable to strongly inhibit task-irrelevant stimuli. Their experiment involved a visual search task where high- and low-skilled football players viewed football situations under near vs. far situation constraints and were tested under high- and low-anxiety conditions. They found the inhibition of worrying thoughts was reduced in the high-anxiety condition, which led to less efficient visual search behaviours during dynamic temporal-constrained situations. This resulted in participants generating longer response times and greater mental effort to complete the task. Accordingly, Vater, Roca and Williams provide substantial support for ACT, demonstrating that anxiety impairs processing efficiency and the possibility that top-down attentional control is impaired across different task constraints too.

Causer, Holmes, Smith and Williams (2011) had earlier investigated the predictions of ACT within a perceptual-motor context where elite shotgun shooters were tested under practice and competition conditions. They examined the effects of anxiety on attentional control and the subsequent influence on processing efficiency and performance effectiveness, predicting the adverse effects of anxiety to have a detrimental effect on performance effectiveness. They tested shotgun shooters in a field setting under both low and high anxiety conditions, where they observed significantly greater mental effort ratings in the elevated anxiety condition. Performance effectiveness, as well as processing efficiency in the high anxiety condition, declined while also demonstrating the aversive effects of anxiety on performance increases when the task demands on the central executive are increased. Overall, their findings demonstrate significant evidence that participants were unable to maintain performance effectiveness when task demands become greater, thus rendering the inhibition (and shifting) function redundant.

Shifting Function

The shifting function of ACT uses attentional control in a 'positive' way to shift the allocation of attention in order to focus on task-relevant stimuli (Eysenck, Derakshan, Santos and Calvo, 2007). Unlike the work of Miyake *et al.* (2000), and Friedman and Miyake (2004), Wager, Jonides and Reading (2004) identified in a meta-analysis that the same seven distinct brain areas were constantly stimulated across a range of diverse shifting tasks, suggesting there is a 'single' important shifting function.

Dual Task Paradigms

When testing ACT (and PET) and specifically the shifting function, researchers have commonly employed procedures that involve abstract secondary tasks or non-task-relevant stimuli in order to load the working memory and test the shifting (and inhibition) function (Runswick, Roca, Williams, Bezodis and North, 2018). Studies investigating the shifting function have predominantly used these types of 'dual task' paradigms as a vehicle to measure performance. This paradigm involves concurrently performing two tasks with performance of one or both tasks being impaired (Karatekin, Couperus and Marcus, 2004).

There are two major approaches to the study of impairment effects in the dual task paradigm. The first approach emphasises structural and processing bottlenecks, or processing stages that cannot be applied to carrying out two tasks concurrently (Pashler and Johnson, 1998). The second approach emphasises functional limitations. Studies taking this perspective often posit a hypothetical and finite entity that confines how much information an individual can process at a given point in time (Karatekin, Couperus and Marcus, 2004).

The latter approach had led to two lines of investigation. The first concerned characterising the architecture of resources i.e. the total amount of resources an individual has and whether they come from a single, undifferentiated pool or from multiple pools (Karatekin, Couperus and Marcus, 2004). The second line of research concerns how resources are allocated as an individual pays attention. The total amount of resources is not as fundamental as how an individual allocates those resources among tasks on a moment-to-moment basis depending on task instructions and that individual's needs and priorities (Karatekin, Couperus and Marcus, 2004). Rather than viewing attention as a 'resource', researchers see attention as a 'skill' (Hirst and Kalmar, 1987) and emphasise the top-down active, and flexible nature of attentional control (e.g. Meyer and Kieras, 1997).

Runswick, Roca, Williams, Bezodis and North (2018) conclude that though it is important to represent perceptual information in an accurate manner, it is also fundamental to ensure that cognitive load and working memory are targeted using representative context-specific manipulations as compared to using abstract secondary tasks in order to investigate how this affects perceptual-motor performance and interactions with anxiety. Studies that utilise dual task paradigms as a means of measuring a certain entity, using a combination of behavioural, psychophysiological, and neuroimaging methods, can have practical implications in understanding how an individual learns to divide attention efficiently across multiple tasks and how this ability may break down in pathological conditions (Karatekin, Couperus and Marcus, 2004).

Derakshan, Smyth and Eysenck (2009) performed a dual task paradigm based study in which low and high anxious participants performed arithmetical tasks under dual task or single task conditions. Relative to the shifting function, they predicted that demands on attentional control would be greater in the dual task condition compared to the single task condition. Their most significant finding was that task switching had a non-significant effect on low anxiety participants, however had a significantly detrimental effect on the performance of high anxiety participants, supporting the predictions of ACT. They found that the major difference between the dual task and single task conditions was the demands on the shifting function. Additionally, they found the significant interaction between anxiety, task type, and complexity of the task specified more closely the adverse effects on anxiety on dual tasks. More so, this three-way interaction indicated that these adverse effects of anxiety on dual task performance centred on tasks of high complexity. In conclusion, they stated that high anxiety participants may have found it more difficult to exert positive attentional control with high complexity tasks compared to low complexity tasks.

Derakshan, Smyth and Eysenck's (2009) dual task study has prompted the exploration of more dual task studies into the effects of anxiety on performance. Nibbeling, Oudejans and Daanen (2012) explored the combined effects of anxiety, cognitive load, and expertise on darts performance and gaze behaviour in a far aiming task. The study involved expert and novice darts player performing a simple dart throwing task under both low and high anxiety conditions, in a single task and dual task paradigm. Derakshan, Smyth and Eysenck manipulated anxiety by performing the dart throwing task on a climbing wall, with and without performing the secondary task. The secondary task consisted of participants counting backwards from a random number between 500-1000 in multiples of three. While principally measuring participants average dart scores, times, and their gaze behaviour, their cognitive efforts were measured using this secondary task. They found that anxiety induced a minor, yet significant decrease in dart throwing performance only in novices. Both novices and experts demonstrated increases in dart times and mental effort, and decreases in response rate in the secondary task, illustrating a detrimental effect on processing efficiency with the presence of anxiety. The anxiety-induced decrease in performance for novices was of fundamental importance, as it was accompanied by final fixations on the target which were significantly shorter and deviated off the target earlier. However, the dual task did not affect performance in any manner. Their findings provide substantial support in the area of far aiming tasks, demonstrating that anxiety affects not only processing efficiency, but sometimes performance effectiveness also. Furthermore, their findings offer support for ACT as a suitable framework for explaining the effects of anxiety and cognitive secondary tasks.

Updating Function

The third function of the central executive identified by Miyake *et al.* (2000) is updating, the ability to update and monitor working memory representations. While this function typically involves updating, monitoring is another important aspect of this function. This function "… involves the transient storage of information rather than being directly concerned with attentional control" (Eysenck, Derakshan, Santos and Calvo, 2007, pp. 339), thus the effects of anxiety are greater on inhibition and shifting compared to updating.

Compared to the two former functions, studies observing the updating function in a sport setting are scarce, with more of a direct approach to testing this function in social- and neuropsychology (for example, Proios, Asaridou and Brugger, 2008). In terms of testing this function, studies have primarily used cognitive tasks that overload the central executive, e.g. random generation tasks. Random generation requires an individual to "… produce a random sequence of items which have strong, overlearned associations, such as numbers" and "… letters of the alphabet" (Proios, Asaridou and Brugger, 2008, pp. 158). Commonly, many of the studies that have used random *number* generation tasks have used a tool called RGCalc (Towse and Neil, 1998). This software programme is unique in that many different indices are produced that correspond to the analysis of randomness.

One such example is a study performed by Audiffren, Tomporowski and Zagrodnik (2008). While not anxiety-related, they investigated the immediate and short-term effects of aerobic exercise on young adults' executive functions and processing. Participants performed a random number generation task that measured two aspects of executive function, before, during and after aerobic exercise. In this task, participants were instructed to say aloud a random number between 1 and 9, one hundred times. Participants performed the same task on the ergometer whilst not pedalling too. Audiffren, Tomporowski and Zagrodnik (2008) found that aerobic exercise has a selective influence on random number generation indices related to the ability to alternate ascending and descending runs throughout the entire exercise bout. They also found that aerobic exercise induced a shift to less effortful number generation strategy, however it has no significant influence on random number generation performance when exercise has ceased. This could be due to the primary task requiring only mechanical work, rather than demanding attentional resources.

Perceptual Anticipation and Anxiety Research

While the literature above provides an insight into the investigations on the functions of attentional control, this following section will provide examples of anxiety affecting attentional control *and* anticipation, specifically in the realm of racket sports. In an early study by Rowe and McKenna (2001), they investigated attentional demands and skilled anticipation in the domain of tennis. In the third of their three experiments, they addressed whether the anticipation skills measured in their first two experiments became more automatic as tennis experience was acquired. They assessed expert and novices using a secondary/dual task on tennis video test performance that was uniquely attention-demanding. They used random letter generation as the secondary task, due to its ability to disrupt performance in a variety of tasks and specifically uses up attentional resources. Participants were instructed to generate a random stream of letters at the rate of approximately two per second, however were instructed to avoid certain abbreviations (e.g. BBC, KFC). They predicted that video testing performance in novices would be more vulnerable to dual task decrement compared to experts. Their results supported their hypothesis, however they found that the total number of letters generated during video test performance had a negative correlation with dual task decrement.

While Rowe and McKenna (2001) have provided an initial introduction into the realm of anticipation in a sport setting, there have been studies that have since investigated the aversive effects of anxiety on an individuals' ability to perceptually anticipate, *along* with testing the assumptions of ACT, in racket sports. Recently, Alder, Ford, Causer and Williams (2016) examined the effects of low versus high anxiety training on anticipation judgements in elite badminton players. They observed the effects of low- versus high-anxiety conditions of anticipation judgements in international level badminton players. Players would face serves during video-based training (low anxiety) and then transfer to field-based conditions (high anxiety). Players were allocated to either a low anxiety training, high anxiety training, or control group in a pre-training-post-test design. Alder, Ford, Causer and Williams found that response accuracy and final fixations were both lower and shorter, respectively, in the high anxiety pre-test compared to the low anxiety pre-test. Both low and high anxiety players demonstrated greater accuracy of judgements and longer final fixations in the low anxiety post-test as compared to the pre-test and control group. In the high anxiety post-test, high anxiety players maintained accuracy when compared with the low anxiety post-test, however low anxiety players demonstrated lower accuracy. With relevance to ACT, Alder, Ford, Causer and Williams' findings offer valuable support for the theory and previous research, demonstrating that high levels of anxiety result in reduced processing efficiency as evidenced by the overall increased effort in maintaining performance outcome.

Another recent study was performed by Cocks, Jackson, Bishop and Williams (2016). They tested the assumptions of ACT by examining the aversive effects of anxiety on anticipation in a time-constrained task. Additionally, the examined the level of involvement of cognitive processes in anticipation and how they interact with anxiety. In their experiment, skilled and less-skilled tennis players anticipated the shots of opponents under both low and high anxiety conditions. This involved viewing three types of video stimuli, each one depicting a different level of contextual information, while they measured performance effectiveness (response accuracy) and processing efficiency (response accuracy divided by corresponding mental effort). Higher levels of processing efficiency were observed in skilled players as compared to their less-skilled counterparts. Processing efficiency significantly decreased under high anxiety conditions as compared to the low anxiety conditions, however there was no observed difference in performance effectiveness. Cocks, Jackson Bishop and Williams found that anxiety was most detrimental to performance in the condition that only conveyed contextual information, suggesting that anxiety may have a greater influence on high level (top-down) cognitive processes. This may have been due to a shift in attentional control. Their findings have provided limited support for ACT, demonstrating that anxiety induced greater decrements in processing efficiency compared to performance effectiveness. This was likely due to predominance of the stimulus-driven attentional system.

Runswick, Roca, Williams, Bezodis and North (2018) examined the effects of anxiety and situation-specific contextual information on attentional, behavioural, and interpretational processes supporting perceptual motor performance as propositioned by Nieuwenhuys and Oudejans (2012). They used an in situ task in which twelve skilled cricket batters played against a skilled spin bowler. Conditions were manipulated so as to induce low and high anxiety levels and influence the presence of low and high levels of situation-specific context. They found that the number of good bat-ball contacts decreased under high anxiety levels, while the number of times the ball was missed increased under high levels of situation-specific context. They also found that under high anxiety levels, participants devoted significantly greater fixations of shorter duration to more locations, however the adverse effects of anxiety were restricted to the attentional level only. Additionally, situation-specific context was only found to adversely affect performance and behavioural measures. Anxiety, cognitive load and perceptual cognitive processes were not affected. Their findings suggest that through different mechanisms from anxiety (independent of working memory load), sporting and/or cognitive performance is influenced.

Runswick, Roca, Williams, McRobert and North (2018) examined the temporal integration of visual and contextual information during skilled anticipation in skilled and less-skilled cricket batters. The participants had to anticipate ball deliveries from bowlers in a video-based simulation task, in which the footage of each bowl was occluded at ‘four-time’ points relative to ball release (pre-run, mid-run, pre-release and post-release). Participants were instructed to rate the importance of different sources of information when making their judgements at each occlusion point. They found that skilled batters had significantly greater anticipation skill, anticipating more accurately at all occlusion points as compared to the less-skilled batters. Additionally, the expert batters considered the use of both contextual and visual information to be of greater importance when anticipating as compared to the novice batters. Contextual information was used throughout the action (mostly by the expert batters) as compared to kinematic cues which were only deemed key to anticipation in the final moments of bowling sequences (i.e. immediately prior to ball release). Their findings offered further understanding into the processes underpinning skilled anticipation and unearthed protocols for designing training programmes to improve skilled anticipation.

