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MEASURING THE IMPACT OF WORRY ON WORKING MEMORY: THE DEVELOPMENT OF A WORRY ANALOGUE DUAL SPAN TASK

by

Rachel Cover

A dissertation

submitted in partial fulfillment

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The members of the committee appointed to examine the dissertation of RACHEL COVER find it satisfactory and recommend that it be accepted.

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February 14, 2014

Rachel Lale, MA
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RE: Your application dated 2/13/2014 regarding study number 4051: Assessing Working Memory in a Worry Analogue Task

Dear Ms. Lale:

I have reviewed your request for expedited approval of the new study listed above. This is to confirm that I have approved your application.

Notify the HSC of any adverse events. Serious, unexpected adverse events must be reported in writing within 10 business days.

Submit progress reports on your project in six months. You should report how many subjects have participated in the project and verify that you are following the methods and procedures outlined in your approved protocol. Then, report to the Human Subjects Committee when your project has been completed. Reporting forms are available on-line.

You may conduct your study as described in your application effective immediately. The study is subject to renewal on or before 2/13/2015, unless closed before that date.

Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Thomas Bailey (208-282-2179; fax 208-282-4723; email: humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

Acknowledgements

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MEASURING THE IMPACT OF WORRY ON WORKING MEMORY:
THE DEVELOPMENT OF A WORRY ANALOGUE DUAL SPAN TASK

Dissertation Abstract – Idaho State University (2016)

Decades of research have revealed moderate albeit robust relationships between anxiety and impaired working memory. Evidence and theory suggest that worry competes for and occupies limited attentional resources, leaving fewer available to perform other cognitive tasks. Unfortunately, few measures are available to directly study the degree to which worry interferes with working memory. The purpose of this investigation was to develop a novel computerized dual span task (i.e., "worry span") that utilizes worry-like sentences interleaved with neutral words to be remembered. This worry span task was designed to emulate the theorized interference of worry on working memory processes.

131 non-anxious participants completed the reading span task, the worry span task, a criterion task of higher cognitive functioning (i.e., Nelson Denny Reading Test), and a worry induction task during which they monitored and tallied intrusive negative thoughts after a five-minute period of intentional worry. Participants also completed self-report measures of trait worry and state anxiety. State anxiety was measured several times throughout the procedure.

State anxiety prior to working memory tasks did not appear related to poorer working memory task performance. However, anxiety generally increased during working memory tasks, and increases in state anxiety during these tasks correlated with reduced task performance. Additionally, the number of tallied intrusions observed by participants after the worry induction was associated with higher (not lower) working

memory scores. The worry induction and monitoring task may have served as an index of the ability to monitor and gate emotional information in the context of performing two competing cognitive operations (i.e., tally worries and return focus to one's breath).

Our results support the worry span task as a measure of working memory based upon correlations with the reading span task, as well as correlations with the criterion task assessing higher cognitive functioning. In addition, the worry span task remained a significant predictor of both reading comprehension and the number of tallied intrusions, after controlling for both state anxiety and reading span performance. Additionally, the worry span demonstrated differential sensitivity to participant increases in state anxiety post worry compared to the industry standard dual span task. This pattern of findings suggests that the worry span may be a superior measurement of the impact of worry and anxiety on working memory compared to other standard measures of working memory.

General Introduction

Emotions mobilize action in the service of one's goals. For instance, fear prepares an individual to escape from imminent threat by quickly organizing physiological responses (e.g., a rush of adrenalin, increased blood flow to the body's periphery, dilation of pupils) as well as cognitive responses (e.g., attentional narrowing on the source of threat; e.g., Esterbrook, 1959)—all in the service of self-preservation. Anxiety and fear result in similar physiological and cognitive phenomena that mobilize defensive escape and avoidance behaviors. Distinguished from fear by its intensity and the imminence of the threatening stimulus, state anxiety is defined as the subjectively distressing experience of arousal in response to distal or anticipated threats to social, safety, security, and other goals (e.g., Ohman, 2008). For example, in anticipation of a poor review from her superior, a colleague may muster additional attentional effort preparing for a critical presentation. In hazardous weather conditions, a driver may attend more closely to the road than usual. After learning of an earthquake in California, a mother in Idaho may call her adult children to verify their well-being. Worry is a cognitive phenomenon often occurring alongside anxiety. Worry is defined as attention demanding, verbal rumination resembling problem-solving, and it is theorized to serve a cognitive avoidance function, alleviating anxious arousal in anticipation of potential threat (Borkovec, Alcaine, & Behar, 2004). Anxiety and worry are both associated with mobilizing behaviors that provoke an individual to expend attentional effort in the service of avoiding some potential threat. However, for those with pathological anxiety and worry, this effort may come at too high a cognitive cost, pulling limited resources away from other critical information.

Intrusive and uncontrollable worry is the cardinal feature of generalized anxiety disorder (GAD), but worry is also commonly experienced in the general population and can become problematic for many individuals who do not meet full diagnostic criteria for an anxiety disorder. Furthermore, research suggests that worry may absorb limited attentional resources in the working memory system, leaving fewer available for normative cognitive functioning. Although critically interconnected, much remains unclear regarding basic relationships between anxiety, worry, and working memory.

There is ample reason to better understand relationships between anxiety, worry, and working memory from an epidemiological perspective. Anxiety disorders constitute the most common class of psychological disorders with an estimated 28.8% of individuals meeting diagnostic criteria during their lifetime (Kessler et al., 2005) and an estimated 18.1% of individuals meeting criteria during any 12-month period (Kessler, Chiu, & Demler, 2005). In addition to causing significant distress, anxiety can impair relationships, academic functioning, occupational functioning, and self-esteem (Hoffman, Dukes, & Wittchen, 2008; Moran, 2016). Anxiety is also frequently comorbid with other behavioral health and psychological problems (e.g., substance use disorders, mood disorders, insomnia, eating disorders; Hoffman et al., 2008; Kessler et al., 2005) and significantly increases risk for physical health problems (e.g., hypertension, heart palpitations, peptic ulcers, bruxism; Hoffman, Dukes, & Wittchen, 2008; Marciniak et al., 2005).

Anxiety disorders are associated with a host of cognitive symptoms that appear to implicate the working memory system. Broadly, these disorders are characterized by cognitive intrusions, manifesting as uncontrollable worry in GAD, ego-dystonic thoughts

(e.g., obsessions) in obsessive compulsive disorder (OCD), and intrusive trauma-related memories in posttraumatic stress disorder (PTSD; American Psychiatric Association, 2013). Furthermore, anxiety is associated with attentional bias, facilitating attention toward threatening information as well as inhibiting disengagement from threatening information. Cognitive intrusions and attentional bias for threat have been observed transdiagnostically, occurring in individuals with OCD, GAD, social phobia, specific phobia, panic disorder, and PTSD, suggesting the potential for etiological overlap associated with information processing (for review, see Bar-Haim, Lamy, Pergamin, Bakersman-Kranenberg, & van Ijzendoorn, 2007). Indeed, some research suggests that cognitive phenomena in pathological anxiety play a causal role in the etiology and maintenance of anxiety disorders.

