# Trait Anxiety and Performance: A Test of Working Memory and Attentional Control in University Students

Samantha Jayne Buckley

University of Huddersfield

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## iii Abstract

*Aims:* This study adopted the Attentional Control Theory (Eysenck, Derakshan, Santos, & Calvo, 2007), in an exploration of differences in performance effectiveness, and in mental effort ratings as an indication of processing efficiency, between participants high and low in trait anxiety on tasks designed to require verbal, visuospatial and central executive working memory functioning. These tasks demanded high levels of attentional control, pushing the boundaries of working memory capacity. The study also explored the effect of anxiety on the following central executive functions: inhibition, shifting, updating, (Miyake *et al*., 2000), critical reasoning, and fluid intelligence. *Method:* An opportunity sample was acquired, consisting of Undergraduate students (n=79). The sample was further split using the State/Trait Anxiety Inventory (STAI; Spielberger *et al.,* 1983). The low trait anxiety group (n=26) consisted of participants with trait anxiety scores between 21 and 38, (male n=11, female n=15). The high anxiety group (n=28) consisted of participants with trait anxiety scores between 49 and 74, (male n=7, female n=21). Participants completed two verbal and visuospatial measures of simple tasks: word span and paper folding; complex tasks: complex reading span (Daneman & Carpenter, 1980) and visual arrays (Shipstead *et al*., 2014); and complex test-style tasks: critical thinking appraisal (Walter & Glaser, 1961) and advanced progressive matrices (Raven, 1962). Participants also completed a mental effort assessment: The Rating Scale of Mental Effort (Zijlstra, 1993) for each task completed.

*Results:* Performance Effectiveness: There was a significant difference between low and high trait anxiety participants when completing the complex and test-style measures. Unexpectedly, there was also a difference on the word span task which was considered a simple measure. Non-significant differences were found between low and high trait anxiety participants on all measures of mental effort.

*Conclusion:* Performance differences on cognitive measures of working memory and attentional control can result in long-lasting consequences for students with anxiety throughout education in a Western Society, in which attainment and intelligence is measured through one-size-fits-all examinations. Based on these results, it would be beneficial for educational bodies to implement alternative, individualised measures of attainment, and/or introduce anxiety reduction interventions, to support the learning and assessment of individuals with high trait anxiety.

# 1 Trait Anxiety and Performance: A Test of Working Memory and Attentional Control in University Students

## 1.1 Anxiety

Anxiety is a generalised mood condition characterised by psychological and physiological symptoms, and comprising cognitive, somatic, emotional and behavioural manifestations (Wahed & Hassan, 2017). A diagnosis of anxiety pertains to a range of clinical disorders that cause an individual to exhibit feelings of nervousness, fear, apprehension and worry, which ranges from mild to severe unease (NHS: Generalised Anxiety Disorder, 2016). Amongst cognitive literature, anxiety is generally regarded as: “an aversive motivational state, occurring in situations in which the level of perceived threat to the individual is high.” (Derakshan & Eysenck, 2009, p. 1).

Throughout the literature, anxiety is frequently explored in two ways: when considering anxiety as a personality dimension (trait anxiety), which refers to the tendency for an individual to experience high levels of anxiety (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983); and when anxiety is explored as a transient mood state (state anxiety), which refers to situational stress - instances in which an individual cognitively appraises a situation as personally and/or fearfully threatening, which can vary in intensity (Spielberger *et al.*, 1983).

Based on Spielberger’s (1972) Trait-State anxiety theory, trait anxiety is a stable dimension, created through reflection on past experiences of state anxiety (Julian, 2011). Individuals who experience high levels of trait anxiety are more likely to experience future state anxiety by nature of their sensitivity to emotional arousal. Spielberger, Anton and Bedell (2015) convey the Trait-State anxiety theory to provide a cognitively adept, conceptual framework, allowing researchers to identify crucial variables associated with high anxiety, such as stress, cognitive appraisal to threat, psychological defences. For example, Trait-state theory suggests that evaluative situations are particularly threatening to high trait anxiety individuals'. Likewise, threats to self-esteem heighten feelings of anxiety (Spielberger, Anton, & Bedell, 2015).

Spielbeger *et al*. (1983) developed the State-Trait Anxiety Inventory (STAI), a widely-used, relatively brief measure of anxiety, designed to distinguish trait and state dimensions. The STAI is particularly useful within cognitive research assessing anxiety, in comparison to other popular measures such as the Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988), as unlike the BAI, STAI assesses cognitive aspects of anxiety including maladaptive cognitions (worry, thoughts and beliefs), metacognitions (thoughts and beliefs about one's thoughts and beliefs; Ferreri, Lapp, & Peretti, 2011). Whereas the BAI tends to focus solely on somatic symptoms (heart racing, dizziness; Julian, 2011). Therefore, measures such as the STAI are particularly useful to gain insight into an individual's subjective experiential states in evaluative situations (Zeidner, 1998).

### **1.2** Test Anxiety

Ten percent of the population are likely to experience a 'disabling anxiety disorder' at some stage in their life (Anxiety UK ©, 2015). University students are a particularly vulnerable population, experiencing a critical transitory period that includes leaving adolescence and entering young adulthood, which can be an exceedingly difficult and stressful milestone (Hicks & Heastie, 2008; Wahed & Hassan, 2017). The average student falls within the age range where common mental health problems are most likely to develop (Farrer *et al.,* 2013). Davies, Morris and Glazebrook (2014) suggests high levels of anxiety can pose a debilitating effect on academic performance, social interactions, and even future career options. As reported by YouGov UK in 2016 alone, one-in-four students suffered with mental health problems, with nearly 80 percent revealing they feel fear of failure (Aronin & Smith, 2016). Moreover, six in ten students reported hardships because of high levels of stress and anxiety which interfered with their daily lives (Aronin & Smith, 2016). This has been supported with several studies which have found high levels of psychological morbidity among students (Dahlin & Runeson, 2007; Stallman & Shochet, 2009; Burris, Brechting, Salsman, & Carlson, 2009).

Due to the increasing pressure and accountability placed on educational bodies, a standard based evaluation has been implemented as a measure of success (Embse & Hasson, 2012). Classically, this involves student examination which involves the assessment of both individual and school achievement. However, feelings of anxiety before and/or during a test have been shown to impair performance on tasks of an evaluative nature (Andrews & Wilding, 2004), with reports of 25-40 percent of students experiencing test anxiety (Cassady, 2010). Moreover, individuals high in test anxiety tend to score approximately 12 percentile points below their low anxiety peers (Hembree, 1988; Bowman & Driscoll, 2013).

The nature of evaluative settings and timed conditions appear to be especially detrimental to anxious individuals (Schutz & Pekrun, 2007). Therefore, inferior performance does not necessarily occur due to lack of understanding or retention of a subject, but rather as a response to the sense of threat created by the test environment, disrupting attention and memory function (Sarason, Sarason, & Pierce, 1995). This decreases the validity and authenticity of examinations designed to measure intellectual ability and comprehension of a topic.

It is important to acknowledge that there are instances in which anxiety has facilitated performance (Jones, Swain, & Hardy, 1993). For example, Chamberlain, Daly and Spalding (2011) conducted a study assessing college student’s anxiety towards their A-level exams and found that only three students reported feeling that their performance was detrimentally impaired by test anxiety. Students did report anxiety aided exam performance which elicited motivation. Likewise, Birjandi and Alemi (2010) found certain levels of anxiety aided students to remain alert during testing. Moreover, individuals experiencing anxiety have been found to develop effective strategies to reduce the effects of threat to achieve a goal (Eysenck, Derakshan, Santos, & Calvo, 2007).

Nevertheless, Zuckerman and Spielberger (2015) assert that high levels of trait anxiety – particularly in students at college and university level, have repeatedly displayed impaired performance during evaluative procedures. They further suggest that individuals high in trait anxiety respond to evaluative situations with intense emotions, resulting in detrimental task-irrelevant worrisome thoughts. For example, Rana and Mahmood (2010) adopted a sample of 414 postgraduate University students. Using the Test Anxiety Inventory (TAI; Spielberger, 1980), they found a significant negative relationship between anxiety and achievement, suggesting test anxiety to bear substantial consequences, with worry accounting for the largest variance as a contributing factor towards poorer achievement. Zhang and Henderson (2014) investigated the relationship between test anxiety and academic performance in chiropractic students, with mid-to-high test anxiety found in 85% of the sample. They found a modest, but significant negative correlation between TAI scores and written examination performance.

Processing deficits that relate to test anxiety include general impairments of attention and working memory (Schutz & Pekrun, 2007). The above studies reveal a strained relationship between student examination techniques and situational test anxiety which is a particularly important area of study due to the high-stakes placed on exam results throughout Western Society's education system (Zeidner, 1998).

## 1.3 The Working Memory System

The Working Memory System (WMS, see Figure 1.), developed by Baddley and Hitch (1974) is a hypothetical cognitive system explaining the complex cognitive processes involved for temporary storage and management of information. The WMS is essential for the necessary selection, initiation and termination of all information, allowing resources to be directed to the most important information in an individual's environment (Carrasco, 2011). The WMS also allows for the encoding of temporary and long-term storage of information and retrieval of goal-relevant memories when appropriate (Logie, 2011). Moreover, the WMS is thought to be integral for everyday cognitive processes. A few examples include language comprehension – retaining spoken messages to follow a conversation; arithmetic – retaining each part of an equation to successfully attain a solution; reasoning – retaining the premise of a circumstance to elucidate or interpret a current situation (Cowan, 2012).