Relating back to tennis, Murphy, Jackson and Williams (2018) performed two experiments in which skilled and less-skilled tennis players were presented with animations of rallies from real matches. These animations omitted access to specific postural information from the opponent, compelling participants to perceptually anticipate based solely on contextual information. In their first experiment, participants were instructed to anticipate the outcome of an opponent's shot under three conditions in which the sequence length (i.e. number of shots in the rally) preceding the same occluded shot was varied. Participants had to successfully anticipate the direction of the shot more accurately when the preceding shot sequence was presented than not. In their second experiment, animations that depicted the ball, the players, or both, in dynamic or stationary form, were presented to participants. They found the lowest response accuracy scores were evident in conditions in which only the ball was depicted. Their findings suggest that information from the player and ball motion is essential to provide the context under which skilled performers are able to consciously pick up information and utilise that information to perceptually anticipate more accurately than their less-skilled counterparts.

Aims and Hypotheses

There has been a clear drive towards exploring the effects of anxiety on perceptual anticipation and attentional control in competitive sport and sport and exercise science, specifically examining the inhibition and shifting functions. However, there is a lack of research on the updating function (specifically in the domain of tennis with the exception of Rowe and McKenna, 2001) and no knowledge of any previous studies that have investigated all three functions together in the same experiment in a sport setting. Therefore, this study attempted to further explore attentional control by examining all three functions of the central executive together as well as perceptual anticipation. For these reasons, this study adopted the third experiment performed by Rowe and McKenna (2001) listed above in which a tennis-related primary task was performed concurrently with a random response generation task. Again, dual task paradigms have offered significant support in impairing attentional control and perceptual anticipation among other entities/abilities.

Multiple hypotheses were established for the following study in a set order that would be straightforward to follow in the method (measures), results and discussion. The first hypothesis was that experimental conditions would elicit greater levels of anxiety compared to control conditions. This would translate to inferior perceptual anticipation performance in high anxiety participants compared to low anxiety participants. In turn, this would denote that their ability to inhibit task irrelevant stimuli had been impaired. Leading on from this, it was hypothesised that greater anxiety levels in the high complexity task (dual task paradigm) as opposed to the low complexity task (single task paradigm) would lead to impaired perceptual anticipation performance due to the greater amount of pressure to maintain performance. Similar to previous literature, it was hypothesised that participants high in state and trait anxiety levels would perform worse compared to low state and trait anxiety participants.

Anxiety impairs attentional control by increasing the influence of the stimulus-driven attentional system in relation to using dual task paradigms (Eysenck, Derakshan, Santos and Calvo, 2007). Thus, it was hypothesised that there would be an increase in mental effort in the dual task paradigm, as opposed to the single task paradigm, to maintain performance levels of perceptual anticipation and random generation performance, thus reducing processing efficiency. As dual tasks involve the use of the shifting function to positively shift between tasks, it was predicted that anxiety would impair task switching, as anxiety habitually impairs processing efficiency and performance effectiveness on tasks involving the shifting function (Eysenck, Derakshan, Santos and Calvo, 2007). Lastly, like the shifting function, it was hypothesised that anxiety would impair the inhibition and updating functions in the dual task paradigm, thus impairing random response generation performance. As anxiety habitually impairs processing efficiency (and performance effectiveness) on tasks involving the inhibition and updating functions, it was predicted that there would be a significant detrimental effect on these functions in a central executive demanding task, more so in a dual task paradigm.

Method

Participants

Forty tennis players of low skill level (M_{age} = 31.2 ± 12.8 years) participated in this study. Prior to the day of the experiment, participants completed an informed consent form and the trait scale of the state-trait anxiety inventory (STAI, Spielberger, Gorsuch, Lushene, Vagg and Jacobs, 1983). No participants were aware or familiar with any literature regarding ACT or dual task paradigms.

Apparatus

The anticipation video task was presented on a video projection unit (In house, Canterbury) using a 20-tennis shot video sequence for participants to view. An answer sheet with a scale drawing of the sports surface was used to aid the participant's responses (see Appendix 4). Measures for the random response generation task were recorded on the RGCalc software programme designed by Towse and Neil (1998). SPSS software programme (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.) was used for all data analyses once testing was complete. Trait anxiety was measured using the trait scale of the STAI prior to testing, while state anxiety was measured using the 6-item short form state scale of the Spielberger STAI (Marteau and Bekker, 1992) in between tasks. The Rating Scale of Mental Effort (RSME, Zijlstra, 1993) was used to measure and compare invested mental effort after each task.

Procedure

Participants were first instructed to complete the 6-item short form of the STAI prior to any task. Participants were then randomly selected to either perform a) anticipation primary task, or b) random response generation (RRG) primary task (both low complexity tasks), in which participants were given a practice trial of five shots to anticipate and to generate ten random numbers at a rate of 2Hz, respectively. This was actioned to reduce the possibility of any learning effect. After completion of the first primary task, participants would complete the 6-item short form of the STAI and RSME, recording their anxiety and mental effort scores, respectively. Participants would then perform their second primary task and again, complete the short form of the STAI and RSME after completing this task (regardless of order). Once both primary tasks had been completed, participants would proceed to and complete the final task, a dual task. After completing the dual task, participants would complete one more 6-

item short form of the STAI and RSME. Scores from the final 6-item short form of the STAI (post-dual task) allocated participants to either the Low State Anxiety (≤10) or High State Anxiety (≥11) responder group (see below for more details). This was required to ensure an analysis could take place (Note: Participants were originally allocated through trait anxiety scores from the trait scale of the STAI. This issue is addressed in the Discussion).

Tasks

Anticipation Primary Task

Participants viewed a video sequence of 20 different tennis scenarios. Each scenario would be a different tennis shot. Each shot was followed by a 3 second period within which the video sequence went blank. Participants were instructed to generate a response, in which participants anticipated where the ball would land on their side of the court, based upon the information offered from the video sequences. A scale drawing of half a tennis court was provided to aid their response (see Appendix 4). The required response was either A, B, C, D, E or F for 'Fault'. Fault shots were used to create a more realistic and comparable task to a real-life game, given that not every shot is 'in'.

Random Response Generation (RRG) Primary Task

For the purpose of this study, a random number generation (RNG) task was used for the RRG primary task. RNG entails participants to generate a response that is minimally associated with what preceded before. The participants were instructed to say a number between 1 and 9 out loud in a random sequence to an auditory signal produced at 2Hz for 2 minutes (same length of time as the anticipation primary task). In total, 60 responses were generated by each participant in both the random generation primary task (and later dual task). If the participant had not recorded 60 responses by the end of the 2 minutes, they were instructed to continue until completion. The importance of maintaining a consistent response rhythm was also emphasised before starting the task. To illustrate the notion of randomness (with replacement), the participants were given the analogy of picking a number out of a hat, reading it out loud, putting the number back, and then picking another continuously (Miyake *et al.*, 2000). Answers were recorded by the examiner (see Figure 1 below).

Figure 1 – RRG Primary Task (RGCalc) with response alternatives and participant's responses.

<u>*Dual Task*</u>

The final task for this study used a 'loading paradigm' dual task, in which both primary tasks listed above were performed simultaneously. While recording their answers for the anticipation component of the task, participants were again instructed to say aloud a number between 1 and 9 every 2Hz (during the blank slides of the video sequence also). This type of task was used to impose greater demands on the central executive compared to performing both primary tasks on their own. The anticipation video featured the same shots used in the first primary task, however sequence order was changed. Scores were recorded and compared with primary task scores from the single task paradigms for both the anticipation and RRG components.

Experimental Conditions

This study had two groups: a control and an experimental group. Participants in the control group performed this experiment under low stress conditions without any outside distractors that could influence their performance, whereas participants in the experimental group performed under high stress conditions. These conditions involved the manipulation of evaluative instructions and information, and participants being subject to evaluation via video recording. These stipulations were used to induce greater levels of anxiety in an attempt to disrupt their attentional control and anticipation skills. Participants were informed that:

- The anticipation tasks were a reliable indicator of talent in tennis and that their scores were transferable to their performance in a real game. Unlike the control group, participants would be given false feedback i.e. participants were informed of their scores after each task and '*how badly*' their scores compared to the other participants in the control group in order to instigate higher levels of anxiety (see Cocks, Jackson, Bishop and Williams, 2016).
- Their scores from the random generation primary task and dual task were a unique and reliable measure of determining their ability to process and update information under pressure (see Peters, Giesbrecht, Jelicic and Merckelbach, 2007).
- Their performance in all tasks (recorded on camera) was to be evaluated by a professional tennis coach and their peers, thus eliciting greater levels of anxiety (see Cocks, Jackson, Bishop and Williams 2016; Vater, Roca and Williams, 2016;

Note: All participants were informed post-testing that all video recordings were deleted).

- Their behaviour from how they performed in all of the tasks, particularly when under pressure, would be an indicator of how they behave in a group of people and/or society (see Vater, Roca and Williams, 2016).

<u>*Measures*</u>

State Anxiety:

The 6-item short form of the STAI was used to measure state anxiety levels across all tasks and pre-testing. The STAI is a self-report inventory that has proven to be a reliable and valid measure of anxiety (Spielberger, Gorsuch, Lushene, Vagg and Jacobs, 1983). These questionnaires use direct-worded items to represent the presence of anxiety in a statement such as ‘I am worried’ and reverse-worded items to represent the absence of anxiety in a statement such as ‘I feel calm’. Reverse-worded item scores (as evident in the name), were reversed when calculating total scores (i.e. scores of 1, 2, 3 and 4 were reversed to 4, 3, 2, 1, respectively). The 6-item short form of the STAI was used due to its ability to be less time consuming than its parent 20-item state scale. Previous research has shown the 6-item short form state scale to have positive internal consistency, reliability and validity when associated with its parent 20-item state scale (Tluczek, Henriques and Brown, 2009). For the 6-item short form of the STAI (and trait scale of the STAI), participants were instructed to complete a ‘Self-Evaluation Questionnaire’, *not* an anxiety questionnaire, to avoid influencing their answers in any way.

Response Accuracy:

Response accuracy was assessed based on the participant’s responses to each shot in the anticipation primary task and dual task. Response accuracy was measured as the percentage of correct responses produced by the participants (scores out of 20 in both the anticipation primary task and dual task). Response accuracy scores were assessed between the anticipation primary (low complexity) and dual (high complexity) task, as well as between low and high trait anxiety and state anxiety responder groups.

Mental Effort:

The RSME was used to measure and compare invested mental effort after each task. It is a one-dimensional subjective scale where participants estimate the effort they invested into each task (Williams, Vickers and Rodrigues, 2001) and has been "… used as an operationalisation of processing efficiency" (Zijlstra, 1993, pp. 137). The scale ranges from 0 to 150 with nine descriptive indicators (0 being *not at all effortful* and 150 being *very effortful*). Zijlstra (1993) regards the RSME score as an adequate estimation of the mental costs associated with task execution. It has been reported as a valid and reliable measure of mental effort (Veltman and Gaillard, 1996), and has demonstrated strong support for the predictions of PET and ACT (Wilson, 2008). As mentioned above, it is habitually observed that processing efficiency decreases as more attentional resources are invested to maintain a given performance level. Thus, it is predicted that the greater the score participants record, the lower their processing efficiency will be. The shifting function of ACT was measured through the RSME i.e. the greater effort participants used to maintain performance in both tasks in the dual task paradigm, the lower their processing efficiency and thus their ability to shift successfully between tasks.

Random Response Generation (RRG):

Response sequencing data was analysed using the RGCalc software programme (see Figure 2 below; Towse and Neil, 1998). Specifically, data was recorded in three ways; the use of multiple performance indices is fundamental insofar as each only measures a certain aspect of response bias:

- Random Number Generation (*RNG*) measures the frequency of response pairs i.e. how often any response alternative follows any other response alternative. *RNG* is calculated as:

$$RNG = \frac{\sum n_{ij} \log n_{ij}}{\sum n_{ij} \log n_i}$$

  Here, $\boldsymbol{n_{ij}}$ is the frequency count for each possible combination of successive responses, and $\boldsymbol{n_i}$ represents the frequency of occurrence of the *i*th response alternative. The range for the RNG score is between 0-1, where the greater repetition of the response pairs, the greater the RNG score. (For a more complete explanation of the example calculations, see Towse & Neil, 1998).

- Redundancy (*R*) is an informational measure derived from Baddeley's Information Theory (1966). This indice reflects the equality of response distribution (i.e. is each number chosen as often as equally as possible?) and as alternatives are produced with too great or small a frequency, *R* scores will increase. *R* scores are obtained as follows:

$$R = 100 \times (1 - [\log_2 n - (\Sigma(\log_2 n_i)/n]/\log_2 m))$$

  Here, $\boldsymbol{n}$ is the number of random responses produced, ***ni*** is the frequency with which the *i*th item is produced, and $\boldsymbol{m}$ is the number of response alternatives.

- Mean Repetition Gap (*MRG*) depicts quantitative measures of repetition performance from repetition distances scores. This measure is obtained via counting the number of gaps between two identical digits. The mean of this number is then calculated (Ginsburg & Karpiuk, 1994; Peters, Giesbrecht, Jelicic and Merckelbach, 2007).