This pattern of attentional symptoms suggests that the utilization of working memory may be compromised in anxiety disorders. Given the scope of anxiety and the cognitive symptomology observed in anxiety disorders, there is good reason to investigate relationships between anxiety and basic cognitive processes, such as working memory. Moreover, translational research bridging the gap between cognitive science and experimental psychopathology has led to innovative treatment options for those with anxiety, such as attention bias modification (ABM; Hakamata et al., 2010).

One area in need of further exploration is the purported impact of anxiety and worry on working memory. However, there are currently no measurements available to systematically assess this relationship. The ability to hold and manipulate information for its immediate use (e.g., Baddeley & Hitch, 1974), working memory is typically assessed using dual span tasks, such as the reading span and operation span tasks (Bud,

Whitney & Turley, 1995; Conway, Kane, Bunting, Hambrick, & Wilhelm, 2005; Daneman & Carpenter, 1980). Dual span tasks incorporate both a processing and a storage component. For example, the reading span task incorporates sentences to be evaluated as valid (e.g., "Jane walked the dog in the park") or invalid (e.g., "Jane the walked dog in the park") interleaved with to-be-remembered unrelated words (e.g., rake; Bud, Whitney & Turley, 1995; Conway, Kane, Bunting, Hambrick, & Wilhelm, 2005; Daneman & Carpenter, 1980). Performance on dual span tasks is based on how well participants recall the unrelated TBR words in the context of also completing the processing component (i.e., evaluating the sentences). In the present study, the worry span task was designed as a dual span task incorporating worry-like sentences to process and unrelated words to be remembered. This novel task was designed to measure the purported interference of worry on working memory, based on theoretical and empirical research reviewed below.

The current study has two primary goals. The first goal of this study is to elucidate basic relationships between anxiety, working memory, and worry. The second goal of this study is to develop an instrument to measure the impact of worry on working memory (i.e., the worry span task).

The following literature review is divided into three sections. First, research regarding the cognitive symptomology in anxiety will be reviewed, focusing on worry and attentional processing of threat. Second, current theories describing the impact of worry on attentional processing and working memory will be presented. Third, the rationale for the development of the worry span task will be discussed. Indeed, research and theory suggest that the development of such a measure may not only elucidate

relationships between anxiety, worry, and working memory, but may also prove a useful research and clinical tool for assessing the purported impact of worry on working memory.

Part I: Worry, Attentional Bias for Threat, and Working Memory

This section begins with a discussion of the overt and covert cognitive phenomena associated with anxiety. Specifically, a description of intrusive worry is provided first, followed by a review of evidence suggesting a causal relationship between attentional bias for threat, attentional control processes (e.g., working memory), and anxiety symptomology. Next, a discussion of the theoretical models for the relationship between anxiety and working memory will follow. This discussion will include a description of Attention Control Theory (ACT), the fear-network theory, and avoidance models of GAD. Finally, the cognitive theory of pathological worry will be explicated, tying together components from these aforementioned sections.

Cognitive symptoms associated with anxiety: Intrusive worry. Cognitive intrusions are core diagnostic criteria in a number of anxiety disorders. Intrusions associated with anxiety disorders include ego-dystonic thoughts and obsessions in obsessive compulsive disorder (OCD) and trauma-related memories in posttraumatic stress disorder (PTSD; American Psychiatric Association, 2013). However, more commonly experienced is intrusive worry. Uncontrollable worry about a number of topics is the cardinal feature of generalized anxiety disorder (GAD; American Psychiatric Association, 2013). Individuals with GAD experience intense, disruptive, and uncontrollable worry that interferes with their quality of life and impairs functioning. Furthermore, the tendency to worry (i.e., trait worry) occurs across a continuum in both

the general population and in clinical populations (Ruscio, Borkovec, & Ruscio, 2001) and can become a serious problem for many individuals who do not meet full diagnostic criteria for GAD. Intrusive worry and other worry-like processing (e.g., rumination) are also common problems for individuals with other anxiety and affective disorders (e.g., Behar, DiMarco, Hekler, Mohlman, & Staples, 2009).

For these reasons, worry has attracted the attention of prominent anxiety researchers. In their seminal definition, Borkovec, Robinson, and Dupree (1983) describe the construct as follows:

> Worry is a chain of thoughts and images, negatively affect laden and relatively uncontrollable; it represents an attempt to engage in mental problem-solving on an issue whose outcome is uncertain but contains the possibility of one or more negative outcomes; consequently, worry relates closely to the fear process.

Thus, the worry construct is defined by the following characteristics: worry is a highly attention demanding activity focusing on avoidance of potential future threat; worry is often experienced as a verbal activity (e.g., a protracted subvocal chain of thoughts); and worry can become uncontrollable (see Behar, DiMarco, Hekler, Mohlman, & Staples, 2009). Each of these features is discussed in turn.

Heimberg, Turk, and Mennin (2004) observed that the etymology of 'worry' implies an intensely attention-demanding activity. *Worry* evolved from the Latin *vertzi* meaning "to constrict" to the Old English *wyrgan* meaning "to strangle." The secondary contemporary definition of *worry* means "to seize with the teeth and shake or tug at repeatedly" (Merriam-Webster.com, 2014). The very etymology of the word implies that the worrier is tenaciously engaged in some goal-directed activity. Of relevance to the current investigation is the implication that one's attention may be doggedly engaged when worrying (Mennin, Heimberg, & Turk, 2004).

Indeed, worry is experienced as attention-demanding. The process of worry involves pseudo-problem solving in which the worrier perseverates and elaborates on the initial problem-solving step of identifying possible negative future outcomes (i.e., problem orientation), without shifting to elaborative processing of strategies to avoid such outcomes (see Dugas, Gagnon, Ladouceur, & Freeston, 1998, and Hirsh & Mathews, 2012). As a result, the solutions are not considered, and worry continues to absorb the worriers' attention. Interestingly, high worriers often harbor both positive and negative attitudes about their worry, perceiving the activity as a means to resolve uncertainty (Borkovec, Alcaine, & Behar, 2004; Dugas, Gagnon, Ladouceur, & Freeston, 1998) but also ultimately futile and dangerous, because it may become uncontrollable (Wells, 1995).

Worry is also experienced as a primarily verbal activity, although negative imagery can accompany worry (Hirsch, Hayes, Mathews, Perman, & Borkovec, 2011). Worry in verbal form appears to rely on attentional resources. In an early study, Rapee (1993) asked undergraduates to perform one of four secondary tasks while worrying. The secondary tasks included either repeating the same number verbally, randomly generating numbers verbally, pressing keys in a circumscribed pattern, or pressing keys in a random pattern. Thus, the secondary task varied along two dimensions: it was either verbal or visuospatial, and it either tapped executive resources (i.e., generating randomness) or did not (i.e., generating patterned responses). Participants who engaged in the verbal secondary task that required executive resources (i.e., verbally generating random numbers) produced fewer worrisome thoughts than participants who performed one of the other secondary tasks. This finding suggests that performing a verbal task that also

tapped executive resources inhibited worry. Broadly, this study supports the claim that worry is typically verbal and requires executive resources.

Leigh and Hirsch (2011) conducted a similar study in which high and low worriers were asked to worry in either verbal or imagery form while performing a second working memory task that employed verbal and visuospatial processes (i.e., pressing a key at random time intervals; Leigh & Hirsch, 2011). They found that high worriers were poorer at generating random responses when engaging in verbal worry compared to imagery-based worry. These findings further suggest that verbal worry utilizes attentional resources. This study also suggests that high worriers may less effectively utilize working memory resources when worrying.