Baddley and Hitch (1974) first proposed the WMS as a three-component model comprising of a commanding system - the central executive, responsible for the co-ordination and operation of the two sub-systems - the phonological loop and the visuospatial sketchpad. The WMS has since been updated, which now includes the theorised addition of the episodic buffer, often referred to as a “backup store”, communicating with all components of the WMS and long term memory (LTM) (see Figure 1.).

### **1.3.1** *The Central Executive*

The central executive is theorised to control attentional processes, ranging from recognition of important information externally and internally, focusing and sustaining attention, inhibiting interference from distraction and prepotent responses, shifting, encoding, updating, monitoring and retrieving information from the LTM (Miyake *et al.*, 2000; Baddeley, 2007; Moran, 2016). The central executive is also imperative in the monitoring and management of the WMS’s sub-systems. This involves assigning the appropriate sub-system to attend to information within the environment and associating information collected to data stored in the LTM (Baddley & Hitch, 1974).

### **1.3.2** *The Phonological Loop*

The phonological loop attends to articulatory-based information, which includes both spoken and written. Spoken stimuli enter the phonological store directly through the ‘inner-ear’, storing information for a few seconds, whereas written stimuli must first be converted into internal speech before storing (Eysenck & Derakshan, 2011). The articulatory control processes can be thought of as the ‘inner voice’, rehearsing information (i.e. mental repetition) obtained from the phonological store to maintain its contents and retain it in the WM. This allows an individual to remember a phone number after verbal rehearsal, words to a song, etc. Access to the store is gained directly upon auditory perception, and through activation of information within the store itself (Logie, 2011). The phonological loop's store is of limited capacity, and information decays rapidly without continual rehearsal or long-term storage.

### **1.3.3** *The Visuospatial Sketchpad*

The visuospatial sketchpad attends to visual and spatial information. Visuospatial stimuli enter the WM through the 'inner-eye', processing visual and spatial information, allowing an individual to consider their environment in relation to other objects. The visual cache temporarily retains recently presented visual information for several seconds (Logie, 2011). The sketchpad is also responsible for accessing, relating and manipulating visuospatial information. This allows an individual to access and recreate images stored in their LTM, such as the layout of their house or their route to work. The visuospatial sketchpad's store is also of limited capacity since images on the mental sketchpad fade quickly. Therefore a constant restoration of the image is necessary, by either acquiring the image directly from the environment, or obtaining the image from the LTM.

### **1.3.4** *Episodic Buffer*

The episodic buffer offers an explanation as to how the sub-systems communicate and integrate information. Rather than sheer isolation of the sub-systems as previously assumed, the episodic buffer is theorised to communicate with the subsidiary components of WMS, increasing the extent of information (not necessarily phonological or visuospatial in nature) entering the WM which is capable of binding information attained with information from the LTM, into a unitary episodic representation. Baddeley (2000) further proposes conscious awareness to be the primary method for retrieval from the buffer.

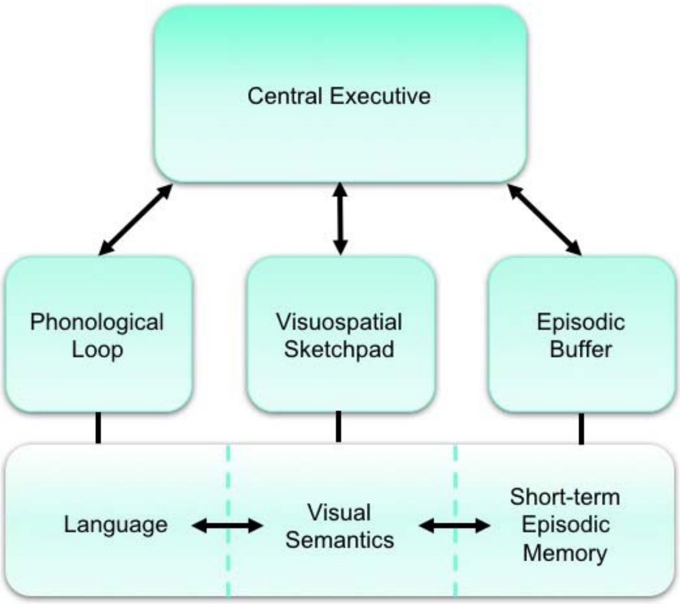



Figure 1. The Revised Working Memory Model (Baddeley, 2000)

The WM receives incoming information through the senses (see Figure 2.), and information attended to by the WM is temporary and must be encoded into the knowledge structures stored in the LTM, or is subsequently forgotten or replaced (see Figure 2.). The duration of information entering the WM is approximately 10-15 seconds, although new information can be maintained when actively attended to through rehearsal (Goldstein, 2010).

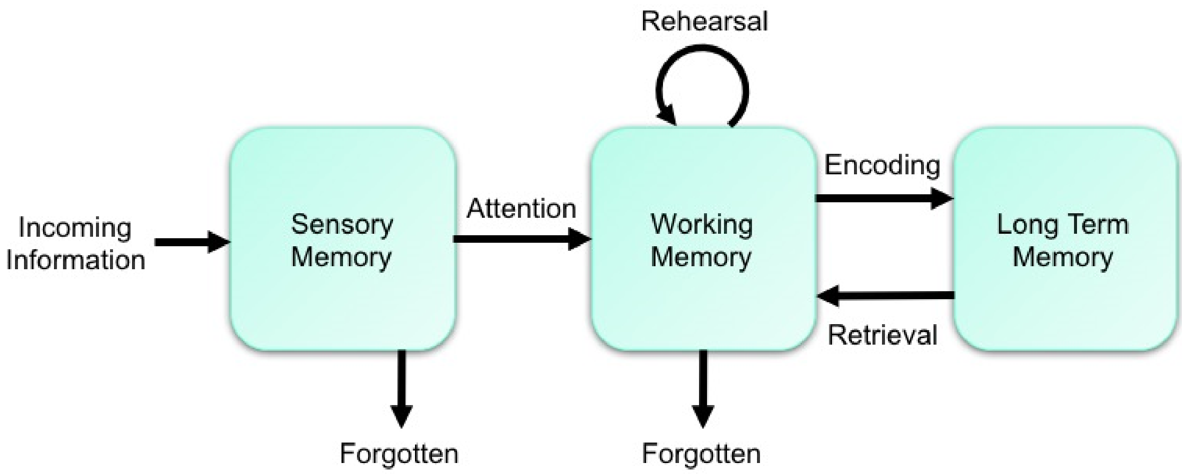



Figure 2. Information Processing Model

**1.3.5** Working Memory Capacity

Working memory capacity (WMC) refers to an individual's capability to control and maintain attention, typically in the face of interference or distraction (Engle, Kane, & Tuholski, 1999; Engle, 2002). It is understood that WM is of limited capacity (Wilhelm, Hildebrandt, & Oberauer, 2013). However, the volume of information that can be consciously experienced and retained at one moment is still disputed (Cowan, 2012).

Measurement of WMC is a relevant and beneficial area of study in an endeavour to identify why individual differences in performance are apparent on a broad range of cognitive tasks requiring WM ability. Cognitive researchers have demonstrated WMC to be essential in the processing and maintenance of goal-relevant information, reflecting individual differences in the ability to focus attention and retrieve relevant information from the LTM (Hicks, Harrison, & Engle, 2015). Individual differences in WMC have been researched in diverse areas of cognition, although a focus has been placed on the measurement of attention; including the ability to multi-task, to deal with task interference and ignore irrelevant distractions, and manage increasing task demands (Hambrick, Oswald, Darowski, Rench, & Brou, 2010). Moreover, outside of the laboratory, WMC can aid an individual to keep track of day-to-day ongoing mental processes such as remembering a shopping list; aiding more effective mental processing to obtain an academic solution. (Logie, 2011).

It is theorised that WMC can also influence both the probability and duration that information remains in the WM, and the capability of the WMS to transfer information to the LTM (Daneman & Carpenter, 1980). In theory, a larger WMC allows for the processing of a larger amount of information, thus offering more opportunities to integrate information into the LTM. Subsequently, future processing will be aided and improve understanding of related information through retrieval from LTM (Daneman & Carpenter, 1980).

## 1.4 The Working Memory System and Anxiety

Amongst cognitive research, anxiety is characterised as “a bias towards threatening information, anxious apprehension, and disrupted concentration” (Vytal, Arkin, Overstreet, Lieberman, & Grillon, 2016). In general, research has found individuals with high trait anxiety display poorer performance on various tasks in comparison to individuals low in trait anxiety. This effect is thought to be mediated under high WM loads (Eysenck *et al.,* 2007). This suggests that individuals with high trait anxiety have reduced attentional resources available to them, due to distractions such as worry. The following theories offer their explanation for this phenomenon: Cognitive Interference Theory (Sarason, 1984), Processing Efficiency Theory (Eysenck & Calvo, 1992), and Attentional Control Theory (Eysenck, Derakshan, Santos, & Calvo, 2007).

## **1.5** Cognitive Interference Theory

Cognitive Interference Theory (CIT) developed by Sarason (1984) suggests that situations threatening to the individual can produce anxiety, resulting in either task-relevant thinking, or task-irrelevant thinking (e.g. worrisome and/or distracting thoughts). Cognitive interference refers to “thoughts that intrude on task-related activity and serve to reduce the quality and level of performance” (Sarason, Sarason & Pierce, 1995, p. 285). CIT further assumes that these thoughts may stem from personality factors such as anxiety, rather than an intellectual deficiency. CIT suggests that errors in performance are likely to arise when task-irrelevant thoughts consume cognitive resources, therefore impeding attention, outweighing goal-relevant thoughts (Sarason, Sarason, Keefe, Hayes, & Shearin, 1986). However, CIT has been criticised for overlooking instances in which worrisome thoughts can support performance effectiveness.