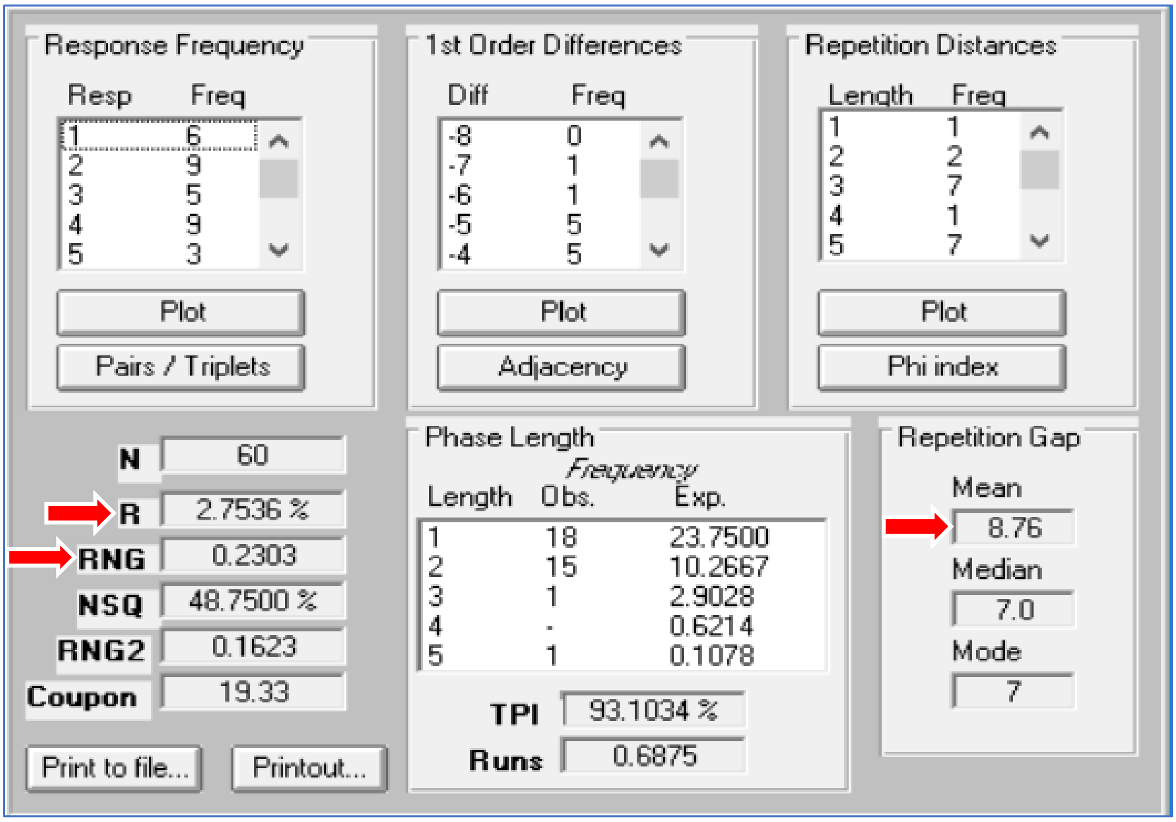

Figure 2 – Functions: Random Number Generation (RNG), Redundancy (R) and Mean Repetition Gap (MRG).

The inhibition function of ACT was measured via the indice *RNG*, while the updating function was measured via the indices *R* and *MRG*.

<u>*Data Analysis*</u>

A Paired Samples T-test was conducted to compare response accuracy scores in the anticipation primary (low complexity) and dual (high complexity) tasks. Two-way repeated measures analysis of variance (RM ANOVAs) were used to analyse response accuracy scores between low and high anxiety groups across the low and high complexity tasks. Numerous separate two-way RM ANOVAs were used to analyse state and trait anxiety, mental effort, and random response measures *RNG, R* and *MRG* across all tasks. Greenhouse-Geisser corrections were administered had Mauchly's Test of Sphericity been violated (p<0.05) otherwise Sphericity was assumed. Partial eta squared (η^2) was used as a measure of effect size for all analyses (except for response accuracy between task complexities). The α level (p) for statistical significance was set at 0.05.

Results

State Anxiety

There was a significant main effect in state anxiety scores across tasks within trait anxiety groups ($F_{1.506, 57.212} = 24.857$, $p<0.05$, $\eta^2 = 0.393$). The RRG primary task elicited a greater anxiety response as compared to the anticipation primary task, while the dual task elicited the greatest anxiety response from pre-testing (increases of 1.36 and 2.56 in the low trait anxiety control and experimental groups, respectively, and 4.9 and 2.86 in the high trait anxiety control and experimental groups, respectively). There was no significant interaction between control and experimental conditions ($p>0.05$, $\eta^2 = 0.015$). The anxiety manipulations had no significant effect within the control or experimental conditions ($F_{1.506, 57.212} = 0.036$, $p=0.929$, $\eta^2 = 0.001$).

Response Accuracy (Task Complexity)

There was a significant difference in response accuracy scores in the low complexity task (M = 52.25, SD = 11.32) and high complexity task (M = 43.88, SD = 12.06); $t_{(39)} = 5.062$, $p<0.05$.

Response Accuracy (Trait Anxiety Groups)

There was a significant main effect in response accuracy scores within the low and high complexity tasks ($F_{1, 38} = 24.307$, $p<0.05$, $\eta^2 = 0.39$). No significant interaction was revealed between trait anxiety groups ($p>0.05$, $\eta^2 = 0.001$). No significant effect was shown in response accuracy scores within the trait anxiety groups ($F_{1, 38} = 0.05$, $p=0.943$, $\eta^2 = 0.000$).

Low trait anxiety sub-groups (control and experimental) recorded greater response accuracy scores in the low (M = 52.61, SD = 10.65) and high complexity tasks (M = 44.13, SD = 11.64) compared to the high trait anxiety sub-groups (M = 51.76, SD = 12.49; M = 43.53, SD = 12.96, respectively).

Response Accuracy (Trait Anxiety Groups and State Anxiety Scores)

A significant main effect was evident in response accuracy scores within the anticipation primary and dual tasks ($F_{1, 37} = 4.73$, $p<0.05$, $\eta^2 = 0.113$). Participants recorded greater response accuracy scores in the anticipation primary task (M = 52.25, SD = 11.32) compared to the dual task (M = 43.88, SD = 12.06). There were no significant interactions between final state anxiety scores ($p>0.05$, $\eta^2 = 0.017$) or trait anxiety groups between tasks, ($p>0.05$, $\eta^2 = 0.001$). There were no significant effects evident in the low and high complexity tasks for either the trait anxiety groups ($F_{1, 37} = 0.107$, $p=0.745$, $\eta^2 = 0.003$) or final state anxiety scores post-dual task ($F_{1, 37} = 0.718$, $p=0.402$, $\eta^2 = 0.019$).

Response Accuracy (State Anxiety Responder Groups)

There was a significant main effect in response accuracy within the anticipation primary and dual tasks ($F_{1, 38} = 24.355$, $p<0.05$, $\eta^2 = 0.391$). There was no significant interaction in response accuracy scores in the anticipation primary and dual tasks between state anxiety groups, ($p>0.05$, $\eta^2 = 0.002$). No significant effect was evident in response accuracy scores within state anxiety responder groups, ($F_{1, 38} = 0.87$, $p>0.05$, $\eta^2 = 0.01$). Collectively, low state (M = 53.18, SD = 10.53) and high state anxiety (M = 51.11, SD = 12.43) responder sub-groups recorded greater response accuracy scores in the anticipation primary task compared to the dual task (M = 43.86, SD = 10.90, and M = 43.89, SD = 13.67, respectively).

Table 1 – Mean Response Accuracy (%) scores for State Anxiety Responder and State/Trait Anxiety sub-groups (standard deviation in parentheses).

Anxiety Group	Anticipation Primary Task	Dual Task
Low State	53.18 (10.53)	43.86 (10.9)
High State	51.11 (12.43)	43.89 (13.67)
Low State/Low Trait	55.63 (9.46)	45 (10.95)
Low State/High Trait	46.67 (11.25)	40.83 (11.14)
High State/Low Trait	45.71 (10.58)	42.14 (13.8)
High State/High Trait	54.55 (12.74)	45 (14.14)

Response Accuracy (State Anxiety Responder Groups and Trait Anxiety Scores)

There was a significant main effect in response accuracy within the anticipation primary and dual tasks ($F_{1, 36}$ = 17.121, p<0.05, η^2 = 0.322). No interactions were found in response accuracy scores between state anxiety responder groups (p>0.05, η^2 = 0.000), trait anxiety scores (p>0.05, η^2 = 0.000), and state anxiety responder groups*trait anxiety scores (p>0.05, η^2 = 0.078). No significant effect was revealed for response accuracy scores between state anxiety responder groups ($F_{1, 36}$ = 0.219, p=0.643, η^2 = 0.006), trait anxiety scores ($F_{1, 36}$ = 0.027, p=0.87, η^2 = 0.001), or state anxiety responder groups*trait anxiety scores ($F_{1, 36}$ = 2.269, p=0.141, η^2 = 0.059). The high state, high trait anxiety group recorded greater response accuracy scores in the anticipation primary task (M = 54.55, SD = 12.74) and dual task (M = 45, SD = 14.14) than the high state, low trait and low state, high trait anxiety sub-groups and performed to the same level as the low state, low trait anxiety sub-groups in both tasks also.

Mental Effort

There was a significant main effect in mental effort for all participants within all three tasks, ($F_{2, 76}$ = 68.733, p<0.05, η^2 = 0.644). There was no significant interaction between state anxiety responder groups and mental effort used (p>0.05, η^2 = 0.053; see Table 2). There was a significant main effect within state anxiety responder groups ($F_{2, 76}$ = 3.736, p<0.05, η^2 =

0.09). The low state anxiety responder group used greater mental effort in the anticipation primary task compared to the random generation primary task, though both state anxiety groups used significantly greater effort in the high complexity dual task.

Table 2 – Mean Mental Effort, RNG, Redundancy, and Mean Repetition Gap scores for State Anxiety Responder groups (standard deviation in parentheses).

Measures	Low State Anxiety	High State Anxiety
Mental Effort (Anticipation Primary Task)	45.23 (16.44)	45 (19.47)
Mental Effort (RNG Primary Task)	35.23 (16.22)	52.5 (26.14)
Mental Effort (Dual Task)	73.86 (19.33)	80.56 (26.4)
RNG (RNG Primary Task)	.302 (0.164)	0.288 (0.087)
RNG (Dual Task)	.313 (0.166)	.321 (0.101)
Redundancy (RNG Primary Task)	1.291 (0.729)	1.827 (0.951)
Redundancy (Dual Task)	1.868 (1.202)	3.409 (3.783)
Mean Repetition Gap (RNG Primary Task)	8.66 (0.23)	8.38 (0.43)
Mean Repetition Gap (Dual Task)	8.56 (0.37)	8.21 (0.82)

<u>*Random Response Generation*</u>

<u>*RNG*</u>

There was no significant effect in *RNG* scores in the RRG primary and dual tasks ($F_{1, 38}$ = 2.064, p=0.159, $\eta^2 = 0.052$). No interaction was found in *RNG* scores between state anxiety responder groups ($p > 0.05$, $\eta^2 = 0.000$; see Table 2). No significant effect in *RNG* scores was found either within state anxiety responder groups, $F(1, 38) = 0.584$, $p = 0.45$, $\eta^2 = 0.015$. *RNG* scores in the high state anxiety responder group (M = 0.2878, SD = 0.0873) revealed to be lower than the low state anxiety responder group (M = 0.3024, SD = 0.1636) in the RRG primary task, though the opposite was found in the dual task with the high state anxiety responder group (M = 0.3214, SD = 0.1009) being greater than the low state anxiety responder group (M = 0.3127, SD = 0.1657).

Redundancy

There was a significant main effect in *R* scores within the RRG primary and dual tasks ($F_{1, 38} = 6.503$, $p<0.05$, $\eta^2 = 0.146$). There was a significant interaction between tasks and state anxiety responder groups ($p<0.05$, $\eta^2 = 0.114$). It is clear that there was a greater detrimental effect on *R* scores in the high state anxiety responder group between the RRG primary task (M = 1.827, SD = 0.951) and the dual task (M = 3.409, SD = 3.783). No significant effect was evident within state anxiety responder groups ($F_{1, 38} = 1.412$, $p=0.242$, $\eta^2 = 0.036$). Mean *R* scores for the high state anxiety responder group in the RRG primary task (M = 1.8266, SD = 0.9509) were found to be almost equal to the low state anxiety group's *R* scores in the dual task (M = 1.868, SD = 1.2017).

Mean Repetition Gap

There was no significant effect in *MRG* scores within the random generation primary and dual tasks ($F_{1, 38} = 1.431$, $p=0.239$, $\eta^2 = 0.036$). There was a significant interaction between state anxiety responder groups ($p<0.05$, $\eta^2 = 0.181$). The switch from low to high complexity and increase in pressure to perform elicited a greater detrimental effect on *MRG* scores in the high state anxiety responder group between the RRG primary task (M = 8.38, SD = 0.43) and dual task (M = 8.21, SD = 0.82) as compared to the low state anxiety responder group (M = 8.66, SD = 0.23 and M = 8.56, SD = 0.37, respectively). No significant effect was found within state anxiety responder groups ($F_{1, 38} = 0.078$, $p=0.781$, $\eta^2 = 0.002$).

Discussion

To recap, the experiment for this study examined the effects of anxiety on attentional control and perceptual anticipation through the use of a tennis-based and random number generation task in a dual task paradigm. Like the hypotheses, measures (in method), and results sections, this discussion will follow the same order with regards to what was examined (state anxiety, response accuracy, mental effort, and random response generation).