Individuals with GAD experience their worry as uncontrollable. It is unclear to what extent this perception underlies a true impairment in the ability to control worry, or the degree of subjective distress associated with worrying. A pattern of recent findings suggests that the subjective appraisal of worry as uncontrollable may reflect a true cognitive control deficit among individuals with GAD. First, Hirsch, Mathews, Lequertier, Perman, and Hayes (2013) found that individuals with GAD experienced more negative thoughts during a thought monitoring task than high worriers without the diagnosis, suggesting that those with GAD do indeed experience more worries than those without the diagnosis. Second, Ruscio and Borkovec (2004) found that individuals with GAD experienced more negative thought intrusions when asked to focus on their breath following a worry induction task compared to high worriers without GAD. Finally, Becker, Rinck, Roth, and Margraf (1998) found that individuals with GAD evidenced more difficulty suppressing negative thoughts than neutral thoughts (i.e., white bears),

but had no difficulty suppressing neutral thoughts compared to non-anxious controls. Taken together, these studies suggest that individuals with GAD experience more intrusive worry than others and demonstrate more difficulty suppressing worry compared to others. Furthermore, these findings suggest that cognitive control deficits in GAD may only occur in the context of negative thoughts (e.g., worry).

Other research indicates that high worriers also experience difficulty controlling worry compared to low worriers, particularly in the context of unsuccessful previous suppression attempts. Iijima and Tanno (2012) conducted a study investigating the rebound effect following worry suppression. Using thought sampling methodology, participants were asked to engage in three thought monitoring tasks: baseline thought monitoring, worry suppression, and a second thought monitoring activity. They found that participants who endorsed higher trait worry demonstrated a greater worry rebound effect than low worriers, but only in the context of poorer performance during the suppression phase. This study suggests that both trait worry and difficulty suppressing worry resulted in later increases in worry. Thus, even without a diagnosis of GAD, high worriers who struggle to suppress worry appear to experience increases in worry after suppression attempts.

To summarize, clinicians and researchers agree about several features of worry. Worry is a cognitive phenomenon that is the cardinal feature of GAD, but it is also commonly experienced in individuals with other anxiety and mood disorders, as well as in the general population where the tendency to worry ranges on a continuum among individuals. Worry is attention-demanding, primarily verbal in form, and can be difficult

to control for some individuals. These defining features suggest that worry is related to basic attention control processes, such as working memory.

Anxiety is also associated with covert attentional phenomena. Research on attentional bias for threat provides additional evidence for a relationship between anxiety and attentional control. The next section of this review details attentional processing patterns associated with anxiety, and argues that these findings suggest a need to further understand relationships between worry and working memory.

Cognitive symptoms associated with anxiety: Attentional bias for threat. Anxiety is associated with attentional biases that may result from impaired attention control when processing threatening information. For example, a robust empirical finding is that individuals who are either currently anxious (i.e., state anxious) or who are prone to experience anxiety across situations (i.e., individuals high in trait anxiety or who meet diagnostic criteria for an anxiety disorder) demonstrate attentional bias favoring threatening information relative to neutral information (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007).

The probe detection task has been widely used to examine threat bias associated with anxiety (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007). In a single trial, participants view two simultaneously presented stimuli, one emotionally negative (e.g., a threatening face or word) and the other benign (e.g., a neutral face or word). The stimuli pair is then replaced by a probe (e.g., a letter) appearing in the position previously occupied by either the threatening stimulus or the neutral stimulus. Participants are instructed to respond to the probe (e.g., identify a letter target as an ‘E’ or an ‘F’). If participants have a bias toward threatening information, it

logically follows that they would respond more quickly to the probe if it replaces the threatening stimulus versus the neutral stimulus because their attention would already be fixated in that spatial location. Thus, a threat bias is determined when, on average, across multiple trials, participants respond more quickly to probes that follow in the position of threatening stimuli compared to neutral stimuli. Such an attentional threat-bias has been found in clinically anxious participants (including individuals with GAD; see Mogg & Bradley, 2005) as well as in state-anxious participants using this task (see Putwain, Langdale, Woods, & Nicholson, 2007).

Research using modified versions of the probe detection task suggests a causal link between attentional bias for threat and anxiety symptomology (i.e., Attention Bias Modification; ABM; Hakamata et al., 2010). In the training version of the probe detection task, participants see two simultaneously presented stimuli differing in emotional valence (e.g., threatening or neutral). However, a contingency is programmed into the training task such that the probe reliably appears in the position previously occupied by one type of stimulus (i.e., only after neutral stimuli). An attentional bias is, thus, modified when participants learn to attend toward the type of stimulus that reliably precedes the probe over several trials.

Importantly, researchers have been able to experimentally manipulate anxiety following ABM training. First, experimentally increasing attentional bias for threat-relevant stimuli has been shown to increase anxious reactivity to subsequent stressful tasks or events (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). Second, experimentally decreasing attentional bias for threat has been shown to decrease anxiety symptoms (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn,

2007). Two recent meta-analyses show that experimentally reducing attentional bias for threat (i.e., training away from threat) has demonstrated significant long-term symptom reductions in social anxiety disorder and generalized anxiety disorder on par with psychopharmacological interventions and cognitive behavioral therapy (CBT; Bar-Haim, 2010; Hakamata et al., 2010).

Importantly, ABM appears to have cascading effects in individuals with intrusive worry. In one study, training high worriers to attend away from threat using the modified probe detection task led to fewer negative intrusions during a subsequent thought monitoring task (Hayes, Hirsch, & Mathews, 2010). These findings beg the question: What is the mechanism responsible for the ameliorative effects of AMB?

Interestingly, attentional bias and anxiety symptomology can both be increased or decreased as a result of ABM training, depending on the direction of training (i.e., training toward threatening stimuli, or training toward neutral stimuli). One purported explanation for the differential effects of the two training conditions is that they each elicit different attentional responses to salient emotional features of the stimuli, favoring either "bottom-up" or "top-down" processing (Eysenck, Derakshan, Santos, & Calvo, 2007). For instance, in the train-toward-threat condition, the probe is reliably paired with salient threatening information. Because threat cues are relevant to the task in this condition, an attentional vulnerability for already salient emotional information may develop (i.e., "bottom-up" processing), which may then generalize to vigilance for threatening cues in the environment after training. However, in the train-toward-neutral condition, the probe is reliably paired with non-threatening stimuli. Thus, participants may learn to *inhibit* salient threatening information in order to improve performance in

the task. In other words, they may be trained to strategically override processing of salient task-irrelevant emotional information (i.e., threat) in favor of task-relevant information (e.g., the probe contingency; i.e., "top-down" processing). Accordingly, improving inhibitory control over threatening stimuli, indexed by attentional bias, may be implicated in managing anxiety.

