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THE EFFECTS OF WORKING MEMORY CAPACITY AND TRAIT ANXIETY ON VISUAL SHORT-TERM MEMORY PERFORMANCE

Celene Gonzalez

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THE EFFECTS OF WORKING MEMORY CAPACITY AND TRAIT ANXIETY ON
VISUAL SHORT-TERM MEMORY PERFORMANCE

A Thesis
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Psychological Sciences

by
Celene Gonzalez
June 2019
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Approved by:

Hideya Koshino, Committee Chair, Psychology
Richard J. Addante, Committee Member
Robert Ricco, Committee Member
ABSTRACT

Anxiety is of importance within the field of cognition because it is often associated with adverse effects on attention, information processing, learning and memory (Eysenck, 1992, 2007). In existing literature, it has been reported that trait anxiety hinders cognitive performance (i.e., working memory capacity WMC). However, the relationship between trait anxiety and cognitive performance might be moderated by working memory capacity (WMC). For example, Owens (2014) reported that trait anxiety was negatively correlated with cognitive performance in the low WMC group and positively correlated to cognitive performance in the high WMC group. Although, past research on the working memory system has focused on the impairments that are triggered by trait anxiety, there may be an exception to these existing findings. Recently, Moriya & Sugiura (2012, 2018) reported that high trait anxiety paradoxically enhances visual-short term memory capacity (VSTMC). In this present study, we sought to identify if WMC modulates the relationship between trait anxiety and VSTM performance. Our first hypothesis stated that there would be a positive correlation between trait anxiety and VSTM capacity. Our second hypothesis stated that the correlation between trait anxiety and VSTM capacity would be modulated by WMC. In this current study, working memory, visual-short term memory and self-report levels of trait anxiety, were evaluated. The results of the current study did not provide strong support for neither of our hypotheses. For hypothesis 1, we were not able to replicate Moriya and Sugiura’s findings; trait anxiety did not enhance VSTM performance. For hypothesis 2, VSTM performance was not influenced by the interaction term of WMC x trait anxiety; in such WMC and trait anxiety combined were unrelated to VSTM performance. Despite this
work, we are still somewhat unclear whether trait anxiety enhances VSTM performance. Although, our data did not provide definitive support for enhanced VSTMC in high trait anxious individuals it did provide three unique findings. First, our results suggest that the level of WMC does in fact modulate the relationship between trait anxiety and VSTMC. Second, only the somatic component of trait anxiety was negatively correlated to VSTM performance for LWMC individuals. Third, WMC and VSTMC were significantly associated with one another. In closing, our three core findings may provide important insights towards improving future research when assessing the relationship between trait anxiety and VSTM performance.
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Finally,

Thank you, God… for your unconditional light during this process.
DEDICATION

Let your heart guide you …
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CHAPTER ONE

ANXIETY

Introduction

Within the field of cognitive psychology, one of the primary goals is to understand how the human mind processes incoming information, this is accomplished by investigating how individuals select, interpret and remember such information from their environments (Mansell, 2004). Recently, cognitive researchers have begun to explore the multidimensional effects that anxiety has on cognitive performance. Anxiety is an unpleasant mood state experienced by individuals in response to potentially threatening situations or environmental stimuli (Eysenck, 1992). The emotional state of anxiety is the result of an individual’s subjective interpretation and relationship to their environment as characterized by threat. Indeed, this multifaceted mood elicits various behavioral, cognitive, and physiological responses in which researchers have begun to systematically identify the distinct characteristics that arise from anxiety (e.g., Eysenck, 1992; Spielberger, 1970, 2010; Craske, Rauch, Ursano, Prenoveau, Pine, & Zinbarg, 2011).

Trait and State Anxiety

Primarily, it is important to understand that there are two well-known dimensions of anxiety, state (SA) and trait (TA) anxiety (Spielberger, 1970, 2010). Specifically, state anxiety (SA), is a temporary emotional state, where the individuals’ level of anxiety is temporarily elevated as a result of a situational or
environmental stress (Eysenck, 1992). Furthermore, SA is associated with the activation of the nervous system and the simultaneous presence of subjective feelings of tension, apprehension, nervousness, and worry (Panganiban, 2011). Thus, when the temporary object or situation that triggered anxiety is no longer present, individuals no longer experience anxiety. On the other hand, trait anxiety (TA) is characterized as a relatively stable personality trait that is derived from the individual’s heightened predispositions and interpretations to forthcoming perceived threats in their immediate surroundings (Spielberger, 1970, 2010). Both dimensions of anxiety are generally captured and assessed with inventories such as Spielberger’s State–Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch, & Lushene, 1970), and the State-Trait Inventory of Cognitive and Somatic Anxiety (STICSA) (Ree, MacLeod, French, & Locke, 2008). Interestingly, anxiety has been acknowledged to be mediated by individual difference in styles of appraisal and coping strategies (Panganiban, 2011). Moreover, individual’s distinct reactions to anxiety are illustrated upon a continuum level, ranging from low to high scores (Spielberger, 2010). Thus, it is important to understand how these subjective processing biases are influenced by both levels of anxiety.

Processing Biases among High and Low Levels of Trait Anxiety. Primarily, anxiety is mapped within a continuous dimension of high and low levels of anxiety. Indeed, high and low levels of trait anxiety elicit different behavioral and physiological responses. According, to Eysenck’s (1992) hypervigilance theory of
anxiety and attention, individuals with high levels of trait anxiety display a “vigilant” processing mode to environmental stimuli. Specifically, hypervigilance characteristics involve monitoring for potential dangers via attentional broadening or alertly scanning their external environments (Eysenck, 1992; Mansell, 2004). This specific hypervigilant processing mode has been theorized to advantageously improve the detection of any possible factors that may trigger anxiety (e.g., Cattell, 1966; Derakshan, Eysenck, & Calvo, 2007; MacLeod, 1999; Mathews & MacLeod, 2002; Mathews & Mackintosh, 1998).

On the other hand, individuals with low levels of trait anxiety display an “avoidant” processing mode. It has been illustrated that low trait anxious individuals are more likely to avoid any external environments or factors that may potentially trigger anxiety (e.g., Mathews & MacLeod, 2002; Mathews & Mackintosh, 1998; MacLeod, 1999). For example, low trait anxious individuals may worry about the perceived threat and try to develop momentary goals and effective strategies to reduce anxiety (Eysenck et al., 2007). Thus, low trait anxious individuals may make deliberate efforts to avoid any situation, environment or stimulus to remain in a balanced state. Such displays of avoidance among anxious individuals may be attributed as a coping mechanism to avoid any hindrances in behavioral, cognitive or physiological responses that are derived from anxiety.

Overall, the distinction between those with high versus low trait anxiety is based on their subjective sensitivity and responsiveness to minor threat cues.
According to Mathews and MacLeod, (2002), trait anxious individuals display a heightened susceptibility towards environmental cues because they exhibit a “lower threshold” that influences their threat evaluation processes. It has been found that individuals with TA have lowered activation levels for both bottom-up processing and top-down processing of threat related stimuli; this means that threatening stimuli in the environment may be automatically processed (Liao, 2014). Consequently, any plausible threatening circumstance may immediately trigger an elevation of physiological responses, which are typically evident in the individual’s intensity, duration and range for how the circumstance is perceived. Furthermore, in order to gain a more thorough understanding of anxiety’s effects, it is important to consider other perspectives.

**Cognitive and Somatic Components of Anxiety.** In recent years, both the cognitive and somatic components of anxiety have assisted with our conceptual understanding for how behavioral, cognitive and physiological reactions arise from threatening or stressful situations (Chong, 2003). Specifically, the State-Trait Inventory of Cognitive and Somatic Anxiety (STICSA) was designed to capture and assess these specific components via a 21-item (10 cognitive and 11 somatic items) (Ree, MacLeod, French, & Locke, 2008). Somatic components of anxiety account for the symptoms of arousal that are triggered by anxiety (e.g., increased heart rate, sweating, and muscle tension) (Grös, Antony, Simms, & McCabe, 2007). On the other hand, cognitive components of anxiety account for symptoms that involve mental thoughts and cognitive processes, such as
worrisome thinking and evaluative concerns as a direct outcome of anxiety (Chong, 2003). Inevitably, the distinct descriptions of cognitive anxiety have advanced our understanding for assessing how anxiety impacts cognitive performance. Within the cognitive domain, many researchers have claimed that anxious individuals display greater signs of cognitive impairments in attention, central executive functions, and working memory (e.g., Bishop, 2009; Darke, 1988; FaLes, Barch, Burgess, Schaefer, Mennin, Gray, Braver, 2008).
CHAPTER TWO
WORKING MEMORY

Defining Working Memory

Working memory (WM) plays a central role in cognition and perception (e.g., Baddeley 1986; Chun et al., 2011; Cowan, 2002). Specifically, WM enables individuals to temporarily select, integrate, manipulate, and actively maintain relevant perceptual information from the external world, so that it may be briefly held in the mind. WM processes are vital for performing daily functions such as decision making, action planning, reading, writing, and problem solving (e.g., Liao, et al., 2014; Oberauer, 2002; Oberauer, Sub, Wilhelm, & Wittman, 2003).