State anxiety was the first measure to be assessed post experiment. The greatest increases in state anxiety levels from pre-testing to post-dual task were found in the high trait anxiety control and experimental sub-groups, however there was no significant effect between low and high trait anxiety groups. The low trait anxiety control sub-group displayed decreases in state anxiety levels in both primary tasks compared to pre-testing, though a major increase was observed after completion of the dual task, likely due to the greater pressure to perform. Unlike the aforementioned sub-group, the low trait anxiety experimental sub-group, showed only minor increases in state anxiety levels after completion of each of the primary tasks. An interesting finding is that state anxiety scores for both trait anxiety control sub-groups were greater than the trait anxiety experimental sub-groups. Reasons for this could be due to the lower participant count for the experimental group (sample size) not being able to yield a relatively equal comparison, or that the participants in the control group were already experiencing high levels of state anxiety prior to the start of the experiment. State anxiety scores from these tasks suggest that there was indeed an anxiety response, particularly in the dual task. Though these results offer very little support to the assumptions of ACT as no significant interaction was evident between the control and experimental conditions or the response in state anxiety levels.

As predicted, the increase in task complexity was profoundly enough to collectively impair the participants ability to perceptually anticipate, leading to reduced response accuracy scores in the dual task. Due to the nature of the dual task demanding attentional resources to be allocated to more than one task and the greater amount of pressure to maintain performance, it is assumed that as a result there was a greater influence on the stimulus-driven attentional system during completion of the dual task, as is stated in ACT (Eysenck, Derakshan, Santos and Calvo, 2007). This implies that the ability to perceptually anticipate in the dual task had been impaired.

As predicted, both the low and high trait anxiety sub-groups recorded greater response accuracy scores in the anticipation primary task as compared to the dual task. Collectively, the control group performed better than the experimental group, in both tasks. A significant decrease in performance was evident, more so in the control group compared to the experimental group, for both low and high trait anxiety sub-groups. Anticipation skill has clearly been impaired as a result of greater levels of stress and the use of a high complexity task. It is interesting to note though that the high trait anxiety control sub-group had a greater response accuracy than the low trait anxiety control sub-group (likely due to sample size). Though Janelle (2002) has earlier noted that performance levels in a given task can be matched under high stress conditions or high pressure situations. However, this will only happen if the individual works hard enough to maintain performance levels (uses greater mental effort; see below). Janelle (2002) notes that in some cases, when an individual experiences anxiety, performance levels can increase as a result of the motivational aspects of anxiety seizing the additional resources for cognitive task performance. This may explain why a select few participants were able to maintain perceptual anticipation performance. Despite this, participants in the experimental group were predicted to score significantly lower than they did. This finding does question the effectiveness of the type of anticipation task used or the manner in which it was executed, though it does provide a valuable insight into the relationship between anxiety, anticipation performance and mental effort. Again, as previously mentioned above for other findings, this could have been due to a sample size issue.

After re-evaluation of these results, statistical analyses for all measures were grouped by final state anxiety scores post-dual task, namely ‘state anxiety responders’, which were then grouped by ‘low’ (N=22) and ‘high’ (N=18) state anxiety responder groups. It was clear that the evaluative instructions given to participants under experimental conditions instigated no significant response in either trait anxiety groups, thus affecting comparisons of overall results up until this point. This was also actioned due to the aims of this study looking for significant state anxiety responses amongst participants in low and high complexity tasks. Stress condition was hence ignored.

Response accuracy was tested again by state anxiety responder groups, though again, no significant effect was found. There was a similar correlation between response accuracy scores when compared between trait anxiety and state anxiety responder groups, showing a reduction in perceptual anticipation skill in the dual task. Similar to the trait anxiety groups, is it assumed that there was a greater influence on the stimulus-driven attentional system, causing reduced perceptual anticipation skill. One outstanding finding was found in that the high state anxiety responder group performed better in the dual task as compared to the low state anxiety responder group. One explanation for this could be that high state anxiety responder group employed greater effort to maintain performance, the next measure to be discussed.

As mentioned above, Eysenck, Derakshan, Santos and Calvo (2007) claim in ACT that as more attentional resources are allocated to a specific task to maintain performance levels of a given task, the resultant effect is that processing efficiency decreases, specifically in dual task paradigms. The amount of mental effort employed to maintain performance under greater pressure increased as predicted across tasks, though there was no significant interaction between the low and high state anxiety responder groups. This keeps with Nibbeling, Oudejans and Daanens' (2012) findings in that both novices and experts demonstrated increases in mental effort and decreases in performance in the secondary task, illustrating a detrimental effect on processing efficiency with the presence of anxiety. With regards to perceptual anticipation skill, despite increased mental effort, collectively response accuracy scores decreased, potentially demonstrating a decrease in processing efficiency and performance effectiveness. There were very few participants that were able to maintain their perceptual anticipation performance, and even fewer who improved in their response accuracy scores, though this was at the expense of using greater mental effort and therefore having a reduced processing efficiency. Interestingly though, the low state anxiety group recorded a marginally greater mental effort score in the anticipation primary task compared to the high state anxiety group. Neither of these results were predicted.

Relaying back to response accuracy scores and the retaining of perceptual anticipation performance, it can be assumed that through the increase in mental effort to maintain perceptual anticipation performance, there was a detrimental 'knock off; effect on random response generation performance (explained below). Consequently, it cannot be wholly assumed that through increased mental effort from the low complexity tasks to the high complexity task that processing efficiency was significantly impaired, furthermore it cannot be assumed that the shifting function was significantly impaired also. A case can be made that the shifting function was impaired to an extent with regards to maintaining perceptual anticipation skill and random response generation performance.

To reiterate, the RGCalc software programme was used to measure random response generation performance. The task of random number generation draws on multiple executive functions, requiring the inhibition function to suppress habitual and stereotyped responses. It also requires the updating function to monitor response distribution (Miyake *et al.*, 2000). The nature and multidimensionality of the random number generation task emphasises the necessity of using multiple randomness indices in order to examine random response generation performance. This is predominantly dependent on what aspects of executive functioning one wishes to investigate (Miyake *et al.*, 2000). Findings regarding the inhibition function demonstrate no significant impairments whatsoever in the dual task when compared with the random response generation primary task. It cannot be assumed that, while performance in the dual task marginally increased *RNG* scores in both state anxiety responder groups, the inhibition function was impaired. It is likely that this is the result of no apparent influences in the goal-driven attentional system during completion of the random response generation primary and dual tasks. Another suggestion as to the scores recorded regarding the inhibition function would be participants worked harder to maintain performance, as Janelle (2002) has stated can happen.

The updating function was measured via the two indices *R* and *MRG*. An increase in *R* scores and a decrease in *MRG* scores would signify an impairment in the updating function. This was found in the shift from a random response generation primary task to the dual task. As the *R* indice is responsible for the reflection of equality of response distribution, it can be assumed that the dual task caused participants to either repeat numbers too often or completely disregard certain numbers altogether. A significant interaction was found between both state anxiety responder groups, demonstrating that the updating function was impaired in participants who experienced greater levels of state anxiety. The high state anxiety responder group recorded significantly worse *R* and *MRG* scores compared to the low state anxiety responder group. Furthermore, the high state anxiety responder group demonstrated a significantly greater decrease in performance for both indices compared to the low state anxiety group also. It can be assumed that there was a significant influence in the stimulus-driven system with regards to monitoring and updating information in this task. Evidently, the switch from the random response generation primary task to dual task was sufficient in impairing the ability to update and monitor short term memory representations, specifically increasing *R* and decreasing *MRG* scores for both state anxiety responder groups. These results suggest that the updating function was significantly impaired in the dual task.

As previously mentioned, ACT holds that as more attentional resources are allocated to a specific task to maintain performance levels in a dual task, processing efficiency and performance effectiveness typically decrease. The dual task was found to be a sufficient tool in impairing perceptual anticipation and, to an extent, attentional control. Collectively, the dual task paradigm induced greater levels of state anxiety amongst the participants in both state anxiety responder groups, more so in the high state anxiety responder group, as predicted. Taking mental effort scores into account, particularly in the dual task, this is equal. It can be assumed that participants did indeed use greater mental effort to maintain performance in the dual task due to the greater amount of pressure. This can be seen with regards to perceptual anticipation performance and the inhibition function, however, this has come at the cost of a reduced performance with regards to the shifting and updating functions. These findings demonstrate profound support that the dual task paradigm is an effective tool for influencing and impairing attentional control and perceptual anticipation skill. In this study, it can be assumed that anxiety has impaired attentional control to an extent by having a considerable influence on the stimulus-driven attentional system. To date, the updating function has not been tested in sport performance research, thus these findings regarding the updating function warrant further investigation in future studies

Future Recommendations

While this study has attempted to expand on previous studies that have investigated the adverse effects of anxiety on perceptual anticipation performance and support the assumptions of ACT (Eysenck, Derakshan, Santos and Calvo, 2007) in a sport setting, this study clearly had its issues with regards to the methodology, the sample size for anxiety groups not generating significant data, and thus the results and unfulfilled hypotheses that came as a result. The evaluative instructions given to participants in the experimental group did not have the impact that was intended on participant's state anxiety levels. There are many methods in which evaluative instructions and manipulation of tasks can instigate greater anxiety levels and this would be something to critically look into should this type of method be used again (see Vater, Roca and Williams, 2016). One such example would be to have a tennis coach or peer present for observation throughout the testing, in the hope of eliciting a greater state of worry and anxiety, and a more detrimental effect on perceptual anticipation performance.

As previously mentioned, results could have been different had there been a greater sample size, which could have generated a different effect collectively between the control and experimental groups, and respective sub-groups. While these reasons have restricted the outcome of potentially significant results, it is important to note that prior to any testing, the control sub-groups displayed relatively high state anxiety scores, though again this may also be a sample size issue also. It is highly recommended that if this study were to be repeated, a larger sample size is an absolute priority to allow for a more ecologically valid comparison of data and results.

The perceptual anticipation component of the methodology was intended for participants to position themselves in an actual live tennis match scenario. With regards to testing perceptual anticipation performance further, this can be improved by adopting the work of Cocks, Jackson, Bishop and Williams (2016). Their study, in which participants are actively engaged in the task, used a life-sized display, in which video sequences of random tennis shots were projected onto a wall, while participants were positioned four metres away from the screen. Four areas, representing the four areas of the participant's side of the court where the ball would land, were marked out at the participant's feet. Following each individual shot, participants were instructed to step into the area they anticipated the ball would land in, stating the number (1, 2, 3 or 4) of that area. As the participants are physically exerting themselves (to a minor extent), this type of task clearly offers a more holistic approach as they are actively engaging in the naturalistic movements associated with tennis.

Due to the frankness of the method used in this study, in which an anticipation task was used in conjunction with only neutral task-irrelevant stimuli (random generation component of the dual task) and no threatening stimuli, it is difficult to evaluate an individual's perceptual anticipation skill further. One such method would be measuring and tracking eye movements. The antisaccade task was identified by Miyake *et al.* (2000) as a prime example. Hallet (1978) found that when predicting anxiety to impair the efficiency of attentional control involving the inhibition function, it could be tested more directly using the antisaccade task due to it involving the measurement of an individual's eye movements. The task involves two visual cues, one presented to the left and one to the right of the fixation point. The individual is instructed to make an eye movement to the opposite side of the visual cue as quickly as possible. One of the main dependent variables (of interest) is the latency of the first saccade to the correct side. A control task is also included known as the pro-saccade task, where an individual is instructed to fixate on the cue when it appears. This type of task can be transferred to testing the inhibition function *and* perceptual anticipation skill in a more critical manner. Wilson, Wood and Vine's (2009) recent study into anxiety impairing performance in penalty kicks used a gaze registration system in which fixations to target locations (goal area and goalkeeper) were verified using frame-by-frame analysis. Like the antisaccade task, in which an individual's eye movements are measured (Hallet, 1978), the measuring of eye movements in a tennis simulated task would provide more explanatory findings, in which the eye fixations can generate a consensus of how an individual performs. This consensus would be able to observe whether the individual focuses on the swing of the racket, the opponent's body position prior to the swing, or if that individual is simply following the flight of the ball. Additionally, the inclusion of any form of threatening stimuli could be used to assess an individual's performance even further. This could determine the allocation of attentional resources in the preparation phase of their return shot. This type of secondary task would have greater implications for ACT and potentially ACTS.

Another suggestion for future studies looking to build on what has been achieved with this study, would be to utilise the temporal occlusion paradigm. This procedure allows the exploration of how much time is necessitated for an individual to visually identify the environmental contextual information that individual uses to perform a skill (in this case, make a decision as to the appropriate shot to make or the most appropriate area to aim their shot at; Magill, 2007). Cocks, Jackson, Bishop and Williams (2016) used this paradigm in their study and were able to generate 144 test stimuli. These included 48 match situations (12 for each of the directional outcomes; short right, short left, deep right, deep left) in three contextual conditions; postural cue only (shot was occluded at ball-racket contact), animation, and wide angle (the latter two began from the serve through to the occlusion of target shot at racket-ball contact). In the instance of this study, videos of the scenarios could be occluded at the point the attacker receives the ball, rather than before the attacker receives the ball. This would offer the participants a more realistic scenario, due to the unpredictability and nature of tennis. Hence, employing this paradigm would be a more effective method in testing the assumptions of ACT and ACTS.

As previously mentioned in the research section, there have been studies that have already tested the assumptions of ACT *and* perceptual anticipation in tennis (see Alder, Ford, Causer and Williams, 2016; Cocks, Jackson, Bishop and Williams, 2016). While this methodological design is relevant to tennis only, future studies could adopt this design and implement scenarios relevant to other sports. Future studies could extend the scope of testing perceptual anticipation into the realm of contact sports, particularly rugby, football and American football. Due to the nature of these team sports, including multiple opponents and the demand to make rapid decisions, this would be a viable area in sport to test perceptual anticipation. With regards to ACT, Wood (2010) has previously stated that future research may wish to test the assumptions of ACT and (ACTS, Groome and Eysenck, 2016) in more dynamic situations in the realm of sport, in which the inhibition of attentional resources towards threatening stimuli (opponents) and shifting of attentional resources between task-relevant stimuli (teammates) could be tested more thoroughly.