## **1.6** Processing Efficiency Theory

Processing efficiency theory (PET) a model proposed by Eysenck and Calvo (1992) whih builds on CIT (Sarason, 1984), in an endeavour to account for the performance deficits exhibited by anxious individuals when experiencing high levels of situational stress.

PET assumes that worry is the main component of anxiety and is responsible for the effects of anxiety on both performance effectiveness (quality of performance) and performance efficiency (the relationship between performance effectiveness and the use of processing resources) (Eysenck & Calvo, 1992). Individuals high in trait anxiety are more likely to experience feelings of worry, such as concerns of judgement and failure (Eysenck & Calvo, 1992). Unlike CIT, PET suggests that feelings of worry can produce two disparate outcomes: (1) task-irrelevant worrisome thoughts preoccupy the limited attentional resources of the WM, requiring self-regulatory processes to supress distracting thoughts, which in turn, further interfere with task processing, subsequently reducing performance effectiveness. (2) Motivation in the form of extra effort can be heightened by worrisome thoughts; aiding an individual to deploy additional resources, compensating for the negative effects anxiety places on performance effectiveness. However, implementation of additional resources further consumes processing resources at the expense of processing efficiency. This has lead Eysenck and Calvo (1992) to conclude that anxiety affects processing efficiency more than processing effectiveness.

PET also assumes that worry predominantly affects the central executive component of the WM which interferes with information processing and temporary storage (Eysenck & Calvo, 1992). Moreover, with regards to the WMS, PET states that anxiety affects the phonological loop component to a greater extent than the visuospatial sketchpad, as they propose that worry is customarily characterised as a verbal even which enters the WM system though the inner ear (Rapee, 1993).

Eysenck and Calvo (1992) concluded that feelings of anxiety are expected to affect performance effectiveness and efficiency, and this effect will be exacerbated as task demand increases, straining the processing and storage capacity of one's WM. Nonetheless, PET has received reasonable criticism and is regarded as an insufficient explanation of the effects of anxiety on the WM system and subsequently cognitive performance. PET was mainly criticised for the following: PET stated that worrisome thoughts result in lesser efficiency, offering an arguably vague explanation (Wilson, 2008). Moreover, PET lacked a precise explanation of the relationship between anxiety and the functioning of the central executive. PET also failed to make assumptions concerning the influence of distracting, task-irrelevant stimuli and threat-related stimuli, and instances in which anxious individuals surpass their non-anxious counterparts (Eysenck *et al*., 2007).

## 1.7 Attentional Control Theory

### **1.7.1** *Building on Processing Efficiency Theory*

Attentional Control Theory (ACT) developed by Eysenck, Derakshan, Santos and Calvo (2007) is an approach to anxiety and cognition, building on its predecessor, PET (Eysenck & Calvo, 1992). PET and ACT share many commonalities, with their main assumptions being that anxiety affects the cognitive processes surrounding the central executive components of Baddeley's (2007) WMS. Furthermore, there is a clear distinction between performance effectiveness and performance efficiency (Derakshan, Ansari, Hansard, Shoker & Eysenck, 2009), with performance efficiency being more adversely affected by anxiety (Eysenck & Calvo, 1992; Eysenck *et al*., 2007). Nevertheless, the movement towards a revised theory was principally to address the theoretical limitations highlighted surrounding the PET described above (1.6).

### **1.7.2** Effectiveness and Efficiency

Using ACT's definitions, performance effectiveness is regarded as the quality of performance, indexed by standard behavioural measures, generally operationalised as correct task responses. Processing efficiency is the relationship between performance effectiveness, and the use of processing resources or effort. Processing efficiency is considered to be high for high-anxious individuals when performance effectiveness is high, and processing resources are similar to that used by low-anxious peers. Whereas processing inefficiency in high-anxious individuals refers to the substantial use of processing resources in order to attain performance effectiveness, in comparison to the use of resources by low-anxious individuals (Eysenck & Derakshan, 2011).

ACT also recognises that performance deficits may not always be displayed when measuring performance effectiveness alone (Eysenck & Derakshan, 2011). Wilson (2008) suggests that ACT's predictions of reduced cognitive effectiveness may be ameliorated by compensatory strategies such as enhanced effort, motivation, increased use of processing resources. Thereby reducing the threat to the current goal, lessening the damage of anxiety, and sustaining adequate performance. Nevertheless, this is most likely at the cost of processing efficiency, for example, time taken to perform the task may be greater. Therefore, ACT asserts that anxiety impairs processing efficiency to a greater extent than performance effectiveness (Eysenck & Derakshan, 2011).

Functional magnetic resonance imaging (fMRI) evidence offers support for this assumption. Fales *et al*. (2008) conducted a three-back task, requiring participants to identify whether a given word was the same as the previous third word presented. They did not find a difference in performance effectiveness among high anxiety and low anxiety participants. Nevertheless, they did find high-anxious participants displayed greater brain activation in the dorsolateral and ventrolateral prefrontal cortex, associated with attentional control, suggesting high-anxious participants adopted more attentional control resources than low-anxious individuals to rectify performance deficits.

Nevertheless, Eysenck *et al*. (2007) clarifies that deployment of extra resources results in an overall lowering of WMC. Consequently, impairments as emerged through anxiety become more difficult to overcome solely through the application of extra processing resources when a task is both attentionally demanding, and requires a large volume of processing power. Therefore, high trait anxiety individuals are still predicted to display poorer performance effectiveness on cognitively demanding tasks requiring efficient processing and greater storage demands, as opposed to more simple tasks, placing less demands on WMC.

### **1.7.3** Effort

As mentioned, task-irrelevant thoughts are experienced by high-anxious individuals, leading them to actively invest extra resources to compensate for cognitive deficits that occur as a result (i.e. in the form of decreased performance effectiveness). Nevertheless, this is often at the cost of processing efficiency (Eysenck *et al*., 2007). Exerting greater effort is a crucial resource high-anxious individuals have demonstrated as a favourable means to achieve adequate performance (Eysenck *et al*., 2007).

Ansari and Derakshan (2011) support this notion. They adopted a mixed antisaccade task using antisaccade trials (ignoring a visual cue as rapidly as possible) and prosaccade trials (fixating on the visual cue) (Miyake *et al*., 2000). During this task, event-related potentials (ERP's) highlighted that high-anxious participants displayed greater slow wave negativity during the longer inter stimulus intervals, indicative of increased use of effort and cognitive resources (Jennings & Molen, 2005).

Eysenck *et al*. (2007) assert that effort can be assessed via self-report measures, psychophysiological measures, and incentive manipulations, offering both subjective and more objective options. An example of a prominent mental effort scale used throughout the literature, and subsequently adopted during the current study, is The Rating Scale of Mental Effort (RSME; Zijlstra, 1993), designed to measure an individual's subjective level of mental effort required to execute a task (Appendix T).

Dornic (1977; cited in Eysenck *et al*., 2007) conducted an experiment using complex closed-system thinking tasks on high and low anxiety participants, finding similar performance. However, high-anxious individuals rated the task significantly more effortful than low-anxious participants, suggesting high anxiety participants invested more attentional resources. Moreover, Smith, Ballamy, Collins and Newell (2001) used self-report effort measures in elite male volleyball players, either high or low in dispositional anxiety. Differences in performance as measured by set scores on a motor-based task, were reflected by higher mental effort self-reports, assumed to be used by high-anxious individuals as a compensatory strategy. Overall, self-report studies afford the assumption that high-anxious individuals exert effort to moderate performance and processing efficiency outcomes (Edwards, 2015). These results demonstrate the importance of effort ratings as a source of processing efficiency during attentionally demanding tasks.

### **1.7.4** Two Attentional Systems: Goal-directed and Stimulus-driven

ACT is based on the theoretical assumption that attentional control is comprised of two attention systems; the goal-directed attention system, and the stimulus-driven attention system (Eysenck *et al.*, 2007). According to Corbetta and Shulman (2002), the goal-directed attentional system is involved in top-down, exogenous control of attention; this form of attention is actively controlled volitionally. This system is mainly influenced by expectation, knowledge, and current goals. Whereas, the stimulus-driven attentional system is involved in bottom-up, endogenous control of attention; this form of attention is driven by objects themselves (e.g. a loud noise), attended to non-volitionally. This system mainly responds to salient or conspicuous stimuli (Carrasco, 2011).

The goal-directed and stimulus-driven attentional systems interact for the harmonious functioning of attentional control. However, ACT states that anxiety disrupts the balance between the two systems, resulting in a dominating influence of the stimulus-driven attention system. As such, high-anxious individuals display a decreased ability to prevent incorrect dominant responses (reduced ability to ignore distraction), and increasing automacy to process threat related stimuli, both external (e.g. threatening task-irrelevant distractors) or internal (e.g. worrisome thoughts), and decreased ability to task-switch (Eysenck *et al*., 2007).

Coombes, Higghins, Gamble, Cauraugh and Janelle (2009), investigated the effect trait anxiety poses on the balance of the above attentional systems. They devised an experiment designed to engage both the goal-directed attentional system - using pre-planned target force contractions, at the offset the stimulus-driven system - using emotion evoking and neutral distractors. They found high-anxious participants displayed slower response times, which assumed to reflect inability to ignore distractors. This suggests high trait anxiety participants may have an overactive stimulus-driven attention system. Although, they found a non-significant difference in performance effectiveness between low and high-anxious groups.