According to Baddeley (1986), WM is managed by the central executive system, which is essential for self-regulatory functions such as learning, attentional control, (e.g., selective attention or switching attention between tasks), planning to achieve a goal and inhibition (e.g., focusing attention on relevant information and inhibiting irrelevant ones) (Brosch, 2013).

The central executive system achieves its fundamental functions by managing three storage sub-systems, known as: (a) the phonological loop (b) the visuospatial sketchpad and (d) the episodic buffer (Baddeley, 1986, 2000, 2003; Baddeley & Hitch, 1974). Specifically, the phonological loop’s role involves processing spoken and written content for the rehearsal and transient storage of verbal information (Baddeley, 1986; Baddeley & Hitch, 1974). The visuospatial sketchpad’s role is to process visual content via the transient storage of visual
and spatial processing of information (Baddeley 2003; Oberauer, Süß, H. M., Wilhelm, O., & Wittman, 2002). Lastly the episodic buffer subsystem communicates, integrates and binds features of stimuli and types of information that occurs from the phonological loop, the visuospatial sketchpad, into long-term memory (Baddeley, 2000, 2003).

In simpler terms, both the phonological loop and the visual spatial sketchpad cooperatively intertwine to process, update, encode, and store incoming information into working memory. Given that incoming information must be briefly held in the mind while simultaneously performing a cognitive task; there are often a limited number of items that are stored and retained within the working memory system. Working memory capacity (WMC) is the ability to actively engage, process, and store a quantifiable number of incoming information, (e.g., Baddeley, 1986; Cowan, 2001, 2005; Fukuda, Vogel, Mayr & Awh, 2010; Wilhelm, Hildebrandt, & Oberauer, 2013). Engle (2002) explained that WMC is closely related to attentional control of executive functions, including updating, switching and inhibition (e.g., Engle et al., 1999; Wilhelm, 2013).

It has been empirically noted that there is a capacity limit of four items within WMC (Cowan, 2001, 2005). Moreover, WMC is known to be an important variable and indicator for individual-differences that accounts for general intellectual ability (Conway, Kane, & Engle, 2003). Specifically, WM span tasks such as, counting span (e.g., Case, Kurland, & Goldberg, 1982), operation span (OSPAN) (e.g., Turner & Engle, 1989), n-back task (e.g., Shackman et al., 2006)
and reading span tasks (e.g., Daneman & Carpenter, 1980) — have been widely used to measure the storage and processing functions of WM. For example, in the reading span task, participants are required to verify the logical accuracy of sentences that are presented in a set size from two to six, while trying to remember words that are presented one at a time. On the other hand, the operation span (OSPAN) (Unsworth, Heitz, Schrock & Engle, 2005) task requires for participants to remember a series of 2–5 words that are combined with math-verification problems (e.g., given “is \([3/1] - 1 = 2\)?”—“cat”—“is \([2 \times 2] + 1 = 4\)?”—“box”). Specifically, the participant is instructed to answer either “true” or “false” to the math problems then remember the words “cat” and “box”. After several pairs of math problems and words, participants are required to recall the words in the order in which they were presented (Watson & Strayer, 2010).

**Defining Visual Short-Term Memory**

The connection between memory and vision is a particularly interesting domain of research because it focuses on both the processes of memory and the nature of the stored visual representations (Luck & Hollingworth, 2008). Within the visual research domain ongoing progress has been especially exciting for understanding how visual information is temporarily maintained, in relation to attention (Chun et al., 2011). Visual short-term memory (VSTM) allows for visual information and representations to be actively maintained, refreshed, and perceptually stored (e.g., Awh & Jonides, 2001; Cowan, 2001). Within this context, it is important to clarify the distinction between WMC and VSTMC.
Respectively, “WMC”, refers to the capability where memory representations are maintained in a highly active state in the presence of a manipulation (i.e., interference). WMC is typically measured with the OSPAN and reading span tasks to account for both the manipulation and maintenance of items.

On the other hand, VSTMC reflects the ability to actively encode and maintain a limited number of visual items and features without any manipulations or interferences. In general, VSTMC, is typically measured via visual cognitive paradigms (Chun, 2011). One of the most commonly recognized tasks that assess VSTM capacity is the “change detection paradigm”, which allows to assess how quickly and accurately information (i.e., features and conjunctions) can be maintained and refreshed within VSTM. (Luck & Vogel 1997). Generally, in this change detection task, participants are shown an array of visual stimuli (e.g., colored squares) for a brief period (e.g., 100 ms). Subsequently, all squares disappear for about a 1-second, then participants are presented with a test array. During this test array participants are required to indicate whether or not any items have changed. Specifically, if a test array reappears with items remaining the same colors and at the same locations, then they would respond “no change”. On the other hand, if the test array reappears and a single item changed into a different color then the individual would respond with “yes change” (Kyllingsbæk & Bundesen, 2009). The accuracy of the individuals’ performance in the task is used to estimate visual short-term memory capacity (VSTMC) (Cowan, 2001, 2005).
VSTMC similarly like WMC is generally estimated via the standard formula, $K = S (H - F)$. Where $K$ is the memory capacity, $S$ is the size of the array, $H$ is the observed hit rate, and $F$ is the false alarm rate (Cowan, 2001). It has been characterized that within the visual domain, individuals generally maintain up to four visual representations in their VSTM (e.g., Alvarez, & Cavanagh, 2004; Luck & Vogel, 1997; Pashler, 1988). Considerable capacity differences across individuals have been reported to be influenced by the complexity of an array size or by the number of objects that are stored within VSTM (Awh, Barton, Vogel, 2007). VSTMC appears to be limited by the number of objects that can be stored, independently of the number of features probed for each object (Alvarez & Cavanagh, 2004; Luck & Vogel, 1997). Furthermore, WMC and VSTMC are vastly influenced by emotions, affective states, and psychopathological individual factors such as anxiety (Derakshan, 2013). Given, that cognitive processes are predominantly influenced by anxiety, it essential to understand the relationship between anxiety and its effects on cognitive performance.
CHAPTER THREE
ANXIETY’S INFLUENCE ON COGNITION

Anxiety is of importance within the field of cognition because it is often associated with adverse effects on cognitive performance (i.e., difficulty concentrating and uncontrolled worry) which directly affect attention, information processing, learning and memory (Eysenck, 1992, 2007). Much research has shown that anxious individuals display greater signs of cognitive impairments in attention, working memory and central executive functions (i.e., selective attention, task-switching, planning, inhibition, updating) (e.g., Bishop, 2009; Darke, 1988; Derakshan & Eysenck, 2009; Edwards & Lyvers, 2015; FaLes et al., 2008). Several cognitive-based tasks such as the change detection task (e.g., Luck & Vogel, 1997), stroop task (e.g., MacLeod, 1992), emotional stroop task (e.g., Williams, Mathews, & MacLeod, 1996), dot probe task (e.g., Fox, Russo, Bowles, & Dutton, 2001; Koster, Crombez, Verschuere, & De Houwer, 2004), visual search task (e.g., Berggren, 2015) have assisted to advance our understanding for how anxiety affects cognitive performance and information processing in humans.

In attempting to explain the widespread relationships between anxiety and cognition, researchers have long posited that anxiety restricts the capacity of WM. Several studies have indeed documented an impaired WMC in anxiety (e.g., Ashcraft & Kirk, 2001; Owens, Stevenson, Hadwin, & Norgate (2014),
Shackaman et al., 2006). Specifically, Owens et al., (2014), examined the relationship between WMC and trait anxiety on cognitive performance. Their results demonstrated that individuals with LWMC showed a negative correlation between trait anxiety and cognitive performance, whereas individuals with HWMC exhibited a positive correlation between trait anxiety and cognitive performance. In other words, WMC modulated the relationship between trait anxiety and cognitive performance among adolescents.

Moreover, to help elucidate anxiety’s effects on the central executive system, two theoretical frameworks have been employed within the cognitive field—such as the attentional control theory (ACT) (Eysenck, Derakshan, Santos, & Calvo, 2007) and the processing efficiency theory (PET) (Eysenck & Calvo, 1992). Given, that anxiety may be related to multiple attentional vulnerabilities, the processing efficiency theory (PET) highlights that anxious individuals often apply compensatory mental efforts to overcome such vulnerabilities which is reflected in their performance (Liao, 2014).

Theories

**Processing Efficiency Theory**

According to the processing efficiency theory (PET) anxiety mainly affects the central executive system. Specifically, the PET elucidates the concepts of “performance effectiveness” and “processing efficiency” and their relationship with cognitive performance (Eysenck & Calvo, 1992). Performance effectiveness refers to an individual’s “accuracy of responses” in performance (i.e., the
individual’s quality in performance on any given task). In contrast, processing efficiency refers to an individual’s utilization of resources to perform and complete any given task (Eysenck et al., 2007). Specifically, a deficit in efficiency indicates the utilization of more resources than is typically expected (e.g., reflected by longer RTs). It has been hypothesized that the negative effects and impairments derived from anxiety are significantly greater on processing efficiency (efficiency is measured by accuracy divided by reaction time) than on performance effectiveness (response accuracy). Indeed, Derakshan & Koster (2010) reported that high anxious individuals displayed increased reaction times in a visual search task among the presence of threatening (angry) images conditions vs. the happy and neutral images conditions.