With regards to the updating function, future studies should look to use 'in game' situations as a vehicle to improving an individuals' ability to update and process information, thus improving decision making and sporting performance. Such examples could use team game scenarios as providing an individual with previous penalty kicks by the same footballer to revise for a penalty shootout, or providing multiple scenarios of rugby line-outs to better an individuals' decision making and defensive ability. This would be invaluable in testing ACT and ACTS.

Conclusion

Despite the limitations in findings and the critical analysis of the methodology not fulfilling its intended purposes, this study has offered a fresh insight into testing all of the assumptions of ACT and perceptual anticipation skill in dual task paradigms. The primary concern regarding the methodology was the evaluative instructions given to participants in the high stress conditions, which in turn instigated a re-evaluation of data analysis. With regards to the hypotheses presented at the start of the study, it can be assumed that the current experiment was insufficient in attaining the required results to support all of the hypotheses. Nevertheless, a select few of the hypotheses have been proven and thus provided relatively mild support for the assumptions for ACT. Perceptual anticipation skill was found to be significantly reduced under high pressure conditions and in the dual task. Interestingly, the least investigated function, updating, was found to be one of the highlighting elements of the study, showing critical impairment in the dual task paradigm, whereas the inhibition and shifting functions are open to further research in this type of study. The use of a dual task paradigm to test the assumptions of ACT has proven to be a useful tool, demonstrating minor and major impairments in multiple functions of attentional control, and used in conjunction with testing perceptual anticipation, has offered a unique and effective manner to testing sporting skills. While it cannot be wholly assumed that attentional control was significantly impaired in this study, there are interesting findings that have unearthed new pathways into the realm of testing ACT, ACTS, perceptual anticipation, and dual task paradigms, and thus improving sporting performance for future endeavours.

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Appendix 1 – Trait Subscale of State Trait Anxiety Inventory (STAI, Spielberger et al., 1983).

SELF-EVALUATION QUESTIONNAIRE

STAI Form Y-2

Name____ Date_________

DIRECTIONS

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you *generally* feel. 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 how you generally feel.

	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21. I feel pleasant	1	2	3	4
22. I feel nervous and restless	1	2	3	4
23. I feel satisfied with myself	1	2	3	4
24. I wish I could be as happy as others seem to be	1	2	3	4
25. I feel like a failure	1	2	3	4
26. I feel rested	1	2	3	4
27. I am "calm, cool, and collected"	1	2	3	4
28. I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
29. I worry too much over something that really doesn't matter	1	2	3	4
30. I am happy	1	2	3	4
31. I have disturbing thoughts	1	2	3	4
32. I lack self-confidence	1	2	3	4
33. I feel secure	1	2	3	4
34. I make decisions easily	1	2	3	4
35. I feel inadequate	1	2	3	4
36. I am content	1	2	3	4
37. Some unimportant thought runs through my mind and bothers me	1	2	3	4
38. I take disappointments so keenly that I can't put them out of my mind	1	2	3	4
39. I am a steady person	1	2	3	4
40. I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

Appendix 2 – Six-Item Short-Form of Spielberger STAI (Marteau and 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 feel **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.

Pre-Testing Score:

	Not at all	Somewhat	Moderately	Very much
1. I feel calm	1	2	3	4
2. I am tense	1	2	3	4
3. I feel upset	1	2	3	4
4. I am relaxed	1	2	3	4
5. I feel content	1	2	3	4
6. I am worried	1	2	3	4

Post-Primary Task 1 Score:

	Not at all	Somewhat	Moderately	Very much
1. I feel calm	1	2	3	4
2. I am tense	1	2	3	4
3. I feel upset	1	2	3	4
4. I am relaxed	1	2	3	4
5. I feel content	1	2	3	4
6. I am worried	1	2	3	4

Post-Primary Task 2 Score:

	Not at all	Somewhat	Moderately	Very much
1. I feel calm	1	2	3	4
2. I am tense	1	2	3	4
3. I feel upset	1	2	3	4
4. I am relaxed	1	2	3	4
5. I feel content	1	2	3	4
6. I am worried	1	2	3	4

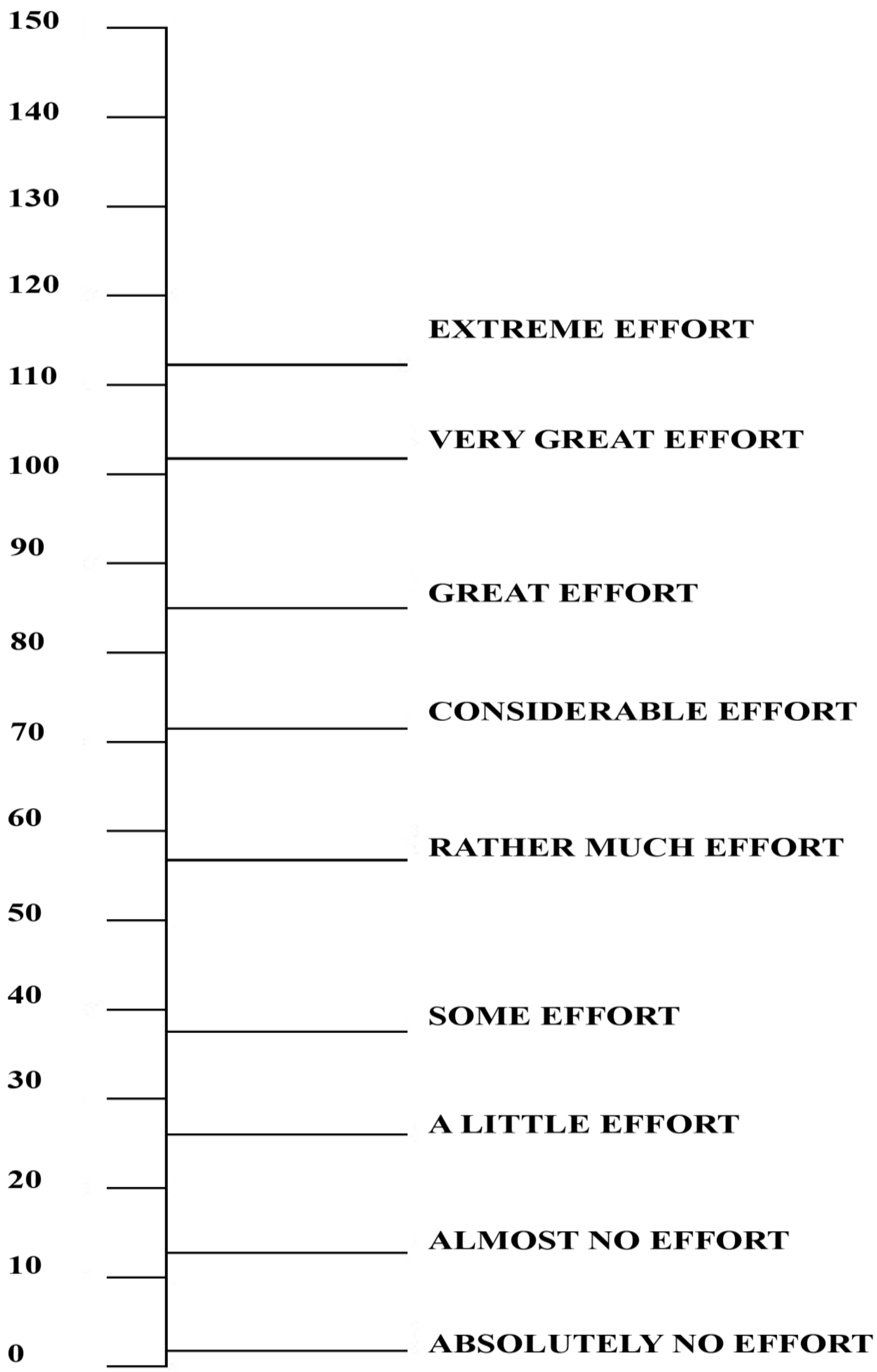
Post-Secondary Task Score:

	Not at all	Somewhat	Moderately	Very much
1. I feel calm	1	2	3	4
2. I am tense	1	2	3	4
3. I feel upset	1	2	3	4
4. I am relaxed	1	2	3	4
5. I feel content	1	2	3	4
6. I am worried	1	2	3	4

Please make sure that you have answered *all* the questions.

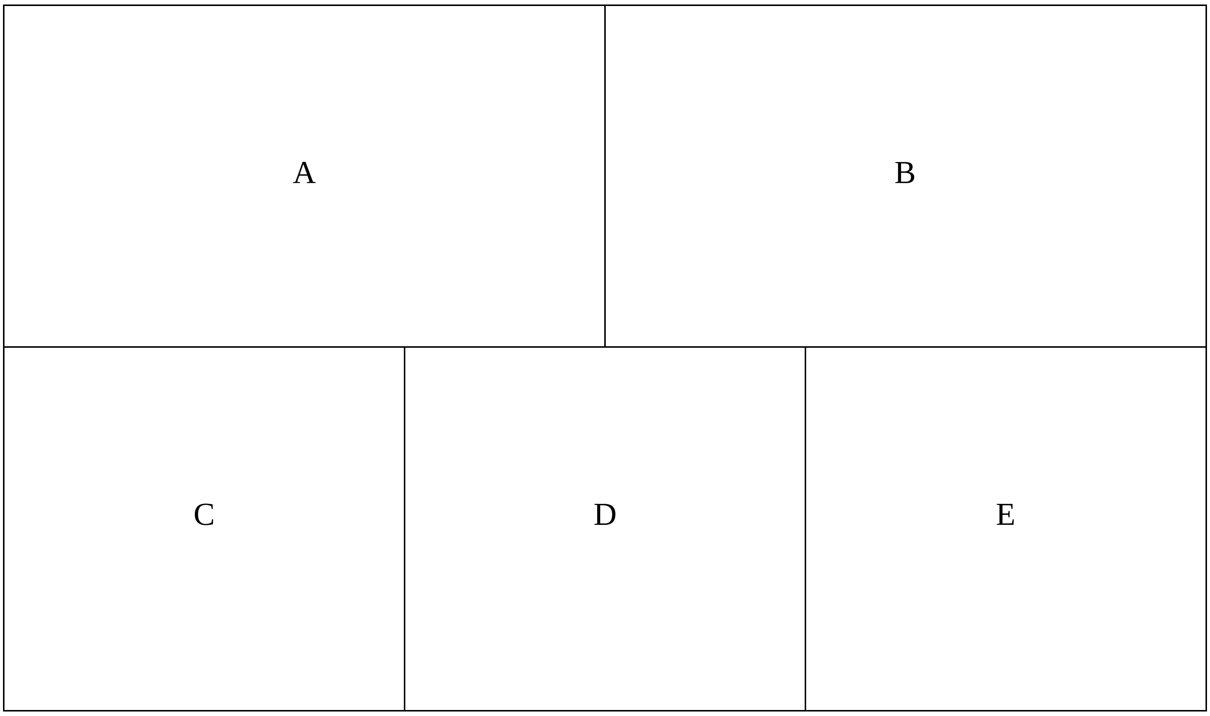
Appendix 3 – Rating Scale of Mental Effort (Zijlstra, 1993).

Please indicate, by marking the vertical axis below, how much effort it took for you to complete the task you've just finished.



Appendix 4 – Scoring Sheet.

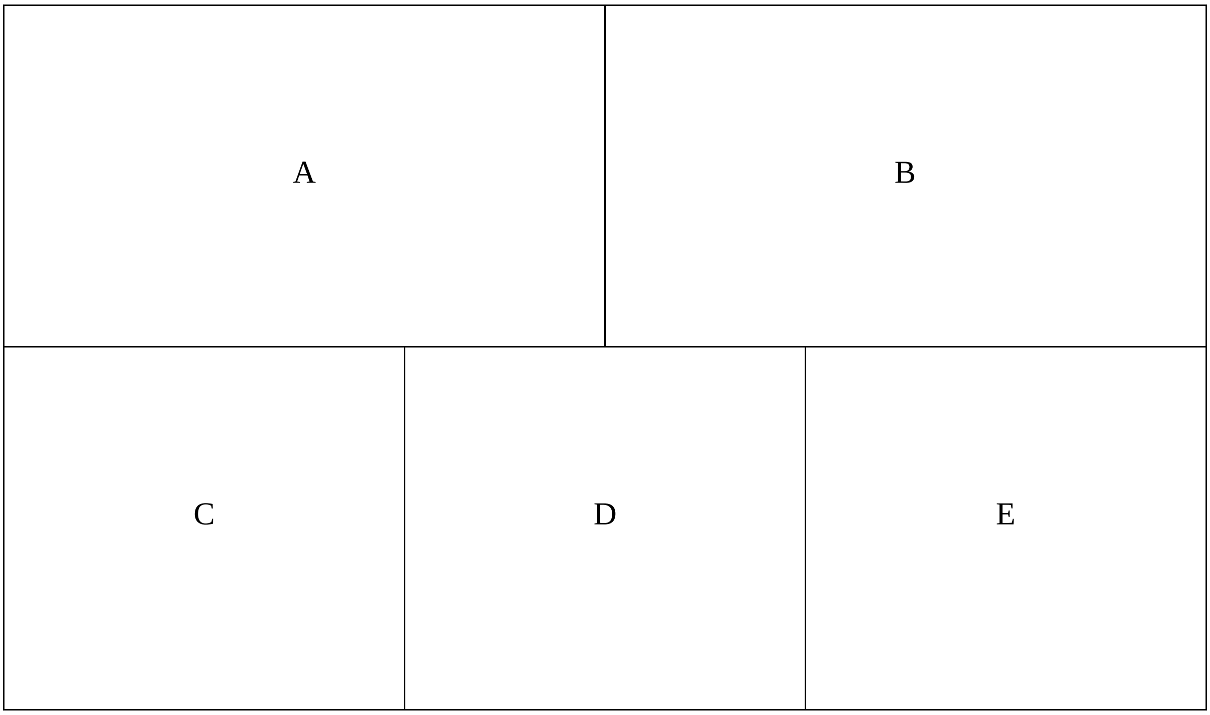
Participant’s side of court (Boxes A and B – service boxes; C, D and E – back side of court; net and tramlines not included).