The ameliorative effects of ABM may be due in part to improving inhibitory control, a feature of the working memory system (reviewed below in detail). In support of this prediction, research using the emotional Stroop task suggests that anxiety is associated with impairment in inhibitory control over emotionally salient task-irrelevant information. In the traditional Stroop paradigm, participants are shown a color word (e.g., "red"), but the word itself is presented in a differently colored ink (e.g., blue ink; Mathews & MacLoed, 1985). Participants are asked to say the color of the ink while inhibiting the prepotent response of reading the word. In the emotional version of the task, the word content is threatening (e.g., "cancer"), and the participant is asked to read the color of the ink. Individuals with anxiety disorders demonstrate slowed reaction times in the emotional Stoop task, suggesting impairment in inhibition of task-irrelevant threat (see Mathews & MacLoed, 2005 for review). Given that inhibitory control is a theorized feature of the central executive, these patterns of findings not only implicate working memory in information processing biases associated with anxiety, but also suggest that improving the utilization of working memory may improve cognitive symptomology of anxiety (e.g., attentional bias for threat and intrusive worry).

In summary, anxiety symptomology is associated with an attentional bias for threatening information, as measured by the probe detection task. This bias is causally

implicated in anxiety, as modifying attentional bias is associated with either an increase in anxiety or a clinically relevant decrease in anxiety symptoms on par with first-line anxiety interventions. Indeed, ABM training resulted in a decrease in intrusive worry in one study. The underlying mechanism for these effects may to be an improvement in the ability to inhibit the influence of irrelevant-threat while managing a focal task. One implication of these findings is that processing threatening material (e.g., worry) may impact working memory functioning in anxious individuals. Furthermore, learning to manage threatening material in tasks that tap working memory processes may yield improvement in the ability to inhibit intrusive worry.

Theoretical accounts of anxiety, worry, and attention control. As previously discussed, anxious individuals experience intrusive worry, display an attentional bias toward threat, and have difficulty disengaging from threatening stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007; Derryberry & Reed, 2002). These features suggest a close relationship between anxiety, worry, and the ability to manage one's attention. Researchers have posited several theoretical models to explain the relationship between anxiety symptomology and attentional control. In the following section, these models will be presented. First, Baddeley's model of working memory will be introduced (Baddeley, 1986; 2012). Then, models accounting for theoretical relationships between anxiety, worry, and working memory will be presented.

The first model presented below is attention control theory (ACT; Eysenck, Derakshan, Santos, & Calvo, 2007). ACT incorporates components of basic cognitive models of attention control (Baddeley, 1986; 2012; Friedman & Miyake, 2004) and dual-processing theories (Liberman, 2007; Smith & DeCoster, 2000; Stanovich, West, &

Toplak, 2011). Models that focus on pathological worry will be presented next. First, the theorized fear network model of anxiety will be described, which accounts for preferential threat processing and the occurrence of cognitive intrusions both across anxiety disorders and in GAD specifically (Reinecke, Becker, Hoyer, & Rink, 2010). Then, Borkovec's (2004) avoidance model of worry will be presented as it accounts for possible learning mechanisms that reinforce worry, contributing to worry's persistence. Finally, a description of Hirsh's cognitive model of GAD will be presented. This comprehensive model ties together empirical evidence from attentional bias literature (described above), and also builds on components of the cognitive models and pathological worry theories presented in these sections.

Decades of research have demonstrated a quadratic relationship between anxiety and task performance. Specifically, individuals tend to perform optimally on tasks when they are neither too relaxed nor too aroused (Yerkes & Dodson, 1908), particularly when these tasks are challenging, recruiting prefrontal cortex activity and requiring working memory (Diamond, Campbell, Park, Halonen & Zoladz, 2007). Working memory is the ability to maintain and manipulate multiple sources of information for its immediate use, and this ability is limited in capacity (e.g., Baddeley & Hitch, 1974). As such, standard assessments of working memory capacity (i.e., dual span tasks) typically require both a storage component (e.g., to-be-remembered words or symbols) interleaved with a processing component (e.g., solving math problems, judgment-making, reading; Daneman & Carpenter, 1980; Dunning & Holmes, 2014; Turley-Ames & Whitfield, 2003; Turner & Engle, 1989). Importantly, working memory capacity is predictive of

higher cognitive functioning, such as reading comprehension (e.g., Daneman & Carpenter 1980).

According to Baddeley's model, working memory consists of two primary support components (i.e., the phonological loop and the visuospatial sketchpad); an episodic buffer; and a limited capacity central executive (see Figure 1; 1986; 2000; 2012). The central executive is theorized to be the seat of attentional control in the working memory system. Its primary functions include shifting attentional focus toward goal-relevant information, maintaining and updating information in working memory, and inhibiting distraction from goal-irrelevant information (i.e., shifting, updating, and inhibition; Friedman & Miyake, 2004). When functioning properly, the central executive selectively directs attention to information relevant for performing a focal task while simultaneously inhibiting the influence of task-irrelevant information on its limited processing resources.

As discussed earlier, state anxiety and worry are highly related constructs and both are associated with reduced working memory efficiency when experienced at high levels (Eysenck, Derakshan, Santos & Calvo, 2007; Hirsh & Mathews, 2011; Yerkes-Dodson, 1908). Indeed, performance on tasks that require working memory have been found to be diminished in highly anxious individuals and under stressful conditions (for reviews, see Eysenck, Derakshan, Santos, & Calvo, 2007; Moran, 2016; Rai, Loschky, Jackson Harris, 2015). Additionally, performance on working memory tasks has been found to be reduced for those with high trait worry (Hayes, Hirsh, & Mathews, 2008) and in non-clinical participants when asked to engage in worry (2008; Rapee, 1983). The mechanisms through which state anxiety and trait worry reduce working memory

performance is currently debated (Moran, 2016). However, in general, theoretical models of these relationships suggest that state anxiety broadens attentional focus, resulting in attentional bias favoring threat to the exclusion of information required for performing a primary task. Furthermore, because arousal is difficult to downregulate due to its utility in aiding survival, information that is threatening gains processing priority over benign information that may be required for performing cognitively demanding tasks (Shackman et al., 2006). These models further suggest that when anxiety results in worry, worry directly impacts executive resources such as inhibition, shifting, and maintenance. These models are discussed below.

Building on Baddeley's model of working memory, Attention Control Theory (ACT; Eysenck, Derakshan, Santos, & Calvo, 2007) proposed that high levels of anxiety can elicit negative cognitive intrusions (e.g., worry) that subsequently interfere with working memory performance. According to ACT, worry leads to inefficient attentional processing because it occupies central executive resources in this system. Specifically, worry is theorized to result in attentional focus favoring potential sources of threat, and thus competes for processing resources required for other critical tasks. When worry occurs, increased attentional effort is needed to inhibit threat processing and to shift attention toward task-relevant information (Eysenck, Derakshan, Santos, & Calvo, 2007). To illustrate, consider an anxious individual delivering a speech--a task requiring executive resources. The anxious speaker might attend to furrowed eyebrows on his audience's faces, triggering worry that the audience members are judging him negatively (e.g., "What if they think what I'm saying is stupid?") The speaker's limited attentional resources thus become occupied both by the content of his speech and his worry,

requiring additional executive shifting, maintenance, and inhibition to process both the worry and the speech. Due to the presence of worry, fewer resources are available for focal task processing and speech performance may suffer. Thus, according to ACT, anxious individuals have difficulty efficiently managing task-relevant information because their attention is simultaneously occupied by task-irrelevant worry, pulling limited executive resources away from processing required for the focal task (Eysenck, Derakshan, Santos, & Calvo, 2007).