According to the PET, anxiety’s effect on cognition involves the unfavorable reactions that are produced by worrisome thoughts (e.g., a component of anxiety activated in stressful situations). Worry results in less available attentional resources, reduced processing and storage of information while performing a task (Eysenck & Calvo, 1992). Therefore, worry is responsible for effects on performance efficiency and effectiveness. Worry creates cognitive interference, which prevents the processing and temporary storage for incoming information within WM. Indeed, differences in WMC are hypothesized to be derived from the intrusive worries that are exhibited by high trait anxious individuals in comparison to low trait anxious individuals (Eysenck, 1992). In
simpler terms, anxiety consumes attentional resources that are available for superior performance within working memory processes.

**The Attentional Control Theory (ACT)**

The attentional control theory (ACT) was developed to elucidate anxiety’s effects on the executive functions (Eysenck et al., 2007). The ACT stemmed off from Eysenck & Calvo’s (1992) processing efficiency theory (PET), with a new focus to account for how attentional control is modulated among low and high levels of anxiety (Eysenck et al., 2007). Empirical investigations have demonstrated that impairments in WM performance are more likely to be observed among high anxious individuals compared to low anxious individuals (Derakshan & Eysenck, 1998, 2013). Using the OSPAN task, Amir and Bomyea (2011) found, that individuals with high levels of social anxiety displayed lower WMC than non-anxious individuals after accounting for intelligence differences.

Additionally, in accordance with a state-trait approach (Spielberger, 2010) the ACT evaluates anxiety as a personality component. One of the assumptions of the ACT is that TA has detrimental effects on verbal WM but no effect of visual-spatial WM because anxiety is typically described in terms of inner verbal activity rather than visual-spatial processes (Rapee, 1993). According to the ACT, it is advantageous for an individual to allocate their visual attention to monitor for potential dangers by alertly scanning their external environments with numerous eye movements (Eysenck, 2002). While such vigilance can manifest itself in any sense modality (i.e., auditory, visual modalities), Eysenck argues that...
cognitive biases are most apparent and easily detected in the visual domain. Several studies have found that anxious individuals are more vigilant to environmental threats or stimuli than non-anxious individuals. Unspecific hypervigilance or heightened alertness even prior to detecting a threat stimulus has previously been described as a characteristic of anxious individuals (Eysenck, 1992). In this perspective, anxious individuals are constantly looking for potential signs of threat or harm in their immediate environment and as a result selectively attend to stimuli signaling possible danger. Specifically, Eysenck (1992) proposed a broadening of attention (general hypervigilance) during excessive environmental scanning for threat cues followed by a narrowing of attention when a stimulus is being processed (enhanced selective attention).
CHAPTER FOUR
THE EFFECTS OF ANXIETY ON VISUAL WORKING MEMORY

Although, past research on the working memory system has focused on the impairments that are triggered by anxiety, there may be an exception to the existing findings. To date, it has not yet been clarified as to which components of the working memory system (i.e., phonological, visuospatial systems) are mostly affected by anxiety (Eysenck, Payne & Derakshan, 2005). Essentially, it is still important to study the dissociation between the both storage components (Moreno, Ávila-Souza, Gomes, & Gauer, 2015). Subsequently, it is important to raise awareness that both the PET and ACT did not account for anxiety’s effects on the visuospatial system (Buckley, 2018). According to the ACT, anxiety affects the storage components of WM in different ways. Pathological worry is mostly a verbal phenomenon; thus, the ACT proposes that anxiety has detrimental effects on verbal WM but no effect on visuospatial WM (Rapee, 1993).

According to the PET, working memory impairments are predominantly evident in the phonological subsystem (Rapee, 1993). Rapee (1993), evaluated the domain specific systems, and reported that worry primarily utilizes the phonological aspect of the central executive of working memory. Specifically, Rapee found that worry interfered with articulatory suppression, whereas worry did not affect visuo-spatial processing (1993). Likewise, Moreno et al., (2015) evaluated the effects of worry on the visual and phonological storage components of WM. The effects of worry were evaluated in terms of performance
(accuracy) and efficiency (Accuracy/RT) by implementing verbal and visuospatial recognition tasks under binding and non-binding conditions. Respectively, they used the constrained sentence span (CSS) task that assessed word interference in the phonological loop and the binding color and shape (BCS) task of to assess visual recognition and engagement in the visuospatial sketchpad.

Participants were then divided into groups of high and low worry based on the Penn State Worry Questionnaire (PSWQ), a measure of worry frequency. They found that the low worry (LW) group displayed higher accuracy and shorter reaction times in the verbal task than the higher worry (HW) group. Remarkably, accuracy was higher in the visual tasks for both LW and HW than the verbal task. Overall, they observed no effects of worry on performance in the visuospatial task, suggesting that the visual spatial system may be behaving differently.

Thus, one current question is, whether or not anxiety’s effects are domain specific? (Moran, 2016). In extant literature, research regarding anxiety’s impact on the visuospatial sketchpad is limited. Currently, it is unclear as to whether anxiety either impairs or enhances the visuospatial subsystem. Recently, it has been hypothesized that anxiety may potentially enhance cognitive performance via the visual modality (Moriya & Sugiura, 2012). Indeed, behavioral and neuroscientific evidence have confirmed that both anxious and non-anxious individuals display a sustained visual acuteness to threatening stimuli. (Berggren & Derakshan, 2012, 2013; Sessa, Luria & Gotler, 2011). Such visual enhancement was confirmed in Sessa et al., (2011) electrophysiological study
where they implemented a modified change detection task to assess VSTM maintenance of neutral and negative faces (i.e., fearful faces). Indeed, they found that encoding and maintenance of threatening faces improved VSTM performance compared to neutral faces; these differences were confirmed in sustained posterior contralateral negativity (SPCN) brain activity via event related potentials (ERP’s). These findings confirmed that SPCN amplitudes were positively correlated with the maintenance of representations in VSTM.

Altogether, Sessa et al., (2011) concluded that representations of fearful faces are perceptually prioritized at early stages of visual processing; which resulted in more efficient, automatic and detailed processing in comparison to representations of neutral faces.

Moreover, trait anxiety (TA) has been associated with a processing of threat-laden information, such as angry and fearful faces, or threatening words (Berggren & Derakshan, 2012, 2013; Bishop, 2009); suggesting that high anxious individuals exhibit an automatic reaction that results in an enhanced allocation of attention towards detecting the source of a perceived threat (Mogg & Bradley, 1998). Furthermore, this automatic effect of selective attention not only occurs with threatening stimuli, but also occurs in non-threatening verbal, spoken words, faces, pictures, and novel sounds. Furthermore, anxiety has also been shown to broaden and enhance the attentional scope, in contexts with no obvious element of threat (e.g., Richards, Benson, Donnelly, & Hadwin, 2014). For example, Berggren (2015) found that anxiety enhances early information
processing. Specifically, Berggren (2015) implemented a visual detection task that required participants to search for a target letter among a several nontarget letters (dependent on perceptual load) while also reporting whether an additional discrete stimulus appeared on trials. Berggren found that self-reported high trait anxiety was associated with shorter reaction times (RT’s) and an improved detection for the additional discrete stimulus, regardless of the level of perceptual load. This specific finding supported the hypothesis that trait anxiety corresponds with an enhanced visual detection. Overall, Berggren (2015) demonstrated that visual detection was generally improved under increasing anxiety, thus providing direct evidence that anxiety may modulate sensory processing regardless of perceptual load difficulty. Similarly, in a recent meta-analysis conducted by Moran, (2016) the most unforeseen finding was that anxiety predicted greater capacity for nonspatial visual features (e.g., nonthreatening stimuli such as color) in East Asian Populations.

Given these recent findings of an enhanced processing mode in trait anxiety, only a few studies have investigated whether trait anxiety may influence the visuospatial WM component. Considering the important role of VSTM to maintain representations spatially and simultaneously, Moriya and Sugiura (2012) were the first to investigate the effects of social trait anxiety on VSTM capacity. Moriya & Sugiura, assessed VSTM capacity via a standard change detection task. They found that social trait anxiety was positively correlated with VSTM capacity even with non-affective items (i.e., colored squares). Recently,
Moriya (2018) reaffirmed that VSTM capacity was uniquely influenced by social trait anxiety. These findings indicate that trait anxious individuals may unconsciously have a higher capacity which may assist their abilities to potentially retain and hold a large amount of information within VSTM.

Summary

In summary, the studies above have suggested that there is a positive relationship between trait anxiety and VSTM performance. Considering the recent support that high trait anxious individuals exhibit hypervigilant characteristics that involve an automatic attentional broadening for enhanced allocation of their visual attention, it may be possible that this enhancement may lead for individuals with higher levels of anxiety to attend, focus, encode, update and maintain many stimuli and representations into VSTM. Given, that Owens et al. (2014) reported that WMC modulated the relationship between anxiety and cognitive performance, we are curious to explore if WMC also modulates the relationship between trait anxiety and VSTM performance.
CHAPTER FIVE
RATIONALE AND HYPOTHESES

In accordance with Eysenck (1992), we believe that it is essential to investigate the cognitive processes of trait anxiety. In the present work, the primary goal is to test whether WMC may modulate the effect of trait anxiety on VSTM performance. Participants completed a three-part automated WMC task (i.e., OSPAN, RSPAN, SSPAN) and VSTM task (i.e., change detection); individuals were categorized into high medium and low groups of WMC, to evaluate the effect of WMC on anxiety and VSTM. We characterized VSTM performance by assessing the number of items that are maintained in VSTM among high trait anxiety. Altogether, this study will enhance our understanding for the recent discrepancies found in the VSTM literature and to explain the widespread relationship between trait anxiety and cognition performance.