Primary Task Score:

1)
2)
3)
4)
5)
6)
7)
8)
9)
10)
11)
12)
13)
14)
15)
16)
17)
18)
19)
20)

Participant’s side of court (Boxes A and B – front half of court; Boxes C, D and E – back side of court; net and tramlines not included).



Dual Task Score:

1)

2)

3)

4)

5)

6)

7)

8)

9)

10)

11)

12)

13)

14)

15)

16)

17)

18)

19)

20)

Appendix 5 – Informed Consent Form and Information Leaflet.

INFORMED CONSENT FORM
MSc by Research
Faculty of Social and Applied Sciences, Canterbury Christ Church University

Name of Student: David Mitchell

Name of University Supervisor(s): Mr Jon Swain and Dr Mark Uphill

Title of Research Project: An Examination of Attentional Control Theory, Perceptual Anticipation and Dual Task Paradigms.

I would like to thank you for your consideration to be a participant in this study, without which, this study would not be possible.

Purpose of the research:
The purpose of this study is to explore the relationship between anxiety and performance in a sport setting using a single task and dual task (two tasks performed concurrently) paradigm. It is well known that individuals who experience high levels of anxiety tend to perform worse than those who experience low levels. This study aims to test individuals who experience different levels of anxiety in a series of tasks, in an attempt to induce greater levels of anxiety to disrupt their processing efficiency and the functions of attentional control.

Participation in this research will involve:
Participants will complete several questionnaires (listed below) and complete three tasks (two single-task paradigms and one dual task paradigm). Below is a timeline and rough estimate of the time it will take to complete each component of the study:-

1. One day before the experiment, participants will complete this Informed Consent Form (should they wish to participate), the Marlowe-Crowne Scale of Social Desirability, and the Trait subscale of the State Trait Anxiety Inventory (Time to complete – 10-15 minutes).
2. On the day of, prior to the experiment, participants will complete the State subscale of the State Trait Anxiety Inventory, allocating them into either the Low or High Anxiety group for the study (Time to complete – 5-10 minutes).
3. Primary Task 1 – an anticipatory-tennis-shot video where participants will estimate where the ball will land on their side of the court (Time to complete – 2-3 minutes).
4. Participants will complete the six-item short-form of the State subscale of the State Trait Anxiety Inventory and the Rating Scale of Mental Effort (Time to complete – 2 minutes).
5. Primary Task 2 – a random number generation task, in which participants will say out loud a random number between 1-9, every second for 2 minutes (Time to complete – 2 minutes)
6. Same as Step 4 (Time to complete – 2 minutes).
7. Dual Task – a combination of both Primary tasks listed above, performed concurrently (Time to complete – 2-3 minutes).
8. Same as Step 4/6 (Time to complete – 2 minutes).

Foreseeable risks or discomforts:
There will be no physical risks involved in this study. However, participants who suffer from anxiety and find themselves panicking/find the tasks too difficult, may stop at any time.

What will happen to your data:
Any data/ results from your participation in the study will be used by David Mitchell as part of their project work. The data will also be available to Mr Jon Swain and Dr Mark Uphill. It may also be published in academic works, but your name or identity will not be revealed.

All data and personal information will be stored securely within CCCU premises in accordance with the Data Protection Act 1998 and the University's own data protection requirements. Data can only be accessed by David Mitchell, as well as Mr Jon Swain and Dr Mark Uphill for supervisor reasons. After completion of the study, all data will be made anonymous (i.e. all personal information associated with the data will be removed).

If you have any questions or queries, David will be happy to answer them. If you have any questions about your rights as a participant or feel you have been placed at risk you can contact Jon Swain and/or Mark Uphill on 01227 767700 on extensions 3211/3184.

I confirm that I have read the above information. The nature, demands and risks of the project have been explained to me. I have been informed that there will be no benefits/ payments to me for participation.

I knowingly assume the risks involved and understand that I may withdraw my consent and discontinue participation at any time without penalty and without having to give any reason.

Participant's signature ____________________________________ Date _____________

Investigator's signature ____________________________________ Date _____________

Note that for anyone under the age of 18 (and for other vulnerable groups) informed consent MUST be given by the next of kin- usually a PARENT or GUARDIAN. It cannot be given by a teacher or coach etc. Such participants cannot be used unless you have been given specific permission as part of your ethical approval.

The signed copy of this form is retained by the student, and at the end of the project passed on to the supervisor.
A second copy of the consent form should be given to the participant for them to keep for their own reference.

INFORMATION LEAFLET
MSc by Research
Faculty of Social and Applied Sciences, Canterbury Christ Church University

Name of Student: David Mitchell

Name of University Supervisor(s): Mr Jon Swain and Dr Mark Uphill

TITLE OF RESEARCH PROJECT: An Examination of Attentional Control Theory, Perceptual Anticipation and Dual Task Paradigms.

I would like to thank you for your consideration to be a participant in this study, without which, this study would not be possible.

By answering our questions, you are consenting to your data being used in my study. No record will be made of your name so information is all anonymous.

Note that for anyone under the age of 18 informed consent MUST be given by a PARENT or GUARDIAN. Such participants cannot be used at all unless you have been given specific permission as part of your ethical approval.

Purpose of the research:
The purpose of this study is to explore the relationship between anxiety and performance in a sport setting using a single task and dual task (two tasks performed concurrently) paradigm. It is well known that individuals who experience high levels of anxiety tend to perform worse than those who experience low levels. This study aims to test individuals who experience different levels of anxiety in a series of tasks, in an attempt to induce greater levels of anxiety to disrupt their processing efficiency and the functions of attentional control.

Participation in this research will involve:
Participants will complete several questionnaires (listed below) and complete three tasks (two single-task paradigms and one dual task paradigm). Below is a timeline and rough estimate of the time it will take to complete each component of the study:-

1. One day before the experiment, participants will complete this Informed Consent Form (should they wish to participate), the Marlowe-Crowne Scale of Social Desirability, and the Trait subscale of the State Trait Anxiety Inventory (Time to complete – 10-15 minutes).
2. On the day of, prior to the experiment, participants will complete the State subscale of the State Trait Anxiety Inventory, allocating them into either the Low or High Anxiety group for the study (Time to complete – 5-10 minutes).
3. Primary Task 1 – an anticipatory-tennis-shot video where participants will estimate where the ball will land on their side of the court (Time to complete – 2-3 minutes).
4. Participants will complete the six-item short-form of the State subscale of the State Trait Anxiety Inventory and the Rating Scale of Mental Effort (Time to complete – 2 minutes).
5. Primary Task 2 – a random number generation task, in which participants will say out loud a random number between 1-9, every second for 2 minutes (Time to complete – 2 minutes)
6. Same as Step 4 (Time to complete – 2 minutes).

7. Dual Task – a combination of both Primary tasks listed above, performed concurrently (Time to complete – 2-3 minutes).
8. Same as Step 4/6 (Time to complete – 2 minutes).

If you have any questions or queries David will be happy to answer them. If you have any questions about your rights as a participant or feel you have been placed at risk you can contact Jon Swain and/or Mark Uphill on 01227 767700 on extensions 3211/3184.

A copy of this sheet must be given to the participants for their own future reference

Appendix 6 – Excel Spreadsheets.

Participant	Trait Anxiety Score	State Anxiety Score	Primary Task 1	Mental Effort Score	State Anxiety Score	Primary Task 2a RNG	Primary Task 2b R	Primary Task 2c MRG	Mental Effort Score	State Anxiety Score	Dual Task 1	Dual Task 2a RNG	Dual Task 2b R	Dual Task 2c MRG	Mental Effort Score	State Anxiety Score
1	29	8	40	40	6	0.2384	0.7911	8.47	10	7	25	0.5755	1.2079	8.9	105	8
2	31	9	60	45	8	0.1621	0.4284	8.8	50	7	50	0.2678	0.5691	8.75	80	10
3	29	7	60	35	8	0.2307	0.8679	8.75	35	6	45	0.1492	0.8999	8.76	75	10
4	33	10	65	40	8	0.9748	0.1159	9	15	7	30	0.8996	0.2246	9	60	8
5	24	6	65	25	6	0.2481	1.9387	8.54	30	6	60	0.3167	2.0516	8.71	45	7
6	30	6	55	40	8	0.3917	2.0784	8.8	30	9	45	0.3493	3.9983	7.8	80	9
7	30	11	40	40	11	0.2671	0.7911	8.76	30	9	55	0.3602	7.6159	7.88	70	13
8	25	9	65	40	9	0.2562	1.9393	8.27	45	9	35	0.2257	1.0269	8.82	90	11
9	33	7	55	30	8	0.3878	0.1158	8.71	45	9	60	0.3583	4.8546	8.08	55	11
10	30	7	60	35	7	0.3197	0.8671	8.53	45	10	50	0.1979	0.6961	8.41	50	10
11	26	8	60	35	8	0.2719	2.3106	8.8	30	9	55	0.2918	2.5573	8.83	60	10
12	29	6	70	20	6	0.1864	2.3014	8.88	25	6	60	0.2031	2.6729	8.9	40	6
13	29	9	55	40	8	0.2092	1.0269	8.75	45	6	45	0.1895	1.0709	8.51	65	10
14	33	9	40	55	9	0.2415	1.3151	8.51	55	10	25	0.3554	2.0906	8.63	70	8
16	39	6	65	10	6	0.2535	1.3151	8.75	0	6	50	0.2505	0.7911	8.8	15	6
15	39	11	40	50	13	0.2453	1.5681	8.43	10	10	35	0.386	2.1948	8.27	80	12
17	34	10	55	70	13	0.273	1.3066	8.41	90	14	40	0.2558	4.6416	8.1	105	13
18	36	11	50	35	11	0.2491	2.8722	8.75	65	13	30	0.4902	2.4548	8.12	85	15
19	49	13	65	55	13	0.5402	1.1675	7.24	25	12	65	0.5353	0.3333	8.94	70	14
20	40	9	50	10	10	0.2453	2.6182	8.1	40	12	50	0.4083	12.6716	5.67	60	14
21	38	9	70	65	13	0.2826	2.0344	8.8	55	14	55	0.4263	0.9784	8.63	60	19
22	35	6	65	35	6	0.3084	1.4861	7.96	55	9	55	0.3029	5.2224	7.39	110	10
23	35	8	50	50	12	0.2716	1.7597	8.12	80	13	60	0.2226	2.2433	8.29	105	16
24	56	9	45	65	10	0.3073	2.4228	8.14	75	15	40	0.3566	1.5949	8.69	105	22
	AVERAGE	8.50	56.04	40.21	9.04	0.31	1.48	8.51	41.04	9.50	46.67	0.35	2.69	8.37	72.50	11.33
	STDEV	1.91	9.78	15.43	2.46	0.16	0.77	0.39	22.55	2.87	11.86	0.16	2.80	0.71	23.68	3.92
Low	29.35714286	8.00	56.43	37.14	7.86	0.31	1.21	8.68	35.00	7.86	45.71	0.34	2.25	8.57	67.50	9.36
High	40.1	9.20	55.50	44.50	10.70	0.30	1.86	8.27	49.50	11.80	48.00	0.36	3.31	8.09	79.50	14.10
Overall	34.72857143	8.6	55.96	40.82	9.28	0.3054	1.5307	8.48	42.25	9.83	46.86	0.3510	2.7826	8.33	73.50	11.73