However, ACT recognises that this imbalance is not solely a disadvantage for performance effectiveness on certain tasks. The increased influence of anxiety on the stimulus-driven attention system can aid correct responses on tasks excluding distractors, such as non-competitional lists (lists with strong within-pair associations, and weak associations between terms from different pairs, e.g. moon-sun) (Wicklund & Brehm, 2013). On the others hand, anxiety produces the opposite effect for competitional lists (lists with strong associations between terms of different pairs, e.g. grape-light, apple-dark) (Wicklund & Brehm, 2013), failing to inhibit pre-potent, incorrect responses (Eysenck *et al*., 2007).

### **1.8** <u>The Central Executive and Anxiety</u>

PET and ACT state that anxiety has a negative impact on attentional control, which is a key function of the central executive (Moran, 2016). However, PET failed to establish which functions of the centre executive are most adversely effected by anxiety (Derakshan *et al*., 2009). Miyake *et al*. (2000) conducted research investigating the control functions of the central executive, and identified three independent control-based operations; inhibition, (task-set) shifting, and WM updating. This finding was adopted by ACT, asserting that the inhibition and shifting functions are most impaired by anxiety, making assumptions about trait anxiety and susceptibility to distraction (notably preferential to threat-related stimuli), dual-task performance, and task-switching performance. Whereas, ACT states that the updating function tends to be more effected by the strains placed on ones WMC than direct adverse effects of anxiety (Eysenck *et al*., 2007).

### **1.8.1** *The Inhibition Function*

The inhibition function is based on negative attentional control, employed by the central executive to prevent attentional resources being allocated to task-irrelevant stimuli (Friedman & Miyake, 2004). ACT states that anxiety disrupts inhibitory processes by decreasing one's ability to suppress dominant, automatic responses to target stimuli and/or deliberately resist attention to distracting, task-irrelevant stimuli, typically resulting in more incorrect responses when compared to low-anxious individuals (Eysenck & Derakshan, 2011). Additionally, ACT clarifies distracting stimuli can be either external (most often researched) or internal (e.g., worry).

Hallio, Tolin, Assaf, Goethe and Diefenbach (2017) suggest that cognitive control and inhibition play an integral role in the maintenance of generalised anxiety disorder (GAD) symptoms. They conducted a study using the Stroop task and Go/NoGo task, classic tasks used to measure inhibition control. GAD patients demonstrated significantly poorer processing effectiveness and efficiency on the Stroop task in comparison to health controls. Although, non-significant results were found on the Go/NoGo task. Feelings of worry were also measured; however, this measure did not significantly predict performance on either task.

Efficiency of inhibition functioning has also been investigated using antisaccade (experimental trial) and pro-saccade (control trial) eye movement tasks. Visual cues are presented on either side of a monitor screen; the antisaccade task requires the participant to look away from the visual cue as rapidly as possible, whereas the prossacade task requires the participant to fixate on the visual cue (Miyake *et al*., 2000). Increased antisaccade latency suggests a failure to inhibit the salient item, indicating a reduction in inhibitory functioning (Derakshan *et al*., 2009). This task is similar to that used in the current experiment – the visual arrays task (Shipstead *et al*., 2014), also requiring participants to either concentrate on an item, or inhibit a neutral distractor item.

Using neutral cues, Ansari and Derakshan (2011) compared high and low anxiety response times when displaying neutral, happy and angry faces. High-anxious individuals demonstrated increased latency on the antisaccade trials for all faces, suggesting high-anxious participants were unable to ignore the distractor items. Furthermore, the overall slowest reaction times were recorded for angry faces, indicating threat-related stimuli to be particularly inefficient.

### **1.8.2** *The Shifting Function*

The shifting function is based on positive attentional control, involving flexibility and adaptation of attentional control (Derakshan & Eysenck, 2009). The shifting function allows for switching back and forth between operations, both between tasks and within a single task (Miyake *et al*., 2000), which allocates attention to the most relevant stimulus in an optimal manner (Friedman & Miyake, 2004). According to Monsell (2003), switching can result in a switch-cost outcome, reflected in one's processing efficiency, often in the form of increased response time. This effect is exacerbated in those with high trait anxiety (Eysenck & Derakshan, 2011).

Efficiency of the shifting function has been investigated using a task-switching paradigm. Classically, two distinct conditions are established (i.e. A and B) requiring the participant to continually shift between conditions within the same trial (experimental condition). Santos, Wall and Eysenck (2006) adopted this method, using three distinct tasks: odd vs. even; 1– 4 vs. 6 –9; or first letter A-R vs. S-Z, signalled by the location of the stimulus on the screen (top third, middle, or bottom third, respectively). They found high-anxious participants to be significantly slower than low-anxious participants, suggesting task-switching efficiency to be impaired.

Furthermore, Orem, Petrac and Bedwell (2008) adopted trial five of The Comprehensive Trail Making Test, involving a visual search and sequencing task, influenced by attention, concentration, resistance to distraction, and shifting flexibility (Reynolds, 2002). The task required participants to draw a line connecting a sequence on numbers (1-13) and letters (A-L) incrementally, whilst ignoring distractor items. They found highly stressed individuals, regarded as highly anxious who demonstrated performance efficiency deficits in comparison to low stress, low-anxious individuals.

Moreover, Santos *et al*. (2006) observed brain activity using fMRI, finding high-anxious participants displayed considerably greater activation than low-anxious individuals in brain areas associated with central executive functioning (right BA 9/46; Bishop, 2009) when undergoing the task-switching condition, as opposed to the no-switch condition.

### **1.8.3** *The Updating Function*

The updating function monitors and revises information in the WM and is particularly important for numerous short-term memory tasks (Friedman & Miyake, 2004). Under stressful conditions when demands on WMC are substantial, ACT predicts high trait anxiety individuals may display deficits in this function, whereas ACT states the inhibition and shifting function can be affected even when conditions are non-stressful (Eysenck *et al*., 2007).

The detrimental effect high trait anxiety bares on complex reading span performance has been thoroughly researched under stressful, threat-related conditions. Soon after the complex reading span task was developed, Darke (1988) investigated the effect high test anxiety had on performance under an ego-threatening condition, finding high-anxious participants displayed significantly lower reading span than their low-anxious peers, whom performed 68% higher. He concluded that high-anxious individuals had poorer updating effectiveness during this condition. Whereas, Calvo (1996) found a non-significant result using a non-stressful complex reading span condition between high and low-anxious participants. Although, when using a threatening condition, Calvo *et al*. (1992) found a significant difference in performance, with low-anxious participants outperforming their high-anxious peers by 64%.

Santos and Eysenck (2005, cited in Eysenck *et al*., 2007) further state that updating (when assessed using the operation and complex reading span under non-stressful conditions), demonstrates non-significant differences between high and low anxiety participants. Dutke and Stober (2001) also support this and found non-significant differences for high-anxious participants on two updating task conditions. However, as the complex reading span is considered to be a complex measure of WMC, acquiring a high level of attentional control, these results are confounding.

### **1.9** The Slave Systems and Anxiety

A vast amount of research supports that anxiety is associated with performance impairments on numerous tasks (Eysenck & Derakshan, 2011). However, there are conflicting findings regarding anxiety's direct influence on the WMS's (Baddeley, 2007) slave components.

The WMS suggests that as well as the central executive, the phonological loop and visuospatial sketchpad have limited processing and storage capacity, and function relatively independent of each other. For example, auditory items such as speech, do not compete with visual items such as video imagery, in comparison to two simultaneous verbal (or visual) items, which would contest for attention, known as the Modality Effect (Penney, 1975).

Findings regarding the adverse effect anxiety bares on the slave systems are ambiguous. Eysenck, Payne and Derakshan (2005) found only the central executive to be effected by anxiety, whereas the phonological loop and visuospatial sketchpad were non-significantly unaffected. Research has demonstrated anxiety to display a variety of effects on the slave systems (Eysenck & Calvo, 1992).

### **1.9.1** *The Phonological Loop and Anxiety*

Most research focuses on anxiety's effect on the verbal system, with a general agreement that the phonological loop is somewhat adversley effected by anxiety. Previous research found high anxiety to be associated with performance deficits and response time increases in a variety of verbal tasks, ranging from verbal reasoning (Darke, 1988) and grammatical reasoning (Eysenck & Derakshan, 1998; MacLeod & Donnellan, 1993), to reading comprehension (Calvo & Carreiras, 1993) and verbal WM (Ikeda, Iwanaga, & Seiwa, 1996; cited in Eysenck *et al*., 2007).

However, revisions of ACT have now excluded assumptions regarding the phonological loop (Berggren & Derakshan, 2013; Eysenck & Derakshan, 2011) due to conflicting and scarcity of empirical evidence regarding this component. Although, in their previous version, PET assumed the phonological loop to play an integral role in the experience of anxiety, as Rapee (1993) highlighted, internal worry operates using the verbal system.

Moreno, Ávila-Souza, Gomes and Gauer (2015) conducted a constrained sentence span task, requiring participants to judge as to whether words presented in the test phase were contiguous to words previously presented in the encoding phase, requiring phonological processing and storage. They found individuals with high anxiety displayed decreased performance accuracy compared to low-anxious participants.