Hypotheses

Hypothesis 1: There would be a positive correlation between trait anxiety and VSTM capacity. Figure 1.
Hypothesis 2: The correlation between trait anxiety and VSTM capacity would be modulated by working memory capacity (WMC). Figure 1, 2.
Figure 1. Hypotheses 1 and 2.

Figure 2. Hypotheses 2.
Methods

Subjects

Subjects had normal or corrected or corrected-to-normal vision, and no trait of color blindness. Subjects were recruited from California State, University San Bernardino. Subjects were required to be 18 and older, fluent in English. Four (4) SONA units were assigned as an incentive. Subjects were treated in accordance with the Ethical Principle and Code of Conduct (American Psychology Association, 2010). Before initiating the study, all subjects signed a written consent approved by CSUSB’s IRB department. (see Appendix A: INFORMED CONSENT FORM).

Experimental Design:

Three multiple regression analyses were performed to test the moderation effect of WMC on the relationship between trait anxiety and VSTM performance. We entered the continuous predictors of trait anxiety and WMC in step 1, followed by the product of these two predictors as an interaction term in step 2.

IV:

a. Trait Anxiety

b. WMC (A tertile split on the OSPAN task was applied to categorize WMC into three levels; High (above 66%), Medium (between 66% and 33%) Low (below 33%))

c. Memory set sizes (4, 8, & 12)
DV:

a. Accuracy of VSTM task (Cowan’s K- capacity formula was adopted to compute VSTMC)

Materials

Working Memory Measures

Participants performed three automated WM tasks, the operation span (OSPAN), reading span (RSPAN) and symmetry span (SSPAN).

The operation span was a complex span task designed to evaluate verbal WM capacity (see Figure 3) (OSPAN, Unsworth et al., 2005). In this task participants were instructed to solve simple math equations while simultaneously trying to remember a series of unrelated words. Two short training sessions, one for solving math equations, another for remembering words were presented before the actual task trials. In each trial participants were presented with one math operation in the center of the computer monitor, they were required to solve and determine if the math problems were either “true” or false during a limited amount of time. Left index finger for letter “Z” was used to indicate if it is false, right index finger was used with letter “M” to indicate if it is true. Once the participant solved and answered the math problem, they were presented with a to-be-remembered letter for 1 s (e.g., given “is [3/1] - 1 = 2?”—“C”—“is [2 X 2] + 1 = 4?”—“T”). As soon as the word disappears from the screen another math operation was presented. After a set of two to seven operation-word pairs subjects was required to recall words from the current set by clicking the words
from the word board displayed on the monitor. Words must be recalled in the order in which they appear, therefore, a correct answer is determined by selecting both the correct word in its correct order. Participants scores were determined by the adding the number of items recalled in their correct sequences. Trials with mistakes (even one) were not included in the total score. Subjects were informed about the importance of solving the equations correctly.

Figure 3. Operation Span Task (OSPAN).
For the reading RSPAN, we used the automated version (Unsworth, Heitz, Schrock, & Engle, 2005). The task is conceptually identical to the OSPAN with the exception that it incorporates solving reading statements and assessing logicality. Subsequently, the participant had to mentally rehearse a series from 2 - 7 memory item letters, with a single letter presented after each statement, which were to be later recalled and input in the same order as presented.

The automated symmetry span SSPAN task is a complex span task designed to measure spatial WM capacity. This task is conceptually identical to the automated operation span task except that participants must remember 2–5 spatial locations (4 x 4 matrix with one cell filled in red; 650 ms) and make intervening symmetry judgments (i.e., Is the presented geometric feature symmetric about vertical axis?).

**Visual Short-Term Memory Task (VSTM)**

VSTM capacity was accessed via the change detection paradigm (Luck & Vogel, 1997). Every trial began with a central fixation cross that was presented for 400~600 ms, followed by a sample array comprised of 4, 8 or 12 colored squares presented in a random order and from a pool of seven highly discriminable colors (red, blue, violet, green, yellow, black, and white) no color appeared more than twice in an array. All the stimuli were presented against a gray background for 100 ms. There was a blank display for a retention interval of 900 ms, followed by a test array with the same number of colored squares as in the memory array. An example of trial sequence is shown in (Figure 4). One item
in the test array was different from the corresponding item in the memory array on 50% of trials; while in the other 50% of the trials the memory and test arrays were identical. Participants were required to indicate whether the two arrays were identical or different by pressing the ‘1’ or ‘2’ key, respectively, with their right hand using the index and middle finger. There were 80 trials in each set size for a total of 240 trials. Stimulus positions were randomized on each trial and the task was performed in a dimly lit room.

Individuals’ VSTM capacity was estimated via the standard formula $K = S(H-F)$ (Cowan, 2001). Where $K$ is the memory capacity, $S$ is the memory set size, $H$ is the observed hit rate, and $F$ is the false alarm rate. To capture individual differences, we focused on capturing the average $K$–estimates for set sizes 8 and 12, given that set size 4 may give us ceiling effects. (e.g., following Moriya and Sugiura’s 2012 procedure).
Anxiety Measurement

Cognitive and somatic dimensions of trait anxiety were measured by the State-Trait Inventory of Cognitive and Somatic Anxiety (STICSA-T) consisting of 21-items (10 cognitive items and 11 somatic items) (Ree, MacLeod, French, & Locke, 2008). (see Appendix B: STICSA-T FORM).

Color Blindness Measure

Color blindness was assessed with Ishihara’s Tests for Color Deficiency (Ishihara, 1960).
General Procedure

Participants performed this experiment in the SB-452 group laboratory setting which sat up to 12 participants. Stimuli presentation and data collection were controlled with E-Prime 3.0 Software System. All participants sat in front of a computer monitor with a keyboard and mouse.

Participants first completed a consent form then performed the three working memory tasks (i.e., OSPAN, RSPAN, SSPAN) followed by the VSTM task (i.e., change detection task). All tasks consisted of trials that were divided into several blocks, so that the participants were able to take short breaks in between those blocks. Participants were given a few practice trials before the main session. Lastly, individuals’ levels of anxiety were measured by the STICSA-Trait questionnaire, then participants were required to fill out a demographics form (see Appendix C: DEMOGRAPHICS FORM) and were given a debriefing statement (see Appendix D: DEBRIEFING STATEMENT). An example of this procedure sequence is shown in (Figure 5).

![Consent Form, WM Task, VSTM Task, STICSA-Trait, Demographics]

Figure 5. General Procedure.
CHAPTER SIX

RESULTS

Data Screening and Analysis
Statistical analyses were carried out in Excel and SPSS (IBM Version 25). We screened for outliers using a -2.5 SD criterion on VSTM capacity means prior to data analysis, which resulted in an exclusion of 19 VSTMC scores from the overall analysis leaving us with total N=84.

Working Memory Independent Measures
To estimate WMC, we calculated composite scores for the Operation Span (OSPA N), Reading Span (RSPAN), and Symmetry Span (SPAN) to calculate participant’s overall WMC level, as recommended by Oswald et al., (2015) that a composite from three WM measures instead of a single measure will help minimize WMC misclassification. Partial scores were equally weighted and averaged to calculate participant’s WMC score. Based on these scores we sorted them in ascending order and then implemented a tertile split on the WMC variable to derive Low (n=28) (below 33rd percentile), Middle (n=28) (between 33 and 66 percentile) and High (n=28) (above 66th percentile) WMC groups.

Visual Short-Term Memory Measure
To estimate VSTMC, we used Cowan’s K formula for set sizes 4, 8 and 12. The standard formula K=S (H-F), where K is the memory capacity, S is the size of the array, H is the observed hit rate or proportion of correct responses when a change is present, and F is the false alarm rate or the proportion of
incorrect responses when no change is present (Cowan, 2001). Cowan’s K formula was used to detect performance accuracy, for each set size we calculated the slope, where VSTM capacity was regressed against WMC and trait anxiety scores for each set size. Overall, participants effectively performed the VSTM task. Their accuracy rates were determined by correct rejections CR, which is the observed rate or proportion of correct responses when no change is present (CR=0.87, HIT=0.62) for array size 4 (CR=0.84, HIT=0.36) for array size 8 and (CR= 0.68, HIT=0.25) for array size 12.

Table 1. Descriptive Statistics for High, Medium and Low Working Memory Capacity Groups (HWMC, MWMC, LWMC), Trait Anxiety, and Visual Short-term Memory Capacity (VSTMC) (Set Sizes, 4, 8 and 12).