ACT is consistent with dual process theories of attention, which posit two cognitive systems that work congruously to manage information (e.g., Liberman, 2007; Smith & DeCoster, 2000; Stanovich, West, & Toplak, 2011). The first system is slow and effortful, allowing the individual to process information sequentially and in a goal-directed manner. The second system processes information automatically and heuristically, and is driven by bottom-up influences. Per ACT, state anxiety is theorized to disrupt the balance of these systems, resulting in attentional processing that disproportionately favors bottom-up processing (e.g., sources of potential threat in the environment) and suppresses top-down processing (Eysenck, Derakshan, Santos, & Calvo, 2007). Indeed, this theory is consistent with predictions based on the aforementioned attention bias modification (ABM) findings. Attention training may restore a balance to the attentional control system by training anxious individuals to attend toward task-relevant information (i.e., top-down) while inhibiting the influence of competing emotional information that is task-irrelevant (i.e., bottom-up).

ACT accounts for a mechanism by which threat processing interferes with working memory—i.e., via increasing cognitive load and occupying limited executive

resources such as shifting, maintaining focus, and inhibitory control. However, ACT does not fully account for biased information processing favoring threat in anxiety disorders. Evidence from probe detection studies and emotional Stroop studies have led researchers to theorize that threat bias results from *both* an impaired ability to disengage from threat once captured by attention (i.e., the 'disengagement hypothesis,' as described by ACT) and also facilitated attention toward threat (i.e., the 'vigilance hypothesis'). While ACT accounts for the impact of worry on executive inhibition, it does not account for facilitated attention toward threat.

Facilitated attention toward threat may result from the development of fear-related schemata in anxious individuals. For example, one model of posttraumatic stress disorder (PTSD) posits the development of an elaborate fear network associated with trauma (Foa & Kozak, 1986; Lang, 1977). According to this model, a complex interaction between vulnerability factors (e.g., genetics) and learning history (e.g., stress/trauma) underlies the development and elaboration of a semantic fear network. The fear network includes fear representations (e.g., memory traces that include negative images, physiological sensations, action tendencies, etc.) It incorporates neutral representations that become integrated into the network via associative learning and repeated processing (e.g., fear experienced in multiple contexts). Furthermore, these representations are perpetually in a weakly activated state. When neutral but threat-related representations are activated, they subsequently trigger representations of threat via spreading activation. Moreover, because behavioral and/or cognitive avoidance typically follows this activation, the network is never fully activated and remains unchanged over time (Clark, 2005; Foa & Kozak, 1996).

The fear network model of PTSD has been extended to explain recent findings in individuals with GAD. In their 2010 study, Reinecke, Becker, Hoyer and Rink found that individuals with GAD exhibited negative implicit attitudes for overtly negative words (e.g., cancer). However, unlike healthy controls, individuals with GAD also exhibited negative implicit attitudes for neutral albeit threat-related words (e.g., doctor; Reinecke, Becker, Hoyer, & Rink, 2010). Using the fear network theory to explain these results, the authors proposed that attentional readiness for threat occurs due to elaborative associative learning that pairs neutral cues with threat-representations. Considering this model in concert with the predictions of ACT, high worriers may experience difficulty inhibiting threatening information due to exhausted working memory resources because the information they need to inhibit may be far greater as a result of elaboration of this network (i.e., even seemingly neutral cues trigger worry activation).

Clinical scientists have posited additional theoretical models to account for the perseverance of worry in individuals with GAD. Borkovec's Avoidance Model of Worry (AMW; Borkovec, Alcaine, & Behar, 2004) proposes that worry, a primarily verbal activity, inhibits the processing of negative imagery associated with potential threat. Because verbal worry is theorized to result in less aversive somatic and emotional arousal than negative imagery, worry functions as a cognitive avoidance strategy that is repeatedly and negatively reinforced. As such, worry occurs with increasing automaticity. Newman (2011) revised Borkovec's avoidance model to instead theorize that worrying facilitates the avoidance of the emotional contrast that may accompany perceived future threat (but not necessarily the imagery associated with threat). According to both of these models, then, worrying is negatively reinforced because it

inhibits aversive emotional processing that, in and of itself, is necessary for successful habituation and eventual extinction of the fear response.

These theories are consistent with the fear network theory described above. Due to negative reinforcement, worry persists over time and across situations. Because worry occurs across different contexts, an elaborated fear (or "worry") network develops in which novel and previously neutral cues become incorporated. Together, these theories provide a framework to explain why individuals with GAD experience difficulty inhibiting worry and support the claim that inhibiting worry can become a Sisyphean task that exhausts executive resources in these individuals.

The cognitive model of pathological worry (Hirsch & Mathews, 2013) integrates these models with empirical evidence presented above. This model suggests that worry is maintained by biased information processing of threatening cues, habitual thought patterns, and exhausted top-down attention control. Per Hirsch and Mathews' comprehensive model, benign, task-relevant representations compete with task-irrelevant representations for processing priority in both non-anxious and anxious individuals. Competing representations are triggered by both internally and externally "bottom-up" sources. Due to limited attentional capacity, the presence of multiple competing representations prompts mutual inhibitory processing—in other words, competing representations inhibit one another. In anxious individuals, pre-existing processing biases favor threat-representations that are generally focal task irrelevant (i.e., attentional bias for threat, negatively reinforced worry across contexts, and priming due to a weakly activated fear network). Anxious individuals are consequently faced with strongly activated threat representations that require heavy top-down (i.e., executive) resources to

inhibit. As a result, fewer attentional control resources are available to maintain attention on the focal task. The authors note that some representations result in implicit processing. However, as threat-representations gain strength, they can intrude into conscious awareness (i.e., negative intrusions). See Figure 2.

Hirsh and Mathews' cognitive theory further accounts for why negative intrusions can result in protracted worry episodes. First, negative intrusions can trigger problem-solving efforts, typically in verbal form (e.g., worry), which require still greater attentional resources to process. Second, worry, by definition, is associated with uncertainty that cannot be resolved with such efforts, so its content is more easily accessed and elaborated on in the future (i.e., the Zeigarnik effect). Third, negative intrusions can trigger the activation of other worry-relevant associations, as predicted by the fear network theory. Finally, often contradictory maladaptive metacognitive beliefs about worry, such as beliefs that worry is uncontrollable and dangerous, or that worry is useful to the worrier, can serve to undermine already exhausted top-down control efforts. Thus, Hirsch and Mathews' cognitive model of pathological worry accounts for how processing biases can result in strong threat-representations that can intrude into conscious awareness and result in protracted worry episodes. Importantly, these intrusions are all theorized to exhaust executive resources needed to perform other cognitive tasks.

Part II: A Dual Span Task to Measure the Impact of Worry on Working Memory

In the previous section, potential causal relationships between anxiety, worry, and working memory were discussed, incorporating both theory and empirical evidence. However, no psychometric tool currently exists to measure the degree to which worry

interferes with working memory. The present study aims to develop a computerized dual span task (i.e., worry span) that utilizes worry-like materials to assess this relationship. Based on the aforementioned cognitive models of worry, this task was designed to emulate the interference of worry on an individual's ability to control his or her attention. This measure may prove to be superior at assessing cognitive interference by worry, thus potentially contributing to the field of experimental psychopathology and providing a useful clinical tool.

The following literature review will focus on the impetus for developing the worry span measure and the rationale for its design. First, an argument will be presented suggesting that a dual span task may be a fitting analogue for studying basic relationships between anxiety, worry, and working memory in general. Research using similar dual span tasks employing threat-relevant materials will be reviewed. These studies establish precedent for the development of the worry span task and inform its design from a theoretical perspective.