Participant	Trait Anxiety Score	State Anxiety Score	Primary Task 1	Mental Effort Score	State Anxiety Score	Primary Task 2a RNG	Primary Task 2b R	Primary Task 2c MRG	Mental Effort Score	State Anxiety Score	Dual Task 1	Dual Task 2a RNG	Dual Task 2b R	Dual Task 2c MRG	Mental Effort Score	State Anxiety Score
1	24	6	55	40	6	0.2044	1.7902	8.86	30	6	40	0.1718	1.6459	8.63	65	8
2	29	7	60	45	7	0.2632	1.7719	8.39	20	8	50	0.173	1.0526	8.78	60	9
3	35	9	45	65	10	0.2522	1.7597	8.2	65	11	35	0.17	1.0526	8.39	85	14
4	28	7	40	35	8	0.1612	0.8999	8.73	35	8	40	0.2416	1.2883	8.55	55	11
5	35	9	35	75	10	0.1757	1.9782	8.61	80	9	20	0.2319	1.5104	8.67	100	11
6	26	7	40	40	9	0.2955	4.4378	7.69	15	10	50	0.3007	3.0034	8.92	70	13
7	31	6	40	55	7	0.2505	0.7911	8.69	40	6	45	0.2326	1.8548	8.31	100	6
8	31	9	45	30	10	0.2482	0.5691	8.71	30	9	55	0.2584	1.1796	8.65	70	10
9	30	7	60	90	8	0.4079	2.1118	8.69	40	7	40	0.394	3.6271	8.53	90	8
10	37	10	65	60	11	0.2704	1.2115	8.57	90	12	50	0.2358	0.6641	8.25	120	15
11	43	8	60	40	9	0.4233	2.1948	8.1	70	11	40	0.3484	2.2822	8.31	85	11
12	38	6	45	70	7	0.3881	0.5554	8.88	25	8	45	0.3867	1.7598	8.47	55	6
13	52	10	40	75	10	0.312	0.4603	8.82	80	9	35	0.3607	1.8863	8.73	85	9
14	50	11	25	25	9	0.2684	2.0542	8.8	40	12	15	0.3665	12.3582	6.66	115	19
15	42	9	55	40	8	0.3106	2.5697	8.61	40	10	50	0.1953	1.8427	8.65	100	10
16	36	6	35	55	7	0.2341	0.696	8.73	35	8	25	0.2218	0.7911	8.73	80	10
	AVERAGE	7.94	46.56	52.50	8.50	0.2795	1.6157	8.57	45.94	9.00	39.69	0.2681	2.3624	8.45	83.44	10.63
	STDEV	1.65	11.36	18.62	1.46	0.0760	1.0202	0.32	23.33	1.90	11.47	0.0798	2.7764	0.51	20.14	3.36
Low	29.88888889	7.44	46.67	52.78	8.33	0.2516	1.7900	8.51	39.44	8.22	41.67	0.2416	1.8016	8.60	77.22	10.00
High	42.57142857	8.57	46.43	52.14	8.71	0.3153	1.3917	8.64	54.29	10.00	37.14	0.3022	3.0835	8.26	91.43	11.43
Overall	36.23015873	8.01	46.55	52.46	8.52	0.2835	1.5908	8.58	46.87	9.11	39.40	0.2719	2.4426	8.43	84.33	10.71

Participant	Trait Anxiety Score	State Anxiety Score	Primary Task 1	Mental Effort Score	State Anxiety Score	Primary Task 2a RNG	Primary Task 2b R	Primary Task 2c MRG	Mental Effort Score	State Anxiety Score	Dual Task 1	Dual Task 2a RNG	Dual Task 2b R	Dual Task 2c MRG	Mental Effort Score	State Anxiety Score
15	42	9	55	40	8	0.3106	2.5697	8.61	40	10	50	0.1953	1.8427	8.65	100	10
16	36	6	35	55	7	0.2341	0.696	8.73	35	8	25	0.2218	0.7911	8.73	80	10
12	38	6	45	70	7	0.3881	0.5554	8.88	25	8	45	0.3867	1.7598	8.47	55	6
13	52	10	40	75	10	0.312	0.4603	8.82	80	9	35	0.3607	1.8863	8.73	85	9
7	31	6	40	55	7	0.2505	0.7911	8.69	40	6	45	0.2326	1.8548	8.31	100	6
8	31	9	45	30	10	0.2482	0.5691	8.71	30	9	55	0.2584	1.1796	8.65	70	10
9	30	7	60	90	8	0.4079	2.1118	8.69	40	7	40	0.394	3.6211	8.53	90	8
1	24	6	55	40	6	0.2044	1.7902	8.86	30	6	40	0.1718	1.6459	8.63	65	8
2	29	7	60	45	7	0.2692	1.7719	8.39	20	8	50	0.173	1.0526	8.78	60	9
22	35	6	65	35	6	0.3084	1.4861	7.96	55	9	55	0.3029	5.2224	7.39	110	10
10	30	7	60	35	7	0.3197	0.8671	8.53	45	10	50	0.1979	0.6961	8.41	50	10
11	26	8	60	35	8	0.2719	2.3106	8.8	30	9	55	0.2918	2.5573	8.83	60	10
12	29	6	70	20	6	0.1864	2.3014	8.88	25	6	60	0.2031	2.6729	8.9	40	6
13	29	9	55	40	8	0.2092	1.0269	8.75	45	6	45	0.1895	1.0709	8.51	65	10
14	33	9	40	55	9	0.2415	1.3151	8.51	55	10	25	0.3554	2.0906	8.63	70	8
15	39	6	65	10	6	0.2535	1.3151	8.75	0	6	50	0.2505	0.7911	8.8	15	6
1	29	8	40	40	6	0.2384	0.7911	8.47	10	7	25	0.5755	1.2079	8.9	105	8
2	31	9	60	45	8	0.1621	0.4284	8.8	50	7	50	0.2678	0.5691	8.75	80	10
3	29	7	60	35	8	0.2307	0.8679	8.75	35	6	45	0.1492	0.8999	8.76	75	10
4	33	10	65	40	8	0.9748	0.1159	9	15	7	30	0.8996	0.2246	9	60	8
5	24	6	65	25	6	0.2481	1.9387	8.54	30	6	60	0.3167	2.0516	8.71	45	7
6	30	6	55	40	8	0.3917	2.0784	8.8	30	9	45	0.3493	3.9983	7.8	80	9
7	30	11	40	40	11	0.2671	0.7911	8.76	30	9	55	0.3602	7.6159	7.88	70	13
8	25	9	65	40	9	0.2562	1.9393	8.27	45	9	35	0.2257	1.0269	8.82	90	11
9	33	7	55	30	8	0.3878	0.1158	8.71	45	9	60	0.3583	4.8546	8.08	55	11
16	39	11	40	50	13	0.2453	1.5681	8.43	10	10	35	0.386	2.1948	8.27	80	12
17	34	10	55	70	13	0.273	1.3066	8.41	90	14	40	0.2558	4.6416	8.1	105	13
18	36	11	50	35	11	0.2491	2.8722	8.75	65	13	30	0.4902	2.4548	8.12	85	15
19	49	13	65	55	13	0.5402	1.1675	7.24	25	12	65	0.5353	0.3333	8.94	70	14
20	40	9	50	10	10	0.2453	2.6182	8.1	40	12	50	0.4083	12.6716	5.67	60	14
21	38	9	70	65	13	0.2826	2.0344	8.8	55	14	55	0.4263	0.9784	8.63	60	19
23	35	8	50	50	12	0.2716	1.7597	8.12	80	13	60	0.2226	2.2433	8.29	105	16
24	56	9	45	65	10	0.3073	2.4228	8.14	75	15	40	0.3566	1.5949	8.69	105	22
3	35	9	45	65	10	0.2522	1.7597	8.2	65	11	35	0.17	1.0526	8.39	85	14
4	28	7	40	35	8	0.1612	0.8999	8.73	35	8	40	0.2416	1.2883	8.55	55	11
5	35	9	35	75	10	0.1757	1.9782	8.61	80	9	20	0.2319	1.5104	8.67	100	11
6	26	7	40	40	9	0.2955	4.4378	7.69	15	10	50	0.3007	3.0034	8.92	70	13
10	37	10	65	60	11	0.2704	1.2115	8.57	90	12	50	0.2358	0.6641	8.25	120	15
11	43	8	60	40	9	0.4233	2.1948	8.1	70	11	40	0.3484	2.2822	8.31	85	11
14	50	11	25	25	9	0.2684	2.0542	8.8	40	12	15	0.3665	12.3582	6.66	115	19

	State Anxiety Score	Primary Task 1	Mental Effort Score	State Anxiety Score	Primary Task 2a RNG	Primary Task 2b R	Primary Task 2c MRG	Mental Effort Score	State Anxiety Score	Dual Task 1	Dual Task 2a RNG	Dual Task 2b R	Dual Task 2c MRG	Mental Effort Score	State Anxiety Score
Low State Anxiety	7.41	54.32	43.41	7.45	0.3028	1.2799	8.68	34.77	7.68	44.55	0.3065	1.8042	8.59	70.91	8.55
High State Anxiety	9.33	49.72	47.22	10.50	0.2873	1.8407	8.36	53.06	11.28	43.06	0.3289	3.4872	8.18	84.17	14.11

Appendix 7a – SPSS Data Analysis. Paired Samples T-test – Response Accuracy Scores and Task Complexity.

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Primary_Task	52.2500	40	11.31994	1.78984
	Dual_Task	43.875000	40	12.0622052	1.9072021

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Primary_Task & Dual_Task	40	.601	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Primary_Task - Dual_Task	8.3750000	10.4628464	1.6543213	5.0288194	11.7211806	5.062	39	.000

Appendix 7b – SPSS Data Analysis. Two Way Repeated Measures ANOVA – State Anxiety Scores and Stress Conditions.

Descriptive Statistics

	Condition	Mean	Std. Deviation	N
State_Anxiety_Pre	Low Stress	8.5000	1.91107	24
	High Stress	7.9375	1.65202	16
	Total	8.2750	1.81147	40
State_Anxiety_PT2	Low Stress	9.5000	2.87417	24
	High Stress	9.0000	1.89737	16
	Total	9.3000	2.51355	40
State_Anxiety_DT	Low Stress	11.3333	3.91948	24
	High Stress	10.6250	3.36403	16
	Total	11.0500	3.67912	40

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Task	.672	14.729	2	.001	.753	.798	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + Condition
Within Subjects Design: Task

Tests of Within-Subjects Effects[b]

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Task	Sphericity Assumed	149.419	2	74.710	24.587	.000	.393	49.174	1.000
	Greenhouse-Geisser	149.419	1.506	99.244	24.587	.000	.393	37.018	1.000
	Huynh-Feldt	149.419	1.595	93.657	24.587	.000	.393	39.226	1.000
	Lower-bound	149.419	1.000	149.419	24.587	.000	.393	24.587	.998
Task * Condition	Sphericity Assumed	.219	2	.110	.036	.965	.001	.072	.055
	Greenhouse-Geisser	.219	1.506	.146	.036	.929	.001	.054	.055
	Huynh-Feldt	.219	1.595	.138	.036	.938	.001	.058	.055
	Lower-bound	.219	1.000	.219	.036	.850	.001	.036	.054
Error(Task)	Sphericity Assumed	230.931	76	3.039					
	Greenhouse-Geisser	230.931	57.212	4.036					
	Huynh-Feldt	230.931	60.625	3.809					
	Lower-bound	230.931	38.000	6.077					

a. Computed using alpha = .05

b. Footnote

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	10358.835	1	10358.835	595.434	.000	.940	595.434	1.000
Condition	10.035	1	10.035	.577	.452	.015	.577	.115
Error	661.090	38	17.397					

a. Computed using alpha = .05

Appendix 7c – SPSS Data Analysis. Two Way Repeated Measures ANOVA – Trait Anxiety Groups and Response Accuracy Scores.

Descriptive Statistics

	Trait_Anxiety	Mean	Std. Deviation	N
Primary_Task	Low	52.6087	10.64612	23
	High	51.7647	12.49264	17
	Total	52.2500	11.31994	40
Dual_Task	Low	44.130435	11.6435872	23
	High	43.529412	12.9620487	17
	Total	43.875000	12.0622052	40

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Epsilon[b] Huynh-Feldt	Epsilon[b] Lower-bound
Task	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + Trait_Anxiety
Within Subjects Design: Task

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Task	Sphericity Assumed	1365.289	1	1365.289	24.307	.000	.390	24.307	.998
	Greenhouse-Geisser	1365.289	1.000	1365.289	24.307	.000	.390	24.307	.998
	Huynh-Feldt	1365.289	1.000	1365.289	24.307	.000	.390	24.307	.998
	Lower-bound	1365.289	1.000	1365.289	24.307	.000	.390	24.307	.998
Task * Trait_Anxiety	Sphericity Assumed	.289	1	.289	.005	.943	.000	.005	.051
	Greenhouse-Geisser	.289	1.000	.289	.005	.943	.000	.005	.051
	Huynh-Feldt	.289	1.000	.289	.005	.943	.000	.005	.051
	Lower-bound	.289	1.000	.289	.005	.943	.000	.005	.051
Error(Task)	Sphericity Assumed	2134.399	38	56.168					
	Greenhouse-Geisser	2134.399	38.000	56.168					
	Huynh-Feldt	2134.399	38.000	56.168					
	Lower-bound	2134.399	38.000	56.168					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	180235.205	1	180235.205	803.208	.000	.955	803.208	1.000
Trait_Anxiety	10.205	1	10.205	.045	.832	.001	.045	.055
Error	8526.982	38	224.394					

a. Computed using alpha = .05

Appendix 7d – SPSS Data Analysis. Two Way Repeated Measures ANOVA – Trait Anxiety Groups, State Anxiety Scores and Response Accuracy Scores.