<table>
<thead>
<tr>
<th></th>
<th>WMC</th>
<th>SOMATIC</th>
<th>COGNITIVE</th>
<th>STICS</th>
<th>VSTMC SS=4</th>
<th>VSTMC SS=8</th>
<th>VSTMC SS=12</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HWMC N=28</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.82</td>
<td>16.07</td>
<td>18.96</td>
<td>35.04</td>
<td>2.31</td>
<td>1.97</td>
<td>-0.63</td>
</tr>
<tr>
<td>SD</td>
<td>0.06</td>
<td>2.88</td>
<td>6.00</td>
<td>7.62</td>
<td>0.74</td>
<td>1.33</td>
<td>1.26</td>
</tr>
<tr>
<td><strong>MWMC N=28</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.64</td>
<td>16.64</td>
<td>20.71</td>
<td>37.36</td>
<td>1.72</td>
<td>1.46</td>
<td>-0.74</td>
</tr>
<tr>
<td>SD</td>
<td>0.06</td>
<td>4.92</td>
<td>6.95</td>
<td>10.71</td>
<td>0.85</td>
<td>1.35</td>
<td>1.41</td>
</tr>
<tr>
<td><strong>LWMC N=28</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.43</td>
<td>17.79</td>
<td>20.29</td>
<td>38.07</td>
<td>1.77</td>
<td>1.18</td>
<td>-1.27</td>
</tr>
<tr>
<td>SD</td>
<td>0.07</td>
<td>6.91</td>
<td>6.41</td>
<td>11.90</td>
<td>0.72</td>
<td>1.39</td>
<td>1.18</td>
</tr>
<tr>
<td><strong>All (N=84)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.63</td>
<td>16.83</td>
<td>19.99</td>
<td>36.82</td>
<td>1.93</td>
<td>1.54</td>
<td>-0.88</td>
</tr>
<tr>
<td>SD</td>
<td>0.17</td>
<td>5.16</td>
<td>6.43</td>
<td>10.20</td>
<td>0.81</td>
<td>1.38</td>
<td>1.30</td>
</tr>
</tbody>
</table>
Hypothesis 1: The Relationship Between Trait Anxiety and VSTMC

To test hypothesis 1, we conducted correlations among Trait anxiety scores, WMC, and VSTMC for each set size (i.e., 4, 8, 12), shown in Table 2.

Table 2. Correlations Among Trait Anxiety, Working Memory Capacity (WMC) and Visual Short-term Memory Capacity (VSTMC) (Set Sizes 4, 8 and 12).

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Somatic</td>
<td>1</td>
<td>.542**</td>
<td>.848**</td>
<td>-0.14</td>
<td>-0.14</td>
<td>-0.07</td>
<td>-0.15</td>
</tr>
<tr>
<td>2. Cognitive</td>
<td>.542**</td>
<td>1</td>
<td>.905**</td>
<td>-0.02</td>
<td>-0.05</td>
<td>0.07</td>
<td>-0.01</td>
</tr>
<tr>
<td>3. STICSA</td>
<td>.848**</td>
<td>.905**</td>
<td>1</td>
<td>-0.09</td>
<td>-0.10</td>
<td>0.01</td>
<td>-0.08</td>
</tr>
<tr>
<td>4. VSTM_4</td>
<td>-0.14</td>
<td>-0.02</td>
<td>-0.09</td>
<td>1</td>
<td>.605**</td>
<td>0.19</td>
<td>.346**</td>
</tr>
<tr>
<td>5. VSTM_8</td>
<td>-0.14</td>
<td>-0.05</td>
<td>-0.10</td>
<td>.605**</td>
<td>1</td>
<td>0.218*</td>
<td>0.355**</td>
</tr>
<tr>
<td>6. VSTM_12</td>
<td>-0.07</td>
<td>0.07</td>
<td>0.01</td>
<td>0.19</td>
<td>0.218*</td>
<td>1</td>
<td>0.263*</td>
</tr>
<tr>
<td>7. WMC</td>
<td>-0.15</td>
<td>-0.01</td>
<td>-0.08</td>
<td>.346**</td>
<td>.355**</td>
<td>.263*</td>
<td>1</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

The Relationship Between WMC and VSTMC

As shown in Table 2, there are positive correlations between WMC and VSTMC for all three set sizes. Set size 4 correlation ($r(82) = .346, p < .05$), regression ($F(1, 83) = 11.148, p < .001, R^2 = .120, R = .346$) (Figure 6). Set size 8 correlation ($r(82) = .355, p < .05$), regression ($F(1, 83) = 11.823, p < .001, R^2 = .126, R = .355$) (Figure 7). Set size 12 correlation ($r(82) = .263, p < .05$), regression ($F(1, 83) = 6.096, p < .01, R^2 = .068, R = .263$) (Figure 8).
Figure 6. The Relationship Between Working Memory Capacity (WMC) and Visual Short-term Memory Capacity (VSTMC) on Set Size 4.
Figure 7. The Relationship Between Working Memory Capacity (WMC) and Visual Short-term Memory Capacity (VSTMC) on Set Size 8.
Hypothesis 2: WMC on the relation between Trait Anxiety and VSTM

Three multiple regression analyses were performed to test the relationship between WMC and trait anxiety on visual short-term memory performance. We entered the continuous predictors of trait anxiety and WMC in step 1, followed by the product of these two predictors as an interaction term in step 2. We tested the interaction hypothesis to determine whether the interaction of trait anxiety and WMC would predict any variance in VSTM performance for each set size 4, 8 and 12 (i.e., three different multiple regression analyses). To fully understand and simplify the interaction, we modeled the trait anxiety and VSTM performance relationship at three levels of WMC.
VSTMC Set size 4. In step 1, a model that predicts VSTMC from WMC and trait anxiety was significant (F (2, 83) = 5.691, p <.005, R2 =.123, R = .351) for set size 4 (Figure 9). WMC was a unique predictor (β =.344, t =3.315, p <.001) for VSTM performance; however, trait anxiety was not (β = -.012, p =.910). The WMC x Trait anxiety interaction term in step 2 did not account for any improved variance in VSTMC (F (3, 83) = 2.031, p =.158, R2 =.145, R = .381).

WMC and Trait Anxiety on VSTMC

Figure 9. The Relationship Between Working Memory Capacity (Low, Medium and High Groups) and Trait Anxiety on Visual Short-term Memory Capacity (VSTMC) Set Size 4.
VSTMC Set Size 8. In step 1, a model that predicts VSTMC from WMC and trait anxiety was significant ($F (2,83) = 6.129, p < .005, R^2 = .131, R = .363$) for set size 8 (Figure 10). WMC was a unique predictor ($\beta = .349, t = 3.337, p < .001$) for VSTM performance; however, trait anxiety was not ($\beta = -.071, p = .517$). The WMC x Trait anxiety interaction term in step 2 did not account for any improved variance in VSTMC ($F (3, 83) = .005, p = .942, R^2 = .131, R = .363$).

**WMC and Trait Anxiety on VSTMC**

![Graph showing the relationship between WMC and Trait Anxiety on VSTMC](image)

Figure 10. The Relationship Between Working Memory Capacity (Low, Medium and High Groups) and Trait Anxiety on Visual Short-term Memory Capacity (VSTMC) Set Size 8.
VSTMC Set Size 12 In step 1, a model that predicts VSTMC from WMC and trait anxiety was significant ($F(2, 83) = 3.063, p < .05, R^2 = .070, R = .265$) for set size 12 (Figure 11). WMC was a unique predictor ($\beta = .268, t = 2.502, p < .001$) for VSTM performance; however, trait anxiety was not ($\beta = .074, p = .514$). The WMC x Trait anxiety interaction term in step 2 did not account for any improved variance in VSTMC ($F(3, 83) = 1.377, p = .244, R^2 = .086, R = .293$).

![WMC and Trait Anxiety on VSTMC](image)

Figure 11. The Relationship Between Working Memory Capacity (Low, Medium and High Groups) and Trait Anxiety on Visual Short-term Memory Capacity (VSTMC) Set Size 12.
WMC and Trait Anxiety on VSTMC

As shown in Table 3, VSTM performance for the LWMC group revealed a negative correlation; as trait anxiety increased VSTM performance decreased for all three set sizes, but only set size 4 reached statistical significance \((r(82) = -0.42, p < .05)\). On the other hand, for MWMC and HWMC groups, there was no significant correlation.

Table 3. Correlations Among Trait Anxiety, Low Working Memory Capacity Group and Visual Short-term Memory Capacity (Set Sizes 4, 8 and 12).