Second, a clinical rationale for the selection of a dual span design for this measurement will be presented. Recent research suggests that working memory can be enhanced via training top-down strategy use (e.g., verbal rehearsal) in dual span tasks. Importantly, if strategy training improves working memory efficiency, and working memory efficiency facilitates the inhibition of cognitive intrusions, then this training may improve the ability to suppress worry. Thus, this review section will argue that the worry span task, which incorporates a dual span design, could be similarly modified and used as an intervention to train individuals to more effectively utilize working memory in the presence of worry. Although this modification will not be made in the present study, the

following rationale informs the design of the worry span task from a clinical utility perspective.

Divided attention in anxiety is analogous to the processing demands of dual span tasks. Dual-span tasks, used extensively to study working memory, may be particularly fitting laboratory/clinic analogues for examining anxiety's interference on attentional control because the processing demands of these tasks may topographically mimic the manner in which worry interferes with attentional processing. In general, dual span tasks require that participants perform some processing operation, such as solving simple math problems or reading sentences, while also performing some storage operation, such as remembering words or symbols for later recall (e.g., Conway, Kane, Bunting, Hambrick, & Wilhelm, 2005; Daneman & Carpenter, 1980). Importantly, dual span tasks in which participants alternate processing and storing information are theorized to tap the executive functions of working memory (Friedman & Miyake, 2004). Specifically, these tasks require alternating between task components (i.e., "shifting"); inhibiting information from previous trials, pre-potent responses, and external and internal task-irrelevant distractors (i.e., "inhibition"); and prioritizing elements that are most important in a hierarchical manner (i.e., "updating;" Friedman & Miyake, 2004).

Simultaneous management of some primary, actively stored information and some secondary, actively processed information may logically require the same executive resources needed to attend to a focal task while worrying. For example, per the cognitive model of worry and Attention Control Theory (ACT), worry itself is theorized to operate like a competing secondary processing task (e.g., the worrisome thought, "What if I say something stupid?") that pulls attentional resources from an individual's primary focal

task (e.g., delivering the points of a speech). The two components of traditional dual span tasks are also organized hierarchically. Participants are required to remember target words or symbols (i.e., the storage component) while also solving simple arithmetic problems or reading sentences (i.e., the processing component). Although participants are required to both store and process information concurrently, the storage component may be considered primary to the processing component because participants must retain the to-be-remembered (TBR) items in working memory throughout the trial set in order to achieve higher scores (note: the standard scoring convention for these tasks is the number of correctly recalled storage items in trials where some processing accuracy criterion has been satisfied.) Similarly, worried individuals must shift their attention between worry content while maintaining focus on their primary task. Thus, the secondary, processing component of span tasks may parallel worry-like processing in individuals with anxiety, whose attention is divided between their primary focal task and their worry. In theory, dual span tasks may target the very executive control functions taxed by worry.

While anxiety is correlated with poorer performance on cognitive tasks that measure attentional control (e.g., dot probe, emotional Stroop, random number generation, etc.), only a few researchers have investigated how anxiety interferes with performance on dual span tasks (Bomyea & Amir, 2011; Mattarella-Micke, Mateo, Kozak, Foster, & Beilock, 2011). Still fewer have investigated the incremental influence of utilizing threatening stimulus materials in dual span tasks (Amir & Bomyea, 2011; Schweizer & Dalgleish, 2011). The extant findings from studies incorporating threatening materials in dual span tasks are reviewed below.

In one study, a reading span task was modified to include trauma-related sentences to process while remembering neutral words. Specifically, sentences were selected from the *Posttraumatic Cognitions Inventory*, a self-report measure of cognitions related to a particular traumatic event. Participants with PTSD demonstrated particular difficulty on trials that included threatening sentences compared to neutral sentences, though their performance was poorer overall across both neutral and threatening trials compared to trauma-exposed controls without PTSD (Schweizer & Dalgleish, 2011).

In a different study, socially anxious and non-anxious participants completed an operation span task that contained both neutral and threatening to-be-remembered words (Amir & Bomyea, 2011). For this dual span task, the storage component contained some threatening content (e.g., a threatening TBR word such as "stupid") whereas the processing component (i.e., solving arithmetic problems) contained only neutral content. Predictably, socially anxious participants performed more poorly than non-anxious participants on this task, in general. However, their performance remembering *threatening* words, in particular, was not different than the non-anxious controls.

Taken together, these studies suggest that individuals with anxiety symptomology perform more poorly on dual span tasks that contain threatening materials compared to non-anxious individuals. However, this pattern may be more robust when the processing component rather than the storage component contains threatening information. The study by Schweizer and Dalgleish (2011) suggests that when the storage task contains neutral stimuli and the processing task contains threatening stimuli, performance suffers significantly more for individuals with anxiety symptomology. In contrast, research by Amir and Bomyea (2011) suggests that incorporating threatening information into only

the storage component may facilitate recall of threatening TBR words for individuals higher in anxiety. This pattern is consistent with the hierarchical argument presented above, the predictions of ACT, and the predictions of the cognitive model of pathological worry—namely, the interference of anxiety on working memory may be most detrimental when it is elicited during active processing of threatening information and less detrimental when threatening material is temporarily stored for immediate recall. Based on this rationale, the worry span task will contain worry-like sentences to process and neutral words to remember, thereby mimicking the interference of worry on primary task processing, supported by aforementioned theory and research.

Clinical implications of the worry span task design: Potential for training. Improving the ability to manage worry while performing a focal task may be useful in ameliorating the cognitive symptoms of anxiety. Moreover, computerized cognitive tasks used to assess attentional processing associated with anxiety have lent themselves to modification for use as training tasks to improve attention control, resulting in clinically relevant improvements in anxiety symptoms. For instance, the probe detection task, once used to measure attentional bias for threat associated with anxiety, was later modified so as to train attentional bias away from threat, resulting in improvements in anxiety symptoms (see Hakamata et al., 2010). The worry span task, designed to measure the impact of worry on working memory, may be similarly modified in future studies and potentially used as an intervention to reduce the impact of worry on working memory.

The worry span was designed after a dual task that has already been modified via instructing individuals to use a verbal rehearsal strategy, and this modification has resulted in improvements in working memory utilization (Turley-Ames & Whitfield,

2003). The following section will provide a brief review of studies examining working memory training and a review of training studies resulting in reductions in anxiety symptomology. The rationale for designing the worry span after a dual span task that has already demonstrated improvements in working memory utilization via employing explicit strategy use will conclude this section (Turley-Ames & Whitfield, 2003).

Training working memory. Evidence suggests that attentional control may be malleable with training. For example, performance on working memory tasks can be enhanced with training in both non-clinical (Turley-Ames & Whitfield, 2003) and clinical populations with poor working memory abilities (Klingberg, 2003, 2010). In one study, Klingberg (2003) randomly assigned children with attention deficit hyperactivity disorder (ADHD) to either a high dose or low dose computer-based working memory training regimen, consisting of both of visuospatial and verbal working memory tasks. Children in the high dose group received five weeks of 20-minute training sessions in which task difficulty increased adaptively based on the child's performance. Children in the low dose control group received training that was not adaptive and was less than 10-minutes per day for five weeks. While all participants improved on the practiced working memory tasks, children in the high dose group improved significantly in non-trained cognitive assessments of working memory and fluid intelligence (i.e., Stroop task, visuo-spatial span, and Raven's progressive matrices). These findings suggest that training can enhance working memory performance and that this training can transfer to other tasks that tap higher cognitive functioning (i.e., reasoning). This study and others (see Klingberg 2010, for review) suggest that training can improve working memory abilities in clinical populations with poor working memory abilities.