However, there are several studies demonstrating anxiety to have a non-significant effect on verbal WM performance effectiveness. For example, Putwain, Shah and Lewis (2014) conducted two studies investigating the effect of performance-evaluative threat on a verbal WM task: the backwards digit span, in individuals with high and low anxiety. Participants completed both threat and non-threat conditions; counterbalancing was used accordingly. They found verbal WMC in students with high test anxiety did not differ between threat and non-threat conditions. Although contradictorily, their second study demonstrated verbal WMC in students with high test anxiety decreased during the evaluative threat condition when participating in the threat condition first. Whereas, their verbal WMC increased when participating in the threat condition after the non-threat condition. These findings are hard to interpret due to the clear practice effects involved, as counterbalancing could have acted as a stress buffer, allowing participants to become more familiar with the threat condition upon completing the non-threat condition. Although, high trait anxiety participants that completed the threat condition first displayed performance impairments on the verbal WMC task which was a pattern demonstrated throughout the research (Eysenck & Calvo, 1992). Putwain, Shah and Lewis (2014) suggest it necessary to consider compensatory strategies employed by high trait anxiety individuals, such as the influence of increased effortful control when researching performance-evaluative threat, which may help to explain the variance in their own, as well as other research demonstrated within this area.

The current research will implement three measures, designed to require phonological processing: simple, complex and test-style, to gain a fuller picture of phonological performance differences in participants with high and low trait anxiety.

### **1.9.2** *The Visuospatial Sketchpad and Anxiety*

Research regarding anxiety's impact on the visuospatial sketchpad is more scarce. Subsequently, whilst PET and ACT did include the phonological loop in earlier models, both theories did not include the visuospatial system. Researchers have investigated the effect anxiety has on this slave system in the domain of attentional-bias, based on long-standing theories that anxiety and threat disrupt the allocation of spatial attention (Janelle, 2002). Attentional-bias theory suggests that individuals allocate attention towards task-irrelevant items in the presence of threat, overriding attention towards relevant goals (Cisler & Koster, 2010). Accordingly, it is theorised that task-irrelevant activation of the visuospatial system results in less visuospatial resources being readily available for goal-relevant tasks (Lavric, Rippen, & Gray, 2003). However, there is a lack of research focusing on the visuospatial sketchpad and anxiety when implementing neutral stimuli, as shall be used in the current research.

Moreno *et al*. (2015) conducted a binding in colour and shape task requiring participants to recognise whether a target stimulus had changed shape or colour based on the previous presentation, assessing the engagement of the visuospatial sketchpad (Wheeler & Treisman, 2000). They found individuals with high anxiety displayed higher response times on the visuospatial task, although this was also coupled with lower accuracy. This finding is similar to that reported by Gray (2001), who found anxiety facilitated visuospatial WM processing efficiency, but disrupted verbal WM.

However, Owens, Stevenson, Hadwin, and Norgate (2014) investigated the interaction between anxiety and spatial WMC, measured using forwards and backwards versions of the spatial span test on the Cambridge Neuropsychological Test Automated Battery (Ozonoff *et al*., 2004), allowing them to determine the variance on a demanding visuospatial, fluid intelligence task: The Raven's Progressive Matrices (Raven, 1962). They found high trait anxiety had a non-significant effect on performance when WMC was average. Whereas, high trait anxiety coupled with low WMC resulted in significantly negative performance. Furthermore, trait anxiety coupled with high WMC resulted in significantly higher performance. These results suggest that WMC may moderate the relationship between trait anxiety and performance on visuospatial tasks, offering an insight into the discrepancies identified throughout the literature.

Staal (2004) further suggests that stress and anxiety have the ability to reduce cue utilisation and reduce an individual's perceptive field, detrimentally influencing visual representation and storage on dual-task paradigms. Moreover, Shackman *et al*. (2006) found anxiety to have an adverse effect on the visuospatial sketchpad, but not the phonological loop. They recruited participants and sorted them into high and low anxiety groups based on the Behavioural Inhibition System (BIS; Carver & White, 1994), assuming high

BIS scores reflected a predisposed nature to react with more intense negative affect in response to threat (Updegraff, Gable, & Taylor, 2004). Therefore, they predicted high BIS individuals to react towards their relatively innocuous, visual cognitive task with higher anxiety. They found even in the absence of threat, high BIS participants exhibited decreased spatial performance effectiveness, suggesting anxiety mediates disruption rather than the threat procedure itself. Shackman *et al*. (2006) also demonstrated through measurement of facial electromyography on the orbicularis oculi and corrugator supercilii muscles, participants displayed physiological signs of anxiety in response to threat, resulting in slower response times. ACT acknowledges processing efficiency on visuospatial tasks may be effected by anxiety, citing Markham and Darke's (1991) research, who also found high anxiety individuals produced slower response times during spatial reasoning tasks (Eysenck *et al*., 2007).

For more advanced visuospatial tasks, i.e. in the form of more complex reasoning or addition of distractor stimuli present, it can be theorised that participants would have less visuospatial resources available in comparison to simple visuospatial measures, resulting in less goal-relevant attentional control. It could also be further theorised that this effect would be particularly detrimental for high anxiety individuals, based on performances differences displayed on complex measures of verbal WMC and threat-related visuospatial WMC measures. Therefore, the current research predicts that there will be a difference between high trait anxiety and low trait anxiety participants on the complex visuospatial tasks.

The current research will implement three measures of visuospatial performance: simple, complex and fluid visuospatial ability, to gain a fuller picture of visuospatial performance differences in participants with high and low trait anxiety.

## **1.10** Time Pressure Conditions

‘Time pressure’ has been implemented throughout psychological and educational research, inflicting stress, anxiety, and often performance deficits, as demonstrated on tasks ranging from chess and maths, to the classic psychological measure, the Stroop task (Ganushchak & Schiller, 2009). Paola and Gioia (2016) also found high time pressure to impair student’s performance on both a verbal task and numerical task.

De Dreu, Nijstad and Knippenberg (2013) state that time pressure strains cognitive resources and undermines goal-directed information processing (De Dreu, 2003; De Dreu *et al*., 2008). Additionally, Roskes, Elliot, Nijstad and De Dreu (2013) suggest time pressure to be a distractor, consuming mental resources and thus, adversely impacting performance, more so for individuals who adopt avoidance-motivation: associated with anxiety and threat appraisals, and depletes self-regulatory resources (De Lange, Yperen, Heijden, & Bal, 2010) rather than approach motivation: actively striving for success.

Roskes *et al*. (2013) further suggest there to be two main reasons for the detrimental effect time pressure poses on cognitive performance. Firstly, time pressure can provoke feelings of stress, diverting attention. Secondly, time pressure prompts individuals to monitor their progress against time remaining which engrosses cognitive resources otherwise used towards effective performance.

In some instances, time pressure has been found to aid performance (Baas, De Dreu, & Nijstad, 2008), focusing attention (Chajut & Algom, 2003), and arousing motivation to activate further resources (Gardner, 1990; cited in Roskes *et al*., 2013). Subsequently, researchers have suggested it appropriate to apply the inverted U-shaped relation between time pressure and performance effectiveness, wherein, low and high levels of time pressure are harmful to performance (Byron, Khazanchi, & Nazarian, 2010).

Nonetheless, time pressure can have particularly damaging implications on performance for individuals with high anxiety, as time pressure is notorious for intensifying stress and arousal (Byron, Khazanchi, & Nazarian, 2010).

## 1.11 Aims of The Current Research

The current study aims to explore performance differences and mental effort rating differences between low trait and high trait anxiety participants on a simple, complex and complex test-style measures, requiring either verbal and visuospatial WM. Each task is also assumed to measure a different aspect of cognitive process or WM construct. Significant differences found in these areas may suggests a need for educational bodies to implement alternative, individualised measures of attainment, or highlight the need for anxiety reduction interventions, to support the learning and assessment of individuals with high trait anxiety.

### **1.11.1** Proposed Tasks

The following tasks have been selected in aid of providing a more complete understanding of the attentional resources used in the WM and how these may be limited for high trait anxiety individuals. This also provides multiple perspectives on the cognitive processes in different types of tasks used (Shipstead *et al*., 2014). More specifically, these tasks allow for the exploration of anxiety's effect on verbal and visuospatial performance, with reference to the ACT and WMC. As complexity increases, there are reduced resources readily available in the phonological loop and visuospatial sketchpad. To reason effectively, individuals must also use the central executive to shift, inhibit and update irrelevant stimuli. A self-report effort scale will be administered upon completion of each task, to assess the use of effort as an additional processing resources. The critical thinking appraisal (1.11.4) task and advanced progressive matrices (1.11.7) involve higher measures of intelligence, including Gf ability, a concept strongly related to WMC (Salthouse & Pink, 2008). Due to their likeness to assessments administered in settings such as schools, workplaces, etc., these measures will be administered under time-pressured conditions.

Verbal Tasks

**1.11.2** *Word Span*

The word span task is a vastly used measure of phonological processing within cognitive research (Sorg & Whitney, 1992), considered to be a simple measure of short term memory (STM), assessing information storage, rehearsal, maintenance, and updating (Colom *et al*. 2006; Unsworth & Engle, 2007), referred to in the psychology dictionary as "a measure of the ability to recall a list of words in order" (Nugent, 2013). Engle, Kane and Tuholski (1999) suggest the WM is a result of STM plus controlled attention. Therefore, it is interesting to measure the ability to process the word span, as longer list recall may rely on the cognitive abilities of the WM (Colom *et al*. 2006), as word span items tend to become displaced on longer list-spans (Unsworth & Engle, 2005). Moran (2016) also suggests a justifiable distinction for simple and complex spans, highlighting complex spans tend to remove the to-be-remembered items from immediate awareness and controlled attention, through distraction techniques, shifting tasks, etc.