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Somatic</td>
<td>1</td>
<td>.596**</td>
<td>.902**</td>
<td>-.459*</td>
<td>-0.24</td>
<td>-0.27</td>
<td>-0.23</td>
</tr>
<tr>
<td>2. Cognitive</td>
<td>.596**</td>
<td>1</td>
<td>.885**</td>
<td>-0.29</td>
<td>-0.08</td>
<td>0.04</td>
<td>0.14</td>
</tr>
<tr>
<td>3. STICSA</td>
<td>.902**</td>
<td>.885**</td>
<td>1</td>
<td>-.425*</td>
<td>-0.19</td>
<td>-0.13</td>
<td>-0.06</td>
</tr>
<tr>
<td>4. VSTM_4</td>
<td>-.459*</td>
<td>-0.29</td>
<td>-.425*</td>
<td>1</td>
<td>.510**</td>
<td>0.29</td>
<td>.381*</td>
</tr>
<tr>
<td>5. VSTM_8</td>
<td>-0.24</td>
<td>-0.08</td>
<td>-0.19</td>
<td>.510**</td>
<td>1</td>
<td>0.29</td>
<td>.631**</td>
</tr>
<tr>
<td>6. VSTM_12</td>
<td>-0.27</td>
<td>0.04</td>
<td>-0.13</td>
<td>0.29</td>
<td>0.29</td>
<td>1</td>
<td>0.37</td>
</tr>
<tr>
<td>7. WMC</td>
<td>-0.23</td>
<td>0.14</td>
<td>-0.06</td>
<td>.381*</td>
<td>.631**</td>
<td>0.37</td>
<td>1</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Analysis of VSTMC, WMC, Somatic and Cognitive Trait Anxiety

Given, that we used the STICSA-Trait form to assess anxiety, which measures the cognitive and somatic aspects of anxiety, we explored further analyses to determine if the somatic or cognitive components of anxiety were independently related to VSTM performance. The results are as follows, the relationship between somatic trait anxiety and VSTM performance for our LWMC group revealed a trend, as somatic trait anxiety increased VSTM performance decreased for all set sizes, but only set size 4 was statistically significant ($r(82) = -0.46, p < .05$) (Table 3. and Figure 12.) When we assessed the relationship between cognitive trait anxiety and VSTM performance for our low WMC group our results revealed no statistically significant effects for any of the three set sizes.
Figure 12. The Relationship Between Somatic Anxiety and Visual Short-term Memory Capacity (VSTMC) on Set Size 4.
CHAPTER SEVEN

DISCUSSION

General Discussion

In this present study, we sought to identify if WMC modulates the relationship between trait anxiety and VSTM performance. Thus, we implemented Owens et al. (2014) WMC framework to extend Moriya and Sugiura’s (2012, 2018) findings that VSTMC increased as trait anxiety increased. Our first hypothesis stated that there was going to be a positive correlation between trait anxiety and VSTM capacity. Our second hypothesis stated that the correlation between trait anxiety and VSTM capacity was going to be modulated by WMC. Thus, the results of the current study did not provide strong support for neither of our hypotheses.

For hypothesis 1, we were not able to replicate Moriya and Sugiura’s findings; in other words, within the context of our current study, trait anxiety did not enhance VSTM performance. For hypothesis 2, WMC did not modulate the relationship between trait anxiety and VSTM performance. Although, our data did not provide definitive support for our hypotheses, it did elucidate three unique findings. First, our results suggested that the low level of WMC does in fact modulate the relationship between trait anxiety and VSTMC. Second, only the somatic component of trait anxiety was negatively correlated to VSTM performance for LWMC individuals. Third, WMC and VSTMC were significantly
associated with one another. Collectively, these three core findings will be insightfully discussed and explained herein.

The Role of Trait Anxiety on VSTM Performance

As mentioned above, we were not able to replicate Moriyas and Sugiura's findings. Our first hypothesis was not supported; trait anxiety alone was not a significant predictor of VSTMC, indicating that trait anxiety did not influence VSTM performance. In our data, there were no positive slopes present for the relationship between VSTM performance and trait anxiety for any of the three set sizes. As a matter of fact, our findings portrayed an evident negative trend. Although our results didn't reach statistical significance, we noticed that VSTMC decreased as trait anxiety increased, which is inversely related to Moriya and Sugiura's findings.

The fact that our data did not provide definitive support for enhanced VSTMC in trait anxious individuals led us to develop additional questions to aid with our understanding as to what specific factors may have influenced our current results. Considering the recent support in the extant literature that high trait anxiety exhibits enhanced cognitive performance that involves an automatic attentional broadening (e.g., Berggren, 2013), enhanced allocation of visual attention (e.g., Berggren, 2015) and an increased visual short-term memory (VSTM) performance (e.g., Moriya & Sugiura 2012, 2018); the question that arose was, “Why within the context of our study didn’t trait anxiety significantly
explain any variance for VSTMC?" Second, we were concerned as to why we derived such distinct variations in our VSTM capacities.

In such, we questioned if our change detection task effectively captured VSTM performance. Typically, in VSTMC literature the inefficiency to detect colors changing is reflected in a sharp slope, where VSTM performance decreases as the set size increases (e.g., Kyllingsbæk & Bundesen, 2009; Schwarb, Nail, & Schumacher, 2016). It has been continuously reported that VSTM performance is nearly perfect for arrays that consist 1 to 3 items while performance systematically declines as the array size increases from 4 to 12 (Luck and Vogel, 2007). Thus, to answer this question we assessed the accuracy on VSTM performance for each set size (i.e., averaging the capacity mean for the CR and HIT scores for set sizes 4, 8, and 12). In line with existing research, we confirmed that both our accuracy and hit scores for each corresponding set size was reflective to the robust array size patterns that are reported for VSTM performance.

Furthermore, within extant VSTM literature, researchers have demonstrated that approximately four (e.g., colors or orientations) may be held in VSTM at one given time (Luck and Vogel 1997, 2010; Zhang & Luck, 2008). With this being said, it is important to note that the individuals within the context of our experiment when averaged by set size were only able to hold 1.94 items for (array size 4), 1.53 items for (array size 8) and -0.88 items for (array size 12) in VSTM at one given time. Thus, our current results for VSTMC suggests that our
student population elicits a slightly lower VSTMC than what is considered typical within the existing literature—which may possibly clarify why we did not replicate Moriya and Sugiura’s findings.

Indisputably, capacity “K” estimates vary across individuals and groups; recent research indicates that some of these true differences are reflected on storage capacity whereas other variations are reflected in the ability to use memory capacity efficiently (Luck & Vogel, 2013). According to many researchers, variances in capacity “K” estimates are principally seen in change detection paradigms that require participants to respond with only two answer choices (i.e., “change” and “no change” responses). In other words, under this liberal method it has been found that participants are more inclined to guess a response; which clearly produces a huge discrepancy when capturing the true capacity “K” estimates for VSTM performance (Kyllingsbæk & Bundesen, 2009).

Specifically, Kyllingsbæk & Bundesen (2009) investigated such capacity discrepancies that are found within the change detection paradigm by examining how such capacity variations occur. Kyllingsbæk & Bundesen found that the variance of VSTM capacity “K” in a change detection paradigm simultaneously increases as the array set sizes increase. Additionally, they reported that the variance of K estimates can be reduced by about 50% when implementing a new alternative unforced-choice version of the change detection paradigm, where the participant is not forced to respond “change” or “no change” but can alternatively respond “don’t know” to refrain from guessing. Interestingly, this new response
paradigm significantly minimized participants guessing responses. Perhaps, if we would have implemented this unforced-choice version within our change detection paradigm, our capacity “K” variances may have significantly been reduced.

Another question that arose from evaluating our current results, was whether the Cowan’s K formula that we implemented to calculate VSTMC may have influenced our overall results. This specific question stemmed off from Rouder, Morey, Morey & Cowan (2011) who acknowledged the problematic averaging of capacity estimates within VSTM literature. Rouder et al., (2011), examined the differences among the two most popular capacity measures for the change detection paradigm— Pashler’s K formula (1988) and Cowan’s K formula (2001), which are used interchangeably, even though they occasionally yield qualitatively different conclusions (Rouder et al., 2011). Additionally, it is important to recognize that there are two versions of the change detection paradigm: a single-probed recognition (i.e., one single item is presented during the test phase) and a whole-display recognition (i.e., a full set of items are presented during the test phase). The difference between the two paradigms are that in a single-probed recognition paradigm, a participant advantageously knows which specific item may change during the test phase. Thus, the participant needs to only evaluate the status of a single item. Whereas, in a whole-display recognition paradigm, the participant does not know which item may change and consequently, must evaluate the status of all items during the test phase.
In such, Rouder et al. suggested that Pashler’s K formula \((K = \frac{N \times (H - FA)}{1 - FA})\) should be implemented to assess VWMC if the task consists of a whole memory array display. Where \(K\) is the memory capacity, \(N\) is the size of the array, \(H\) is the observed hit rate or proportion of correct responses when a change is present, and \(FA\) is the false alarm rate or the proportion of incorrect responses when no change is present. On the other hand, Cowan’ K \((K = N \times (H - FA))\) should be implemented only when a single memory array appears on the display. It is important to note, that we adopted both Moriya & Sugiura’s whole-display change detection paradigm and Cowan’s K formula so that we may be consistent with their study. Thus, we implemented Rouder et al. suggestions and re-analyzed our data using Pashler’s K formula. We applied this technique to determine if there may have been any discrepancies within the capacity scores in our results— we found that there were no significant differences between Cowan’s K and Pashler’s K.