Interventions aimed to improve attentional control have demonstrated efficacy in alleviating anxiety symptoms specifically. As reviewed above, training attentional disengagement from threat using a modified probe detection procedure (i.e., ABM) has been shown to reduce anxiety in clinical samples, including participants with GAD (Amir, Beard, Burns, & Bomyea, 2009). This particular intervention has demonstrated long-term clinical effects on par with psychopharmacological interventions and CBT (see Beard, 2011; Hakamata et al., 2010; Hallion & Ruscio, 2011), and has demonstrated reductions in negative intrusions in a subsequent thought monitoring task (Hayes, Hirsch, & Mathews, 2010). Moreover, one study of non-anxious individuals found that ABM training resulted in improved performance on the operation span task, a dual-span task commonly used to measure working memory capacity (Cover & Amir, *under review*). It may be that improvement in working memory utilization underlies clinically relevant improvements following ABM training.

Other working memory training tasks have yielded improvements in inhibiting unwanted negative intrusions as well. In one study of non-anxious participants, reading span training that involved the inhibition of built-up proactive interference (i.e., inhibition training) was found to yield not only better performance on a second working memory task (i.e., operation span), but also superior performance inhibiting an unwanted, personal memory compared to a control training condition (Bomyea & Amir, 2011). Considering these findings together, it is possible that an improvement in working memory may contribute to the reduction of anxiety symptomology in clinical studies using ABM and other training tasks. Working memory training may result in improved inhibitory control over intrusive worry.

Strategy training in dual span tasks. Performance on dual span tasks, specifically, can be improved by training participants to utilize explicit strategies. In one study, participants assigned to receive a chaining strategy demonstrated improved reading span performance above participants who received no strategy instruction (McNamara & Scott, 2001). In another study, operation span scores improved significantly when participants were instructed to employ a verbal rehearsal strategy for to-be-remembered words (Turley-Ames & Whitfield, 2003). Given that training non-anxious participants to use a volitional strategy can improve operation span performance, it is possible that similar strategy training can enhance working memory in anxious individuals, as well. Furthermore, using a verbal rehearsal strategy to manage the contents of working memory may be particularly apropos for inhibiting worry, given that worry is primarily verbal in form.

Turley-Ames and Whitfield (2003) found that the improvement in working memory performance following strategy training was significantly greater for individuals with low working memory capacity prior to training (i.e., low spans). Strategy training may improve working memory efficiency for individuals with higher anxiety, who also tend to demonstrate poorer performance than non-anxious individuals on dual-span tasks (Bomyea & Amir, 2012; Derakshan, & Eysenck, 2009; Mattarella-Micke, Mateo, Kozak, Foster, & Beilock, 2011). Furthermore, this training may be especially effective when working memory tasks incorporate threat-relevant materials, given the predictions of ATC, and Hirsh and Mathews' 2013 cognitive theory of pathological worry. Given its dual span design, the worry span task would easily lend itself to this training modification in future studies. Training anxious participants to use a verbal rehearsal strategy during

the worry span task may yield an improvement in cognitive control because this verbal strategy may inhibit worry that would otherwise compete for attentional resources. Taken together, future studies may be able to test this hypothesis, due to the dual span design of the worry span.

To summarize, the worry span was designed as a dual span task for two reasons. First, the cognitive model of pathological worry and ACT assert that the process of managing worry while attempting to perform a primary task may structurally resemble processing that occurs while performing dual span tasks. Research also indicates that anxiety is associated with diminished performance on dual span tasks and that the inclusion of threatening materials in these tasks further exacerbates poor performance as a function of participant anxiety. Thus, a dual span task that mimics the theoretical interference of worry on attentional control topographically may provide a more precise assessment tool for clinicians and researchers investigating these processes. Second, in virtue of its design, the worry span task may also lend itself to the exploration of strategy training as a potential intervention for intrusive worry in the future. Therefore, the worry span task was designed to yield both research and clinical utility, first as an assessment tool for measuring the impact of worry on working memory in the laboratory, and second as a potential intervention for improving the utilization of working memory in the presence of worry.

Part III: Criterion Validity of the Worry Span: Higher Cognitive Functioning and Worry

The current study aims to elucidate basic relationships between anxiety, worry, and working memory, and to create a measurement that assesses of the impact of worry

on working memory capacity (i.e., worry span). The worry span task developed for this study required participants to alternate between semantic processing of worry-like sentences (e.g., "If I give the wrong answer in a meeting or in class I could look stupid) and viewing to-be-remembered neutral words (e.g., jacket). Based on the predictions from ACT and the cognitive model of pathological worry, this task requires participants to manage both threatening information and neutral information, thus, inducing divided attention due to worry-like processing and utilizing limited executive resources.

To establish its criterion validity as a measure of working memory abilities, performance on the worry span should correlate with performance on an industry standard measurement of working memory (i.e., reading span). Furthermore, as with traditional measures of working memory, performance on the worry span should correlate with performance on a criterion task of higher cognitive functioning (i.e., reading comprehension). Additionally, performance on this task may also predict performance on clinically relevant behavior that is associated with worry and working memory performance (Brewin & Beaton, 2002)—i.e., the ability to suppress negative intrusions. A rationale for these predictions is discussed below.

Higher cognitive functioning. Worry is theorized to disrupt working memory processing. However, one critical piece of evidence missing to support this mechanistic assertion is a demonstration that the disruption of anxiety on dual span tasks also predicts a disruption of anxiety on tasks that require higher cognitive functioning. Indeed, performance on the reading span and operation span tasks predicts performance on tasks that measure higher cognitive functioning, such as reading comprehension (r = .30 - .52; Daneman & Merikle, 1996). Critically, these findings suggest that dual span tasks

measure a domain general executive process critical for higher cognitive functioning. Theoretically, this domain general executive process, when interrupted by worry, should also be interrupted when worry-prone individuals engage in tasks that require higher cognitive functioning. However, no studies to date have investigated how the predicative validity of dual span tasks may change as a function of participant anxiety, or after the introduction of threatening materials into a dual span task. These relationships were, therefore, investigated in the current study.

Negative thought intrusions. Uncontrollable worry is an intrusive symptom of GAD and occurs in the general population. As discussed previously, one possible mechanism responsible for difficulty controlling worry is its utilization of limited executive resources in the working memory system. In addition to theory reviewed above, this hypothesis is supported by cognitive research suggesting that higher working memory is associated with the ability to manage proactive interference (Rosen & Engle, 1998), and to suppress both unwanted neutral thoughts and unwanted personally relevant thoughts. For instance, Brewin and Beaton (2002) found that operation span scores correlated strongly with participants' success at suppressing neutral thoughts about white bears (White Bear paradigm; Wegner, Schneider, Carter, & White, 1987). In a different study, a similar pattern was revealed such that better performance on the operation span task was found to predict better volitional suppression of personally relevant intrusive thoughts, even after controlling for negative mood (Brewin & Smart, 2004). Furthermore, using the same thought suppression paradigm, individuals with GAD demonstrated impairment in suppressing worry compared to neutral thoughts, and suppressing worry compared to control participants (Becker, Rinck, Roth & Margraf,

1998). Taken together, performance on the worry span task, designed to measure the impact of worry on working memory, should correlate with performance on the analogue of intrusive worry used in the current study.