**1.11.3** *Complex Reading Span*

(Daneman & Carpenter, 1980)

This task has been commended as a classic measure of individual differences in verbal WMC, as task demands prevent rehearsal and grouping processes (Engle & Oransky, 1999; Shipstead *et al*., 2014), with many researchers exclusively relying on some form of the complex span as a measure of WMC (Wilhelm, 2013). Conway *et al*. (2007) describe the complex reading span as adoptive of a simple word span, with the addition of a concurrent processing task, creating a dual-task paradigm designed to inflict a trade-off between storage and processing (Engle, 2002; Kane, Conway, Hambrick, & Engle, 2007).

Unsworth and Engle (2007) highlight that both storage and processing ability is crucial for sufficient higher order cognition, rather than storage alone, and this combination reflects Baddeley's (2007) depiction of the WM's function to simultaneously store and process information.

*Executive Functioning:* The complex reading span entails the use of the updating function: referring to the ability to monitor incoming information for relevance (to the task at hand) and appropriately updating information by replacing older, no longer relevant information with newer, more relevant information (Miyake *et al*., 2000).

### **1.11.4** *Critical Thinking Appraisal*

(Watson & Glaser, 1961)

This task is assumed to measure an individual's critical reasoning ability. Measures of WMC are strongly related to performance in complex cognitive tasks, such as reading comprehension, problem solving, measures of reasoning ability, and intelligence quotient – all elements of the critical thinking appraisal task (Conway, Kane, & Engle, 2003).

Specifically, the Critical Thinking Appraisal (Walter & Glaser, 1961) measures the ability to reason with fact versus assumption, most often conducted under timed conditions, demanding a higher level of attention and use of resources than simple word tasks.

Moon (2008, p. 30) defines critical thinking as, "the ability to consider a range of information derived from many different sources, to process this information in a creative and logical manner, challenging it, analysing it and arriving at considered conclusions which can be defended and justified". Much like Gf, higher executive functions such as critical thinking are closely related to WM functioning (Floyd, 2011).

Visuospatial Tasks

### **1.11.5** *Paper Folding*

(Ekstrom, French, Harman, & Derman, 1976)

The paper folding task is regarded as a measure of visuospatial ability. It involves a coordinated sequence of mental transformations (Glass *et al*. 2012), engaging cognitive resources such as logical reasoning ability (Chein & Morrison, 2010), and engaging processes of “apprehending, encoding, and mentally manipulating spatial forms" (Carroll, 1993, p. 309). Miyake, Friedman, Rettinger, Shah and Hegarty (2001) further suggest that spatial transformation involves goal management, multitasking and inference. However, complexity of the paper folding task can be manipulated (Ekstrom *et al*., 1976), allowing for a more simple measure of visuospatial WMC.

### **1.11.6** *Visual Arrays*

(Shipstead, Lindsey, Marshall & Engle, 2014)

The visual array task is a rapid change-detection measure assumed to reflect primary memory capacity, also referred to as immediate memory, in the absence of rehearsal processes and LTM (Hall *et al*. 2015). Primary memory plays an integral role in successful WM processes (Hall *et al*., 2015).

The visual cache retains a brief representation of visual information, however capacity is affected by complexity of stimuli presented. For example, change-detection is high for four items or less, however beyond this four-item limit, accuracy declines consecutively due to an inability to store representations (Luck & Vogel, 1997), exceeding primary memory storage.

*Executive Functioning:* The visual arrays task entails the use of the shifting function: referred to as the ability to flexibly switch back and forth between tasks or mental sets (Miyake *et al*., 2000), i.e. shifting between set sizes, rules and trial types. This task also requires the inhibition function: the ability to inhibit dominant, automatic, or pre-potent responses (Miyake *et al*., 2000), i.e. ignoring a certain colour or a position of items on the screen.

### **1.11.7** *Advanced Progressive Matrices*

(Raven, 1962)

This task is a visuospatial measure of Gf and inductive reasoning, independent of language, reading and writing skills, appropriate for adults and adolescents of above-average intelligence (Domino, Domino, & Marla, 2006). Measures of WMC assume to predict higher order cognition such as fluid abilities (Unsworth & Engle, 2005).

Fluid intelligence can be defined as the capability to reason and solve novel dilemmas, separate from previously acquired knowledge and skills (Williams & Prince, 2017). In other words, an individual must adapt their thinking to a new, unfamiliar problem, “fluidly”. WMC and Gf are strongly associated, with Gf being a relatively stable construct across ones’ lifespan (Conway *et al*., 2003), classically measured using the Raven’s Advance Progressive Matrices (Raven, 1962; Melby-Lervåg & Hulme, 2013, Ali & Ara, 2017).

Carpenter, Just and Shell (1990) suggest that individual differences in Gf reflect an individual’s ability to form and find patterns in abstract relations, whilst maintaining a multiple set of goals in their WM. Jaeggi, Buschkuehl, Jonides and Perrig (2008) further argue that retaining numerous goals in the WM is a pivotal relation to consider when assessing Gf, as this allows for the maintenance of multiple representations, thereby facilitating completion of the task at hand.

## Hypotheses

### **1.12** Performance Effectiveness

#### **1.12.1** Hypothesis One

1. There will be a non-significant difference in performance effectiveness on the word span task and the paper folding task between participants with low trait anxiety and high trait anxiety.

*This condition should not be anxiety evoking or push the boundaries of WMC as they are considered quite straight-forward tasks, conducted on the computers privately. Low WMC, low attentional demand conditions are theorised to mainly require slave system functioning, using little central executive resources.*

#### **1.12.2** Hypothesis Two

2. There will be a significant difference in performance effectiveness on the complex reading span task and the visual arrays task, with low trait anxiety participants displaying higher performance than high trait anxiety participants.

*This condition should push the boundaries of WMC and are overall much more difficult. High WM, high attentional demand conditions are theorised to require the use of central executive resources, due to the greater amount of inhibition, task-shifting, and WM updating required, straining attentional control.*

#### **1.12.3** Hypothesis Three

3. There will be a significant difference in performance effectiveness on the critical thinking appraisal task and the advanced progressive matrices task, with low trait anxiety participants displaying higher performance than high trait anxiety participants.

*This condition is conducted privately, with participants being allocated a cubicle, completing this task in silence under timed conditions. Participants are monitored by the researcher, as is seen in real-life testing in schools. These tasks should be highly attentionally demanding as they are evaluative in nature, theorised to evoke test anxiety and stress in the form of time pressure. The tasks involve critical thinking and Gf, mimicking tests used in real-life. They are made for persons of above-intelligence and participants should find them considerably difficult and attentionally demanding.*

### **1.13** Additional Resources: Effort Ratings

**1.13.1** Hypothesis Four:

4. There will be a non-significant difference in mental effort ratings on the word span task and the paper folding task between low trait anxiety and high trait anxiety participants.

*High-anxious individuals should not feel the task is effortful enough, nor attentionally demanding enough to deploy extra resources, as low WM conditions are theorised only to require slave system functioning, as little inhibition, task-shifting and WM updating is required, therefore, it is predicted they will have comparable effort expenditure regardless of anxiety level.*

**1.13.2** Hypothesis Five:

5. There will be a significant difference in mental effort ratings between low trait anxiety and high trait anxiety participants on the complex reading span task and the visual arrays task, with high trait anxiety participants reporting higher mental effort scores.

**1.13.3** Hypothesis Six:

6. There will be a significant difference in mental effort ratings between low trait anxiety and high trait anxiety participants on the critical thinking appraisal task and the advanced progressive matrices task, with high trait anxiety participants reporting higher mental effort scores.

*Hypothesis five and six: High anxiety individuals are theorised to mark these tasks as more effortful, indicating that they utilised a higher level of mental effort for the task, employing extra resources for comparable performance. High WM, high attentionally demanding tasks are theorised to require central executive functioning in the form of inhibition, task-shifting and WM updating.*

# 2 Method

## 2.1 Participants and Sample Characteristics

The experiment involved 51 female participants (M age = 23.67, SD = 7.30, age range = 19-52) and 28 male participants (M age = 22.32, SD = 5.59, age range = 18-49) (*n*=79), with an age range of 34, from 18 to 52 years. An opportunity sample was acquired, consisting of both Undergraduate and Masters students attending the University of Huddersfield. Participation was voluntary, with many participants recruited either through use of the psychology department's SONA experiment management system: allowing participants to respond to adverts and opt to take part in the study, or via responding to flyers distributed around the University's main psychology building. Many psychology undergraduates were awarded SONA course credits for their participation when relevant. Most participants were 1$^{st}$ and 2$^{nd}$ year students studying a psychology related course, with a minority of students of different courses, different years of study and various schools within the University of Huddersfield. 13 students disclosed they had been diagnosed with anxiety.

Inclusion criteria: To be eligible for this study, participants were required to be fluent in English; both reading and writing. Visual capability was also a requirement, for example, volunteers with visual impairments were unable to participate if they had not brought their corrective glasses. Participants who had been diagnosed with epilepsy were also unable to participate due to the flashing during the visual arrays task.

Data was split into three groups using participant's Trait anxiety scores, measured using the State/Trait Anxiety Inventory (STAI; Spielberger *et al*., 1983). The low anxiety group (*n*=26) consisted of participants with trait anxiety scores between 21 and 38, (male *n*=11, female *n*=15). The high anxiety group (*n*=28) consisted of participants with trait anxiety scores between 49 and 74, (male *n*=7, female *n*=21). This resulted in the medium anxiety group's (*n*=25) data being removed, leaving an overall sample size of *n*=54 (male n=19, female *n*=36). A *t*-test confirmed that there was a highly significant difference between the low anxiety group (M = 32.15, SD= 5.45) and the high anxiety group (M = 56.36, SD= 6.97), $t(52) = -14.14$, $p<.001$.