Additionally, it is important to mention that we acknowledge that there are some limitations within our current study. First, we questioned if our -2.5 SD outlier cutoff point may have been a strict measure on our VSTMC scores. One benefit of the -2.5 SD application resulted in the elimination of all 19 non-responders within our change detection task. Perhaps an alternative or less conservative outlier method could have been implemented (i.e., transformation methods on all the 19 scores).
Furthermore, according to the processing efficiency theory (PET) the negative effects and impairments derived from anxiety are significantly greater on “processing efficiency” than “performance effectiveness”. As discussed earlier, performance effectiveness is revealed in the individual’s “accuracy of responses” (i.e., the individual’s quality in performance on any given task). Whereas, processing efficiency is revealed in the “amount of time” the individual spent utilizing resources to perform and complete any given task (e.g., efficiency is measured by accuracy divided by reaction time) (Eysenck et al., 2007). Thus, we acknowledge that we did not conduct any analyses on reaction times to assess individuals VSTM performance, which may have perhaps given us additional insights on our results.

In addition, one important distinction between Moriya and Sugiura’s 2012 study in comparison to our current study, was that that they investigated the effects of social trait anxiety on VSTM performance. Moriya and Sugiura provided self-report questionnaires to measure social trait anxiety by simultaneously administering both the Brief Fear of Negative Evaluation Scale (BFNE) and the STAI-Trait inventory. The BFNE is a commonly used measure that assesses trait social anxiety on 12 items using a 5-point Likert scale. Thus, the BFNE scores were entered in their analyses to assess the relationship between social trait anxiety and VSTMC. Whereas, in our study we only administered one self-report measure to specifically assess trait anxiety (i.e., State-Trait Inventory of Cognitive and Somatic Anxiety (STICSA)). One of the primary reasons we did not
include neither the STAI or BFNE and decided to only integrate the STICSA inventory within the context of our current study, was that recent reports had claimed that the STICSA inventory truthfully captures the conditions of trait anxiety. The inventory accomplishes this by accounting for both the somatic and cognitive components of anxiety; components of which the STAI and BFNE clearly do not account for. Given the fact, that Moriya and Sugiura reported that there was a positive association with both BFNE and STAI on VSTM performance (i.e., as BFNE and STAI scores increased VSTMC also increased); perhaps, it would have been beneficial to simultaneously integrate both the STAI-Trait and STICSA anxiety measures to capture different aspects of our data within the context of our current study.

Lastly, another clear distinction for the existing variances for our VSTM capacity “K” scores may be distinctly portrayed within our subject pool; in such Moriya & Sugiura’s findings of an increased VSTMC in HTA was attributed to only an East Asian population (i.e., Japanese college students). Whereas, our student population entailed of a diverse Hispanic, African American, Caucasian and Asian populations. Descriptively, most of our students were female, Hispanic and bilingual. In addition, 35% of our student pool reported that they had a history of a clinical disorder (i.e., depression, anxiety and PTSD). Thus, both the cultural and psychological differences may possibly account as alternative explanations for not deriving the same findings as Moriya and Sugiura.
WMC on the Relation Between Trait Anxiety and VSTM

In our current study, we found that both WMC and trait anxiety combined were unrelated to VSTM performance. For hypothesis 2, VSTM performance was not positively influenced by the interaction term of WMC x Trait Anxiety. In simpler terms, the trait anxiety and WMC interaction did not explain any variance for VSTM performance within any of the three set sizes (4, 8 and 12). In such, our second hypothesis was not supported; WMC did not modulate the relationship between VSTM and trait anxiety in the positive directions as we originally hypothesized. As demonstrated in Figures 9, 10 and 11 there were no positive slopes for VSTM as a function of WMC and trait anxiety for both the LWMC and HWMC groups.

On the contrary, our data portrays negative slopes for VSTM performance only for the LWMC group when combined with trait anxiety. Additionally, as described in Table 3 the correlations between trait anxiety and LWMC group were only significant on set size 4. This specific finding reinforces extant WM literature in which LWMC is associated with hindered or impaired cognitive performance. Specifically, our current finding is in line with Owens et al. (2014) study, where they reported that LWMC was negatively correlated with cognitive performance among adolescents with trait anxiety. Interestingly, Owens at al. also stated that anxiety alone did not significantly affect test performance; which is parallel to the finding that we derived from our present results—that trait anxiety alone was not a significant predictor for VSTM performance.
Furthermore, as shown in Table 2 our results unexpectedly portrayed that somatic anxiety independently had a greater influence on VSTM on set size 4 for those in the LWMC group. This finding suggests that the somatic component of trait anxiety independently affected VSTM performance only for those in the LWMC group, whereas the cognitive component of trait anxiety had no impact on VSTM performance. As explained earlier, the somatic component of anxiety accounts for the symptoms of arousal that are triggered by anxiety (e.g., increased heart rate, sweating, and muscle tension) (Grös et al., 2007). In such, our current finding that somatic anxiety is negatively correlated to VSTM performance among LWMC group offers a paradoxical discovery. Given the fact that within the WM literature the cognitive symptoms of anxiety (i.e., mental thoughts of worrisome thinking and inability to concentrate) predominantly account for impairments in cognitive performance. Thus, to the best of our knowledge no one within the existing VSTM literature has directly measured the relationship between somatic trait anxiety and VSTMC. Moreover, no one has ever reported this unique finding – that the somatic component of trait anxiety has a negative influence on VSTM performance only for those in the LWMC group.

One question that arose was, “What specific factors may have driven our results for hypothesis 2”. Hence, we acknowledge that was a clear distinction between Owens et al. (2014) study in comparison to our own. In such, Owens et al. (2014) measured WMC, by an accumulation of several battery tests (i.e., the
automated working memory assessment (AWMA; Alloway, 2007) and the Cambridge automated neuropsychological test battery (Cambridge Neuropsychological Test Automated Battery (CANTAB), 2004)). The CANTAB specifically, uses non-verbal tasks to measure a range of 94 executive functions. In addition, the CANTAB assesses spatial WMC using a forwards and backwards version of the spatial span test and digit recall tests to assess verbal WM.

Whereas, in our current study we integrated a combination of the three automated WM tasks the OSPAN, RSPAN, and SSPAN tasks to yield an overall composite score for WMC. Thus, the distinct difference from Owens et al. (2014) WMC measures and our WMC measures may help explain any discrepancies within our current results.

The Relationship Between WMC and VSTMC

As discussed in the previous section both WMC and trait anxiety combined were unrelated to VSTM performance in our current study. On the other hand, WMC alone was in fact a significant predictor for VSTM performance. In simpler terms, this present study revealed that WMC was strongly associated with VSTM capacity for all given set sizes— as WMC increased VWM also increased. Therefore, this surprising association between WMC and VSTMC propelled us to question and offer insightful interpretations as to what factors may have influenced these significant results. One specific challenge, that arose while interpreting our current results, is that within extant literature there is no direct evidence that supports the relationship between WMC and VSTMC. To the best
of our knowledge, no one has ever directly measured this specific association. Thus, we had to find relevant and interrelated research to interpret this specific finding.

Our first attempt, to interpret the positive association between WMC and VSTMC may be elucidated by the visuospatial subcomponent of WM. As discussed earlier, the visuospatial subcomponent of WM allows for the recruitment, maintenance and retention of visual information even after the information is no longer available in the environment (Baddeley and Hitch, 1974, Baddeley 2003; Oberauer, Süß, H. M., Wilhelm, O., & Wittman, 2002). In such, extant research has continuously emphasized that WMC allows individuals the ability to hold and process enough information that is beneficial for achievement in cognitive performance —which is also parallel to VSTMC. In the same way, VSTMC also allows individuals to hold and process visual information that is beneficial for achievement in cognitive performance. Similarly, it has been empirically noted that individuals exhibit the same capacity limit, in maintaining approximately four items both in the WM domain (e.g., Cowan, 2001, 2005) and VSTM domain (e.g., Alvarez, & Cavanagh, 2004; Luck & Vogel, 1997; Pashler, 1988). Altogether, these similarities within both domains specify that there is an undefined missing piece that may be acting as the intermediate ground for these associations.

Another interpretation to assist our understanding for our positive association between WMC and VSTMC is offered by Awh & Jonides (2001) who
suggested that visuospatial memory is closely linked to both WM and visual attention. In such, it is important to recognize that visual attention is the mechanism in which relevant visual information is selected, and irrelevant visual information is ignored (Olivers, 2008). Whereas, VSTM is defined as the mechanism by which relevant visual information is actively maintained, refreshed, and perceptually retained by preventing interference from irrelevant visual information for a task (Awh & Jonides, 2001; Cowan, 2001; Olivers, 2008). Finally, WM is the mechanism in which information is temporarily processed, updated and temporarily maintained (Baddeley & Hitch, 1974).

Altogether, these three clear definitions offer an intuitive explanation for our current findings. In such, we concluded that WMC and VSTMC are largely associated for the reason that as individuals demonstrate an increased cognitive ability to process, update and retain relevant information—this should naturally elucidate their cognitive capability to visually select and maintain beneficial and relevant information to accomplish a given task. In simpler terms, an individual's cognitive ability to maintain relevant information in WM, must be a direct result of their capability to focus their visual attention towards such relevant information so that is may be actively maintained within their VSTM. This specific interpretation was manifested in our results, which demonstrated that as WMC increased VSTMC also increased.