Descriptive Statistics

	Trait_Anxiety	Mean	Std. Deviation	N
Primary_Task	Low	52.6087	10.64612	23
	High	51.7647	12.49264	17
	Total	52.2500	11.31994	40
Dual_Task	Low	44.130435	11.6435872	23
	High	43.529412	12.9620487	17
	Total	43.875000	12.0622052	40

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Task	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + State_Anxiety_DT + Trait_Anxiety
Within Subjects Design: Task

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Task	Sphericity Assumed	267.677	1	267.677	4.730	.036	.113	4.730	.563
	Greenhouse-Geisser	267.677	1.000	267.677	4.730	.036	.113	4.730	.563
	Huynh-Feldt	267.677	1.000	267.677	4.730	.036	.113	4.730	.563
	Lower-bound	267.677	1.000	267.677	4.730	.036	.113	4.730	.563
Task * State_Anxiety_DT	Sphericity Assumed	40.609	1	40.609	.718	.402	.019	.718	.131
	Greenhouse-Geisser	40.609	1.000	40.609	.718	.402	.019	.718	.131
	Huynh-Feldt	40.609	1.000	40.609	.718	.402	.019	.718	.131
	Lower-bound	40.609	1.000	40.609	.718	.402	.019	.718	.131
Task * Trait_Anxiety	Sphericity Assumed	6.072	1	6.072	.107	.745	.003	.107	.062
	Greenhouse-Geisser	6.072	1.000	6.072	.107	.745	.003	.107	.062
	Huynh-Feldt	6.072	1.000	6.072	.107	.745	.003	.107	.062
	Lower-bound	6.072	1.000	6.072	.107	.745	.003	.107	.062
Error(Task)	Sphericity Assumed	2093.790	37	56.589					
	Greenhouse-Geisser	2093.790	37.000	56.589					
	Huynh-Feldt	2093.790	37.000	56.589					
	Lower-bound	2093.790	37.000	56.589					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	16711.706	1	16711.706	73.786	.000	.666	73.786	1.000
State_Anxiety_DT	146.872	1	146.872	.648	.426	.017	.648	.123
Trait_Anxiety	7.610	1	7.610	.034	.856	.001	.034	.054
Error	8380.111	37	226.489					

a. Computed using alpha = .05

Appendix 7e – SPSS Data Analysis. Two Way Repeated Measures ANOVA – State Anxiety Groups and Response Accuracy Scores.

Descriptive Statistics

	State_Group	Mean	Std. Deviation	N
Primary_Task	Low	53.1818	10.52723	22
	High	51.1111	12.43283	18
	Total	52.2500	11.31994	40
Dual_Task	Low	43.863636	10.9034527	22
	High	43.888889	13.6721653	18
	Total	43.875000	12.0622052	40

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Task	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + State_Group
Within Subjects Design: Task

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Task	Sphericity Assumed	1354.246	1	1354.246	24.355	.000	.391	24.355	.998
	Greenhouse-Geisser	1354.246	1.000	1354.246	24.355	.000	.391	24.355	.998
	Huynh-Feldt	1354.246	1.000	1354.246	24.355	.000	.391	24.355	.998
	Lower-bound	1354.246	1.000	1354.246	24.355	.000	.391	24.355	.998
Task * State_Group	Sphericity Assumed	21.746	1	21.746	.391	.535	.010	.391	.094
	Greenhouse-Geisser	21.746	1.000	21.746	.391	.535	.010	.391	.094
	Huynh-Feldt	21.746	1.000	21.746	.391	.535	.010	.391	.094
	Lower-bound	21.746	1.000	21.746	.391	.535	.010	.391	.094
Error(Task)	Sphericity Assumed	2112.942	38	55.604					
	Greenhouse-Geisser	2112.942	38.000	55.604					
	Huynh-Feldt	2112.942	38.000	55.604					
	Lower-bound	2112.942	38.000	55.604					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	182563.210	1	182563.210	814.586	.000	.955	814.586	1.000
State_Group	20.710	1	20.710	.092	.763	.002	.092	.060
Error	8516.477	38	224.118					

a. Computed using alpha = .05

Appendix 7f – SPSS Data Analysis. Two Way Repeated Measures ANOVA – State Anxiety Groups, Trait Anxiety Scores and Response Accuracy Scores.

Descriptive Statistics

	State_Group	Trait_Anxiety	Mean	Std. Deviation	N
Primary_Task	Low	Low	55.6250	9.46485	16
		High	46.6667	11.25463	6
		Total	53.1818	10.52723	22
	High	Low	45.7143	10.57850	7
		High	54.5455	12.73863	11
		Total	51.1111	12.43283	18
	Total	Low	52.6087	10.64612	23
		High	51.7647	12.49264	17
		Total	52.2500	11.31994	40
Dual_Task	Low	Low	45.000000	10.9544512	16
		High	40.833333	11.1430098	6
		Total	43.863636	10.9034527	22
	High	Low	42.142857	13.8013112	7
		High	45.000000	14.1421356	11
		Total	43.888889	13.6721653	18
	Total	Low	44.130435	11.6435872	23
		High	43.529412	12.9620487	17
		Total	43.875000	12.0622052	40

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Task	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + State_Group + Trait_Anxiety + State_Group * Trait_Anxiety
Within Subjects Design: Task

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Task	Sphericity Assumed	944.730	1	944.730	17.121	.000	.322	17.121	.981
	Greenhouse-Geisser	944.730	1.000	944.730	17.121	.000	.322	17.121	.981
	Huynh-Feldt	944.730	1.000	944.730	17.121	.000	.322	17.121	.981
	Lower-bound	944.730	1.000	944.730	17.121	.000	.322	17.121	.981
Task * State_Group	Sphericity Assumed	12.059	1	12.059	.219	.643	.006	.219	.074
	Greenhouse-Geisser	12.059	1.000	12.059	.219	.643	.006	.219	.074
	Huynh-Feldt	12.059	1.000	12.059	.219	.643	.006	.219	.074
	Lower-bound	12.059	1.000	12.059	.219	.643	.006	.219	.074
Task * Trait_Anxiety	Sphericity Assumed	1.510	1	1.510	.027	.870	.001	.027	.053
	Greenhouse-Geisser	1.510	1.000	1.510	.027	.870	.001	.027	.053
	Huynh-Feldt	1.510	1.000	1.510	.027	.870	.001	.027	.053
	Lower-bound	1.510	1.000	1.510	.027	.870	.001	.027	.053
Task * State_Group * Trait_Anxiety	Sphericity Assumed	125.180	1	125.180	2.269	.141	.059	2.269	.311
	Greenhouse-Geisser	125.180	1.000	125.180	2.269	.141	.059	2.269	.311
	Huynh-Feldt	125.180	1.000	125.180	2.269	.141	.059	2.269	.311
	Lower-bound	125.180	1.000	125.180	2.269	.141	.059	2.269	.311
Error(Task)	Sphericity Assumed	1986.512	36	55.181					
	Greenhouse-Geisser	1986.512	36.000	55.181					
	Huynh-Feldt	1986.512	36.000	55.181					
	Lower-bound	1986.512	36.000	55.181					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	152312.545	1	152312.545	698.644	.000	.951	698.644	1.000
State_Group	.564	1	.564	.003	.960	.000	.003	.050
Trait_Anxiety	2.229	1	2.229	.010	.920	.000	.010	.051
State_Group * Trait_Anxiety	665.000	1	665.000	3.050	.089	.078	3.050	.398
Error	7848.417	36	218.012					

a. Computed using alpha = .05

Appendix 7g – SPSS Data Analysis Two Way Repeated Measures ANOVA – State Anxiety Groups and Mental Effort Scores.

Descriptive Statistics

	State_Group	Mean	Std. Deviation	N
Mental_Effort_PT1	Low	45.2273	16.43727	22
	High	45.0000	19.47849	18
	Total	45.1250	17.63183	40
Mental_Effort_PT2	Low	35.2273	16.21854	22
	High	52.5000	26.13596	18
	Total	43.0000	22.69644	40
Mental_Effort_DT	Low	73.8636	19.32996	22
	High	80.5556	26.39568	18
	Total	76.8750	22.72149	40

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Task	.982	.675	2	.714	.982	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + State_Group
Within Subjects Design: Task

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Task	Sphericity Assumed	28296.393	2	14148.197	68.733	.000	.644	137.466	1.000
	Greenhouse-Geisser	28296.393	1.964	14404.014	68.733	.000	.644	135.025	1.000
	Huynh-Feldt	28296.393	2.000	14148.197	68.733	.000	.644	137.466	1.000
	Lower-bound	28296.393	1.000	28296.393	68.733	.000	.644	68.733	1.000
Task * State_Group	Sphericity Assumed	1538.060	2	769.030	3.736	.028	.090	7.472	.667
	Greenhouse-Geisser	1538.060	1.964	782.935	3.736	.029	.090	7.339	.662
	Huynh-Feldt	1538.060	2.000	769.030	3.736	.028	.090	7.472	.667
	Lower-bound	1538.060	1.000	1538.060	3.736	.061	.090	3.736	.470
Error(Task)	Sphericity Assumed	15644.024	76	205.842					
	Greenhouse-Geisser	15644.024	74.650	209.564					
	Huynh-Feldt	15644.024	76.000	205.842					
	Lower-bound	15644.024	38.000	411.685					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	364558.594	1	364558.594	415.922	.000	.916	415.922	1.000
State_Group	1859.428	1	1859.428	2.121	.153	.053	2.121	.295
Error	33307.239	38	876.506					

a. Computed using alpha = .05

Appendix 7h – SPSS Data Analysis. Two Way Repeated Measures ANOVA – State Anxiety Groups and Random Number Generation Scores.

Descriptive Statistics

	State_Group	Mean	Std. Deviation	N
Primary_Task_2a_RNG	Low	.302418	.1635876	22
	High	.287800	.0872663	18
	Total	.295840	.1333548	40
Dual_Task_2a_RNG	Low	.312682	.1657431	22
	High	.321372	.1008720	18
	Total	.316592	.1387316	40

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Task	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + State_Group
Within Subjects Design: Task

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Task	Sphericity Assumed	.010	1	.010	2.064	.159	.052	2.064	.288
	Greenhouse-Geisser	.010	1.000	.010	2.064	.159	.052	2.064	.288
	Huynh-Feldt	.010	1.000	.010	2.064	.159	.052	2.064	.288
	Lower-bound	.010	1.000	.010	2.064	.159	.052	2.064	.288
Task * State_Group	Sphericity Assumed	.003	1	.003	.584	.450	.015	.584	.116
	Greenhouse-Geisser	.003	1.000	.003	.584	.450	.015	.584	.116
	Huynh-Feldt	.003	1.000	.003	.584	.450	.015	.584	.116
	Lower-bound	.003	1.000	.003	.584	.450	.015	.584	.116
Error(Task)	Sphericity Assumed	.175	38	.005					
	Greenhouse-Geisser	.175	38.000	.005					
	Huynh-Feldt	.175	38.000	.005					
	Lower-bound	.175	38.000	.005					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	7.419	1	7.419	222.665	.000	.854	222.665	1.000
State_Group	.000	1	.000	.005	.943	.000	.005	.051
Error	1.266	38	.033					

a. Computed using alpha = .05

Appendix 7i – SPSS Data Analysis Two Way Repeated Measures ANOVA – State Anxiety Groups and Redundancy Scores.

Descriptive Statistics

	State_Group	Mean	Std. Deviation	N
Primary_Task_2b_R	Low	1.2914	.72913	22
	High	1.8266	.95090	18
	Total	1.5323	.86782	40
Dual_Task_2b_R	Low	1.8680	1.20174	22
	High	3.4092	3.78286	18
	Total	2.5615	2.76012	40

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Task	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + State_Group
Within Subjects Design: Task

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Task	Sphericity Assumed	23.078	1	23.078	6.503	.015	.146	6.503	.700
	Greenhouse-Geisser	23.078	1.000	23.078	6.503	.015	.146	6.503	.700
	Huynh-Feldt	23.078	1.000	23.078	6.503	.015	.146	6.503	.700
	Lower-bound	23.078	1.000	23.078	6.503	.015	.146	6.503	.700
Task * State_Group	Sphericity Assumed	5.010	1	5.010	1.412	.242	.036	1.412	.212
	Greenhouse-Geisser	5.010	1.000	5.010	1.412	.242	.036	1.412	.212
	Huynh-Feldt	5.010	1.000	5.010	1.412	.242	.036	1.412	.212
	Lower-bound	5.010	1.000	5.010	1.412	.242	.036	1.412	.212
Error(Task)	Sphericity Assumed	134.849	38	3.549					
	Greenhouse-Geisser	134.849	38.000	3.549					
	Huynh-Feldt	134.849	38.000	3.549					
	Lower-bound	134.849	38.000	3.549					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	348.876	1	348.876	80.209	.000	.679	80.209	1.000
State_Group	21.341	1	21.341	4.906	.033	.114	4.906	.579
Error	165.285	38	4.350					

a. Computed using alpha = .05

Appendix 7j – SPSS Data Analysis. Two Way Repeated Measures ANOVA – State Anxiety Groups and Mean Repetition Gap Scores.

Descriptive Statistics

	State_Group	Mean	Std. Deviation	N
Primary_Task_2c_MRG	Low	8.6636	.22574	22
	High	8.3750	.43346	18
	Total	8.5338	.36123	40
Dual_Task_2c_MRG	Low	8.5609	.36875	22
	High	8.2094	.82397	18
	Total	8.4028	.63286	40

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Task	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + State_Group
Within Subjects Design: Task

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Task	Sphericity Assumed	.356	1	.356	1.431	.239	.036	1.431	.215
	Greenhouse-Geisser	.356	1.000	.356	1.431	.239	.036	1.431	.215
	Huynh-Feldt	.356	1.000	.356	1.431	.239	.036	1.431	.215
	Lower-bound	.356	1.000	.356	1.431	.239	.036	1.431	.215
Task * State_Group	Sphericity Assumed	.020	1	.020	.078	.781	.002	.078	.059
	Greenhouse-Geisser	.020	1.000	.020	.078	.781	.002	.078	.059
	Huynh-Feldt	.020	1.000	.020	.078	.781	.002	.078	.059
	Lower-bound	.020	1.000	.020	.078	.781	.002	.078	.059
Error(Task)	Sphericity Assumed	9.461	38	.249					
	Greenhouse-Geisser	9.461	38.000	.249					
	Huynh-Feldt	9.461	38.000	.249					
	Lower-bound	9.461	38.000	.249					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	5658.087	1	5658.087	23368.085	.000	.998	23368.085	1.000
State_Group	2.028	1	2.028	8.376	.006	.181	8.376	.805
Error	9.201	38	.242					

a. Computed using alpha = .05