## 2.2 Apparatus and Materials

<u>Anxiety Assessment:</u>

**2.2.1**

- **The State/Trait Anxiety Inventory (STAI)**; developed by Spielberger, Gorsuch Lushene, Vagg and Jacobs (1983) (Appendix A).

*Apparatus and Materials:*

- Qualtrics*:* an online research software used to present experiments in questionnaire-form.

*Method:* The STAI is a 40-item likert-type scale, comprised of two 20-item sub-scales:

1. State anxiety (Y-1): concerned with present feelings and severity of anxiety at the time of measurement, designed to measure subjective feelings of apprehension, tension, nervousness, worry and activation/arousal of the automatic nervous system (Julian, 2011). Response options were as follows: *at this moment, not at all, sometimes, often, almost always*. (Example of questions: I feel tense, I feel nervous, I feel self-confident...)

2. Trait anxiety (Y-2): concerned with the general susceptibility to be anxious, a presumably stable, longstanding aspect of personality, designed to evaluate feelings of calmness, confidence and security (Julian, 2011). Response options were as follows: *almost never, sometimes, often, almost always*. (Example of questions: I feel nervous and restless, I have disturbing thoughts, I feel secure…).

Restrictions were applied to the task, ensuring participants could select only one question, and were required to select a response before proceeding to the next trial. A reliability analysis was conducted on the 'State' and 'Trait' sub-scales to verify internal consistency. Both State (αs = .93) and Trait (αs = .93) demonstrated to be above .7, considered an acceptable cut-off point when assessing reliability (Field, 2005). For more information regarding the STAI's validity and reliability (Appendix Aa).

*Procedure:* The STAI was always administered as the first measure to ensure a base level of anxiety was taken before a potential 'testing effect' evoked feelings of anxiety by each upcoming task (Spielberger & Vagg, 1995). Participants first completed the state items (Y-1) followed by the trait items (Y-2). Higher scores for both trait and state sub-scales indicate greater anxiety.

<u>Working Memory Task:</u>

Verbal Tasks:

**2.2.2**

- **Word Span**
  Low WM, Low Attentional Control

*Apparatus and Materials:*

- Computer and paper based:
- Stimuli: The task was constructed using a list of single-syllable, neutral words, verified by Anderson *et al*. (2004). 81 words were used altogether (Appendix B).
- Participant word span sheet (Appendix C).
- Paper, pencil, eraser.
- The font used was Arial, sized at 115, with each word being presented in black.
- Each word was presented on a computer screen for 1000ms within a 38cm x 28cm grey field, considered to be a neutral background (Movellan, Wachtler, Albright, & Sejnowski, 2003), aesthetically

designed to resemble the visual arrays task for consistency throughout the trials (Figure 3., Figure 4.).

- Superlab (4.5.4): an experiment generator used to build and run experiments, collecting data automatically.

*Method:* The word span task was based on the procedures followed by Pointe and Engle (1990). The task involves six sets based on span-length, ranging from two words (a practice trial), to three, four, five, six and seven words. Each set involves three trials (18 trials altogether). Three trials constituted a set. Due to memory load, the task gradually became more demanding as span size increased. Participants recorded their answers using a sheet designed respectively, highlighting how many words appeared in each trial, as such participants were aware of how many words they were expected to recall. If participants recalled a word with a different feature (such as “dear” instead of “deer”), it was scored as correct, as this could have reflected an orthographic confusion rather than a memory lapse. Words were re-randomised every 10 participants through insertion in an online randomiser (Randomiser.org).

Word span will most likely be higher if items are closely related. Additionally, word span is also often higher for short words in comparison to long words, as shorter words are quicker to process (Baddeley, Thomson & Buchanan, 1975). Therefore, items used in the current word span task were checked for structural, phonological, and semantic similarity; if any of these occurred, these words were again randomised. Moreover, items used were similar in length.

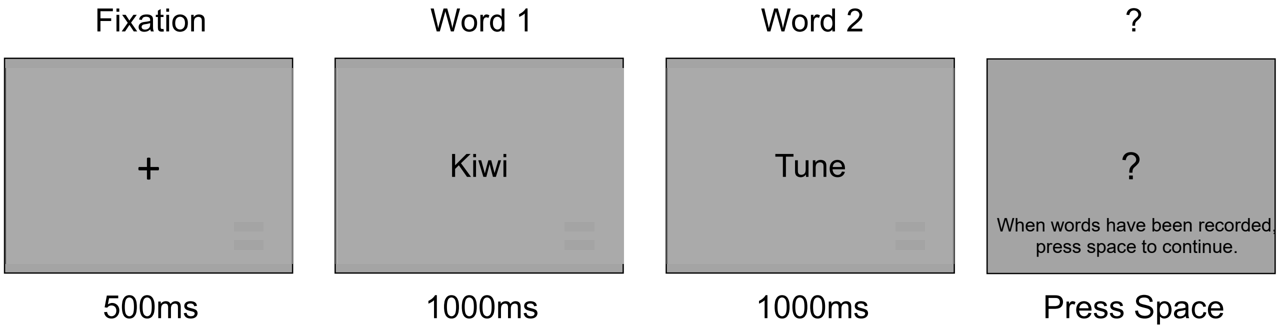



Figure 3. Order of word span presentation

*Procedure:* Participants were given all instructions before the test commenced. If participants failed at the practice set, they were re-issued the instructions and administered another practice trial. Participants were informed that each word would appear on their computer screen for one second, and the number of words presented during each trial would increase in span order, gradually becoming more effortful as the task went on. To begin each set, participants controlled the programme, pressing ‘space’ to move on at their own pace – this ensured that slow-writers were not penalised. They were instructed that they must remember the words presented on the screen and record them in order of presentation, this rule was reiterated, as they were further informed that recalling the right word in the wrong order resulted in an incorrect mark. Participants were informed that they could only recall their answers when a question mark appeared on the screen. Recollection involved participants to record the words using pencil and eraser, and a participant sheet tailored to the task. Scores required summing the total number of words recalled in each trial, resulting in three scores for each span, referred to as the absolute span score (based on Pointe & Engle, 1990). This score was averaged for each set, with higher scores indicating better performance.

**2.2.3**

- **Complex Reading Span**; developed by Daneman and Carpenter (1980)

High WM, High Attentional Control

*Apparatus and Materials:*

- Paper based
- Index Cards (5”x3”).
- Check-sheet for complex reading span (Appendix D).
- Sentences constructed using historical texts in the public domain, sourced through Project Gutenberg: Aesop's Fables (Aesop, 2006), Don Quixote (Cervantes Saavedra, 2004), Gulliver's Travels (Swift, 2009), The Happy Prince and Other Tales (Wilde, 2015), The Adventures of Tom Sawyer (Twain, 2006), and Around the World on a Bicycle Volume II (Stevens, 2004).
- 60 sentences altogether, sentences were 13-16 words in length, each ending in a different word (Appendix E).
- Each sentence was typed in black ink on two lines across a 5x3” index card; the font used was Arial, sized at 16 (Appendix F).

*Method:* The test involved five levels based on span-length, ranging from two sentences (a practice trial), to three, four, five and six sentences. Each level involved three sets. Blank cards were inserted to mark the beginning and end of each set. Spans are divided into stacks based on level. The task gradually became more demanding as span size increased.

Sentence order was re-randomised every 10 participants through insertion in an online randomiser (Randomiser.org). Upon randomisation, last-word groupings were checked for structural, phonological, and semantic similarity; if any of these occurred, these sentences were again randomised.

*Procedure:* Participants were given all instructions before the test commenced. If participants failed at the practice level, they were re-issued the instructions and administered another practice trial. Participants were instructed to pick up the first stack and read each sentence aloud at their own reading pace (approximately five seconds), placing the card face-down upon completion. Upon finishing each sentence, they moved directly on to the next sentence to minimise overt rehearsal until a blank card was reached, signalling the end of the trial. They were tasked with recalling the last word of each of the sentences in the trial. Participants recalled words in an order of their choosing, with constraints that the last word read could not be recalled first. Participants started at the two-sentence practice level, and proceeded to each stack in order of increasing span level. Each stack was labelled by span length, as such participants were already aware of how many words they were expected to recall. Daneman and Carpenter (1980) previously suggested using an absolute span score as indication of WMC, involving recording span up until errors emerged and terminating the experiment at this point. However, discarding performance on subsequent trials has been criticised as lacking sensitivity, especially on studies exploring individual differences (Conway *et al*., 2005). Sorg and Whitney (1992) offer an alternative form of scoring, involving comprising the total number of words recalled in each trial, resulting in three scores for each span. This score was averaged for each set, with higher scores indicating better performance.

**2.3.4**

- **Critical Thinking Appraisal**; developed by Watson and Glaser (1961) High WM, High Attentional Control – Test Condition

*Apparatus and Materials:*

- Questions selected from the Watson-Glaser Critical Thinking Appraisal YN Form (1961).
- Qualtrics: an online research software used to present experiments in questionnaire-form.

*Method:* Restrictions were applied to the task, ensuring participants could select only one question, and were required to select a response before proceeding to the next trial. The task required participants to complete five subtests, designed to measure an individual's ability to reason analytically and logically. The full YN form consisted of 100 questions spread across each sub-test. Due to time constraints and inappropriateness of questions, this was shortened to a total of 42 multiple choice questions. The examinee was asked to think critically about problems involving "neutral" topics such as the weather, scientific facts or experiments, and other topics in which people generally do not have strong feelings or prejudice.