Furthermore, Vogel & Awh (2008) also suggested that visual attention is a fundamental factor in VSTMC. In line with this statement, Theeuwes, Kramer &
Irwin (2011), reported that individuals skillfully used their visual attention to retrieve information from WM. This was accomplished as individuals strategically allocated their visual attention towards the location that contained the information to be retrieved. Given this finding, Theeuwes et al. (2011) made this insightful statement, “Not only is visual attention the vehicle to keep and store information into WM, it is also the vehicle by which information is retrieved from VWM”.

In closing, the association among WM and VSTM is of a particularly fascinating domain since it focuses on both the processes of memory and the nature of how visual representations are stored (Luck & Hollingworth, 2008). Not only does WMC predict higher cognitive performance but its high correlation with VSTM suggests that WMC may be linked to an enhancement in visual performance. Explicitly, the relationship between WMC and VSTM is not only important within the cognitive literature but most importantly it is essential within the context of real-world settings. Moreover, as Schwarb & Schumacher (2016) described that the cognitive capability of VSTM is particularly advantageous for air traffic controllers, system managers, machine operators, warfighters, or any other environment that necessitates the capability to detect visual patterns or for monitoring fluctuations in visual displays.

**Conclusion and Future Directions**

One of our expectations for this study was to replicate the finding that trait anxiety enhances VSTM. However, neither our first hypothesis nor second hypotheses were supported—our data did not provide definitive support for
enhanced VSTMC in high trait anxious individuals. Despite this work, we are still somewhat unclear whether trait anxiety enhances VSTM performance. On the other hand, three main conclusions were derived from our results: First, our results suggest that the level of WMC does in fact modulate the relationship between trait anxiety VSTMC. Second, only the somatic component of trait anxiety was negatively correlated to VSTM performance for LWMC individuals. Third, WMC and VSTMC were significantly associated with one another.

Altogether, our current findings suggest that the level of WMC should be taken into high consideration when assessing the variances in VSTM performance—now not only are capacity variances affected by the complexity of an array size, but VSTM capacity variances may adversely be affected by the level of WMC. In such the levels of WMC may have an underlying effect on individuals’ abilities to maintain non-affective stimuli within VSTM. Additionally, it may be beneficial to further investigate the specific role that somatic anxiety plays on VSTM performance. Lastly, the association between WMC with VSTMC should be further explored to assess if individual’s performance is a direct outcome of enhanced visual attention. In closing, these three core findings may provide significant insights towards improving future research when assessing the relationship between trait anxiety and VSTM performance.
APPENDIX A

CONSENT AND INSTITUTIONAL REVIEW BOARD FORM
STUDENT INFORMED CONSENT

You are invited to participate in a study being conducted by Celene Gonzalez, a graduate student under the direction of Professor Hideya Koshino of the Psychology Department of California State University, San Bernardino (CSUSB). This study is approved by the Psychology Department subcommittee of the Institutional Review Board of California State University, San Bernardino, and a copy of the official Psychology IRB stamp of approval should appear on this consent form. The University requires that you give your consent before participating in this study.

IRB #: IRB-FY2019-144
Title: Colorful Thought
Creation Date: 1-27-2019
End Date: 2-16-2020
Status: Approved
Principal Investigator: Celene Gonzalez
Review Board: Main IRB Designated Reviewers for Department of Psychology

In this study you will be asked to complete computer-based tasks. The experiment will take no more than 60 minutes. At the beginning of each trial, a central fixation point will appear. Then a stimulus display is presented, and you are asked to make a response according to instructions. After the computer task, you will be asked to complete some questionnaires. All your responses will be held in the strictest of confidence by the researchers. You will also be asked to complete a demographic questionnaire. This information will be stored separately from your responses to protect the anonymity of your responses. The data will be locked and stored in SB-452G. No identifying information will be attached to your data from this study, so your participation will be anonymous. The SONA system does record identify information so that you can be awarded extra credit in one of your psychology classes, but this will not be attached to your data and cannot be connected to your responses in any way, so maintaining your anonymity. The data might be deposited to a repository. All data will be reported in group form only. You may receive the group results of this study after Spring 2019 by contacting Dr. Hideya Koshino at hkoshino@csusb.edu.

The experiments involve no risks beyond those of daily life, and no direct benefits to the individual other than an introduction to psychological research and extra credit in one of your courses. However, your data may help to increase our understanding of attention and emotion.

Your participation in this study is completely voluntary and you are free to withdraw at any time without negative consequences. You may receive (4) units of extra credit at your instructor’s direction for your participation. Please feel free to ask any questions that you have. Should questions concerning the study arise at a later date, please do not hesitate to contact the principal investigator at the phone number or address below; or in the event of a research-related concern or injury, please contact the Psychology Department subcommittee of the Institutional Review Board of California State University, San Bernardino. Results of this study will be available from Dr. Koshino after the Spring quarter of 2019 upon request.

Please read the following before indicating that you are willing to participate.

1. The study has been explained to me and I understand the explanation that has been given and what my participation will involve.

2. I understand that my participation is entirely voluntary, and that I may withdraw from participation at any time, or refuse to answer any specific question, without penalty or withdrawal of benefit to which I am otherwise entitled.

3. I understand that if I have any questions or concerns regarding this study, or if I wish to receive additional explanations after my participation is completed, I can contact Dr. Koshino at (909) 537-5425 or hkoshino@csusb.edu.

I acknowledge that I have been informed and understand the true nature and purpose of this study, and I freely consent to participate. I acknowledge that I am at least 18 years of age.

Please indicate your desire to participate by placing and “X” on the line below.

Participant’s X ________

Date: ______________

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APPENDIX B

STICSA-TRAIT-FORM

(Ree, MacLeod, French, & Locke, 2008)
STICS: YOUR GENERAL MOOD

Below is a list of statements which can be used to describe how you feel. Besides each statement are four numbers which indicate the degree with which each statement is self-descriptive of mood at this moment (e.g., 1 = not at all, 2 = a little, 3 = moderately, 4 = very much so). Please read each statement carefully and circle the number which best indicates how you feel right now at this very moment, even if this is not how you usually feel.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Not at all</th>
<th>A Little</th>
<th>Moderately</th>
<th>Very Much So</th>
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<tbody>
<tr>
<td>1. My heart beats fast.</td>
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<tr>
<td>2. My muscles are tense.</td>
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<td>3. I feel agitated over my problems.</td>
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<td>4. I think that others won't approve of me.</td>
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<td>5. I feel like I'm missing out on things because I can't make up my mind soon enough.</td>
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<td>6. I feel dizzy.</td>
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<td>7. My muscles feel weak.</td>
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<td>8. I feel trembly and shaky.</td>
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<td>9. I picture some future misfortune.</td>
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<td>10. I can't get some thought out of my mind.</td>
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<td>11. I have trouble remembering things.</td>
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<td>12. My face feels hot.</td>
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<td>13. I think that the worst will happen.</td>
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<td>14. My arms and legs feel stiff.</td>
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<td>15. My throat feels dry.</td>
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<td>16. I keep busy to avoid uncomfortable thoughts.</td>
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<tr>
<td>17. I cannot concentrate without irrelevant thoughts intruding.</td>
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<tr>
<td>18. My breathing is fast and shallow.</td>
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<tr>
<td>19. I worry that I cannot control my thoughts as well as I would like to.</td>
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<td>20. I have butterflies in the stomach.</td>
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<tr>
<td>21. My palms feel clammy.</td>
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APPENDIX C

DEMOGRAPHICS FORM
MOOD INDUCTION – Demographic Information

1. Age: …………………………………………
2. Sex: …………………………………………
   Male  Female  Decline to answer
3. Class Standing: …………………………
   Freshman  Sophomore  Junior  Senior
4. Ethnicity: ………………………………
5. Handedness: ……………………………
   Left-dominant  Right-dominant
6. How fluent are you in English? (circle level) Not fluent at all > 1 ——— 2 ——— 3 ——— 4 ——— 5 < Native fluency
7. Other language(s) spoken: ……………
8. Have you ever been diagnosed with psychological/neurological condition (e.g., Depression, Anxiety disorder, etc.) by a professional? (PLEASE CIRCLE ONE) Yes / No
9. If you answered Yes to question 8:
   a. please list condition(s): ………………………………
   b. list prescription medications you are taking for condition(s): ………………………………
   c. have you received any CSUSB disability services for condition(s) listed? Yes / No

CONTINUED ON BACK OF SHEET———>
APPENDIX D

DEBRIEFING STATEMENT
Colorful Thought
Debriefing Statement

This study was designed to investigate the effects of working memory capacity and anxiety on visual-short term memory. In this study both working memory capacity and short-term memory capacity were assessed. We are particularly interested to examine if WMC and high levels of trait anxiety may influence visual short-term memory capacity.

Thank you for your participation and for not discussing the contents of this experiment with other students. If you have any questions about the study, please feel free to contact Celene Gonzalez at gonzc418@coyote.csusb.edu. If you would like to obtain a copy of the group results of this study, please contact Professor Dr. Koshino at (909) 537-5435 or hkoshino@csusb.edu at the end of Spring Quarter of 2019.
REFERENCES


Johnson, D. R., & Gronlund, S. D. (2009). Individuals lower in working memory capacity are particularly vulnerable to anxiety's disruptive effect on performance. *Anxiety, Stress, & Coping, 22*(2), 201-213.