Five Subtests as described by Watson and Glaser (1961, p 2.) within the YN form manual:

(1) Inference: "Samples ability to discriminate among degrees of truth or falsity of inferences drawn form a given statement". (10 Questions). (Appendix G for the instructions, an example of an extract and an example of a question).

(2) Recognition of Assumptions: "Samples ability to recognise unstated assumptions or presuppositions which are taken for granted in given statements or assertions". (8 Questions). (Appendix H for the instructions, an example of a statement and an example of a question in response to a proposed assumption).

(3) Deduction: "Samples ability to reason deductively from given statements or premises; to recognise the relation of implication between propositions; to determine whether what may seem to be an implication or a necessary inference from given premises is indeed such". (12 Questions). (Appendix I for the instructions, an example of a statement and an example of a question).

(4) Interpretation: "Samples ability to weigh evidence and to distinguish between (a) generalisations from given data that are not warranted beyond a reasonable doubt, and (b) generalisations which, although not absolutely certain or necessary, do seem to be warranted beyond a reasonable doubt". (12 Questions). (Appendix J for the instructions, an example of a statement and an example of a question).

(5) Evaluation of Arguments: "Samples ability to distinguish between arguments which are strong and relevant and those which are weak or

irrelevant to a particular question at issue”. (7 Questions). (Appendix K for the instructions, an example of a statement and an example of a question).

*Procedure:* Participants were given an overall instruction before the test commenced. Each subtest also included instructions. Understanding was acquired at each subtest. If participants did not understand, they were re-administered the instructions verbally, and again checked for understanding. Participants completed this measure in the order set by Watson and Glaser (1961), starting with inference, followed by recognition of assumptions, deduction, interpretation and evaluation of arguments. Participants were under strict test-like conditions, with a 15-minute time limit for completion. Participants completed this task in a private cubicle with a researcher nearby to assist with questions. Scores were calculated based on the total number of correct answers provided, with higher scores indicating better performance.

Visuospatial Tasks:

**2.2.5**

- **Paper Folding**; developed by Ekstrom, French, Harman and Dermen (1976)
  Low WM, Low Attentional Control

*Apparatus and Materials:*

- Paper folding items designed by Ekstrom *et al*. (1976) (Appendix L).
- Qualtrics: an online research software used to present experiments in questionnaire-form.

*Method:* This test consisted of 14 items. The full 20 item version by Ekstrom *et al*. (1976) was shortened due to time constraints. Trials were chosen systematically from the full version, removing only multiples of 3. (leaving questions 1, 2, 4, 5, 7, 8, 10, 11, 13, 14, 16, 17, 19, and 20, see Appendix L). The test required the mental rotation of a square; participants must imagine a 2-dimensional representation of a piece of paper, folding and unfolding. This task also required participants to reveal the correct location of a hole that had been punched through the folded paper, when said paper was unfolded. This involved several stages of mental rotation to produce a solution (Whitlock *et al*., 2012). Five unfolded paper representations appear, with one correct choice. Trials gradually became more complex as the task progressed. Restrictions are applied to the task, ensuring participants could select only one question, and were required to select a response before proceeding to the next trial.

*Procedure:* Participants were given all instructions before the test commenced. Firstly, participants were provided with a detailed example of a paper folding question, the answer, and an explanation for this answer (Appendix M). Understanding is acquired verbally. If participants did not understand, they were re-administered the instructions and again checked for understanding. Participants imagined folding paper based on an illustration representing a piece of paper folded, either once or several times depending on difficulty, with the last picture in each series displaying a hole punched in the paper. Participants then mentally unfolded the paper and were tasked with determining which of the five choices depicted the correct location of holes in the paper. Scores were calculated based on the total number of correct answers provided, with higher scores indicating better performance.

**2.2.6**

- **Visual Arrays**; developed by Shipstead, Lindsey, Marshall and Engle (2014)
  High WM, High Attentional Control

*Apparatus and Materials:*

- Visual Arrays Stimuli: created using Microsoft PowerPoint (based on images and instructions of Shipstead *et al*., 2014).
- Superlab (4.5.4): an experiment generator used to build and run experiments, collect data automatically.
- Restrictions enabled on Superlab, forcing participants to response using only the “1” and “0” keys.
- Modified Keyboard, “S” and “D” stickers placed over “1” and “0” keys.

Exclusion criteria: due to the speed of the display, participants diagnosed with epilepsy were unable to proceed with this task.

*Method:* In all trials, participants were to judge whether a probed item had either changed, or remained the same. Response was recorded via key press, “S” and “D” stickers were place over the “1” and “0” keys, “S” = Same and “D” = Different respectively. All information was presented within a 38cm x 28cm grey field, considered to be a neutral background (Wachtler, Sejnowski & Albright, 2003), aesthetically designed to resemble the word span task for consistency throughout the trials (Figure 3., Figure 4.). There were four sub-tests involving different variations of the visual arrays task:

*(1) Colour Judgement Trial (VA1)*

The VA1 block is a basic task, which required participants to respond as to whether a relevant characteristic of a probed item had changed. All information is relevant at the time of array. The arrays sets consisted of 4, 6, or 8 coloured squares. There were 7 possible colours: white, black, red, yellow, green, blue, and purple. Firstly, a fixation was presented, followed by the array, followed by an inter-stimulus interval (ISI). The trial finished with the presentation of the probed array, which participants responded as to whether a circled item had changed colour (Figure 4). The VA1 block consisted of 42 trials, split evenly between array sets (14 x 4, 6 and 8). 22 trials were 'change', 22 were 'non-change'. (See Appendix N for an example of a change trial and non-change trial for all set sizes).

Colour choices and probed items were generated at random. Set sizes and 'change' and 'no-change' trials were randomly distributed.

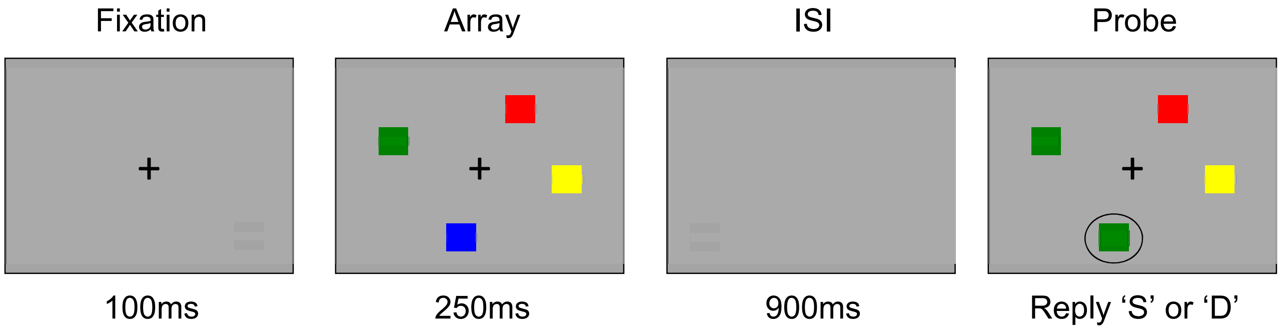
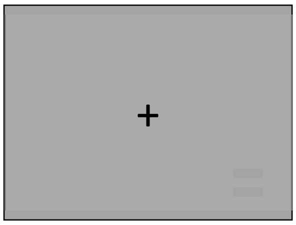



Figure 4. VA1 – Colour Judgment

*(2) Orientation Trial (VA2)*

The VA2 block is a basic task based on one of the conditions used by Luck and Vogel (1997), which required participants to respond as to whether any bar had changed orientation. All information is relevant at the time of array. The arrays sets consisted of 5 or 7 coloured bars. There were 2 possible colours: red and blue. Colours did not change within this trial. Each bar was either horizontal, vertical, or slanted 45° right or left. Firstly, a fixation was presented, followed by the array, followed by an inter-stimulus interval (ISI). The trial finished with the presentation of the array, which participants responded as to whether any bar had changed orientation (Figure 5.). The VA2 block consisted of 40 trials, split evenly between array sets (20 x 5 and 7). 20 trials were 'change', 20 were 'non-change'. Moreover, due to the odd set numbers, the number of coloured bars in each set was evenly distributed from set to set. (See Appendix O for an example of a 'change' trial and 'no-change' trial for all set sizes). Set sizes, orientations, and 'change' and 'no-change' trials were also randomly distributed.

Fixation Array ISI Probe




100ms 250ms 900ms Reply ‘S’ or ‘D’

Figure 5. VA2 – Orientation trial

*(3) Selective Colour Judgment Trial (VA3)*

The VA3 block is a more advanced task based on one of the conditions used by Vogel, Woodman, and Luck (2005), which required participants to respond as to whether any of the relevant squares had changed colour. This task explicitly involved a selective attention component, requiring participants to ignore specific distractor items.

To minimise eye-movements, the sequence of the events presented in this trial was accelerated, relative to previous tasks. The arrays sets consisted of 4, 6, or 8 coloured squares. There were 7 possible colours: white, black, red, yellow, green, blue, and purple. The trial began with a cue that indicated which information would be relevant in the form of an arrow indicating either left (<) or right (>), followed by a short inter-stimulus interval (ISI). This was followed by the array, again followed by an ISI. The trial finished with the presentation of two equally sized arrays (e.g. 4 left, 4 right) of coloured squares, which participants responded, as to whether an item had changed colour relative to the initial presentation (Figure 6.).

The VA3 block consisted of 42 trials, split evenly between array sets (14 x 4, 6 and 8). 22 trials were change, 22 were non-change. Colour choices and probed items were generated at random. (See Appendix P for an example of a ‘change’ trial and ‘no-change’ trial for all set sizes). Set sizes and ‘change’ and ‘no-change’ trials were randomly distributed.