Present Study Overview

To summarize, anxiety disorders are common, debilitating mental health concerns, and they are often associated with intrusive cognitive symptoms, such as worry. Worry is an attention demanding, verbal activity that is difficult to control for individuals with GAD and for many individuals in the general population. Research suggests that anxiety influences information processing, resulting in impaired attention control when processing threatening material. Based on both ACT and Hirsch and Mathews' 2013 model of worry, worry may impact working memory processes specifically. Because worry occurs on a continuum in the population, studying these processes in an unselected sample with varying degrees of anxiety and trait worry should allow for a meaningful investigation of the relationships between anxiety, worry, and working memory. The current study aims to evaluate a new instrument intended to measure the purported impact of anxiety and worry on working memory in an unselected sample of undergraduate participants.

Anxiety, worry, and working memory were investigated in the current project with the overarching goal of creating a measurement to assess the purported impact of worry on working memory. An overview of the current study's procedure is presented briefly below and illustrated in Figure 3. At the beginning of the study, participants completed self-report measures assessing baseline state anxiety and trait worry. Participants completed an industry standard reading span task to assess basic working

memory abilities. In the reading span task, participants were presented with valid (e.g., "Jane walked the dog in the park") or invalid (e.g., "Jane the walked dog in the park") sentences to evaluate interleaved with to-be-remembered (TBR) words (e.g., rake; see Method for task details). Participants also completed the worry span task, which contained worry-like sentences to process (e.g., "If I make a mistake while talking to a crowd everyone might laugh at me") and unrelated words to remember (e.g., desk). In the worry span task, participants were required to decide if the sentence reflected something they might worry about (see Method for task details). To assess for concurrent validity, participants completed a measure of higher cognitive functioning (i.e., Nelson Denny Reading Test – Reading Comprehension). To assess for divergent validity of domain vocabulary knowledge, participants completed the Nelson Denny Reading Test – Vocabulary. Finally, to assess for predictive validity of intrusive worry, participants completed the Worry Induction Task. This three-phased task included a baseline assessment of worry intrusions, a five-minute period of intentional worry (worry induction), and a post-worry assessment of worry intrusions. Post worry intrusions were used as an index of participants' worry intrusions following the period of induced worry. Self-reported state anxiety was assessed throughout the study, including after the span tasks, the Nelson Denny Reading Test, and the Worry Induction Task.

Specific hypotheses for the current investigation are presented below. These hypotheses were intended to test relationships between anxiety, worry, and working memory, and to test construct validity and criterion validity of the worry span task.

Worry span as a measure of working memory.

Hypothesis 1. The worry span task was predicted to tap working memory. Therefore, performance on the worry span task was hypothesized to positively correlate with performance on an industry standard measure of working memory (i.e., reading span).

Anxiety, worry, and working memory.

Hypothesis 2. Previous research has found that individuals higher in state anxiety and worry tend to perform more poorly on tasks that tap working memory abilities (e.g., Ashcraft & Kirk, 2001; see Moran, 2016). In general, higher state anxiety and trait worry were expected to predict poorer performance on the worry span task as well as on the reading span task. Specifically, higher state anxiety was hypothesized to negatively correlate with working memory scores, and higher trait worry was also hypothesized to negatively correlate with working memory scores.

Hypothesis 3. Anxiety and worry have been found to impact attentional processing (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007) and working memory abilities when tasks contain threatening materials compared to neutral materials (Amir & Bomyea, 2011; Schweizer & Dalgleish, 2011). Therefore, worry span scores were hypothesized to be lower than reading span scores, due to the addition of threatening materials in the worry span task. Furthermore, the difference in reading span scores and worry span scores was also expected to depend on participant state anxiety and worry. While worry span scores were expected to be lower than reading span scores in general, this difference was hypothesized to increase for participants

reporting higher state anxiety and worry due to greater sensitivity to threatening materials in individuals reporting higher levels of anxiety.

Worry span concurrent and divergent validity.

Hypothesis 4. Tasks that tap working memory abilities correlate with measures of higher cognitive functioning, such as reading comprehension (e.g., Turley-Ames & Whitfield, 2003; Daneman & Merikle, 1996). If the worry span taps working memory, then it should also correlate with performance on a measure of reading comprehension (i.e., Nelson Denny Reading Test-Reading Comprehension). Therefore, performance on the worry span task was hypothesized to positively correlate with performance on a criterion measure of reading comprehension (i.e., Nelson Denny Reading Test – Reading Comprehension).

Hypothesis 5. To test divergent validity, it was expected that the correlations between the working memory task performance and reading comprehension would be stronger than the correlations between working memory task performance and a measure of vocabulary knowledge (i.e., Nelson Denny Reading Test – Vocabulary).

Hypothesis 6. It was expected that the worry span would correlate positively with reading comprehension, and this relationship was expected to be stronger for individuals who report higher state anxiety and higher worry. Furthermore, this relationship was hypothesized to remain after controlling for performance on reading span. Such a finding was expected to demonstrate incremental validity of the worry span task as a measure of working memory performance over and above performance on a neutral working memory span task for individuals with higher state anxiety and worry.

Worry span as a predictor of intrusions.

Hypothesis 7. Previous research has demonstrated a relationship between working memory and the ability to inhibit proactive interference (Rosen & Engle, 1998) and intrusive negative thoughts (Wegner, Schneider, Carter, & White, 1987). Therefore, both worry span scores and reading span scores were hypothesized to negatively correlate with the behavioral index of intrusive worry used in this study (i.e., the number of intrusive thoughts recorded after the worry induction task).

Hypothesis 8. Previous research has demonstrated that individuals higher in anxiety and worry experience difficulty inhibiting intrusive worry (Becker, Rinck, Roth & Margraf, 1998). Therefore, state anxiety and worry were hypothesized to positively correlate with the number of intrusions reported in the behavioral index of intrusive worry used in this study (i.e., the number of intrusive thoughts recorded after the worry induction task).

Hypothesis 9. Worry span performance was hypothesized to correlate negatively with the number of intrusive worries reported following the Worry Induction Task in general. However, this relationship was hypothesized to be stronger for individuals who report higher state anxiety and trait worry. Furthermore, this interaction was expected to remain after controlling for performance on the reading span task. Such a finding was intended to support the worry span as a superior tool for measuring intrusive worry over a neutral dual span task and therefore demonstrate incremental validity for the worry span.

Hypothesis 10. Working memory (as measured by the worry span task) was expected to mediate the relationship between state anxiety and the number of intrusive thoughts tallied after a period of intentional worry. A mediational analysis was

conducted using the products-of-coefficients approach (MacKinnon et al., 2007), which is an alternative to the causal steps approach (Baron & Kenny, 1986), and which tests if the mediated effect (a*b) is significant. Specifically, higher state anxiety was expected to predict poorer performance on the worry span task (a path). Second, better performance on the worry span task was expected to predict fewer intrusions following the worry induction (b path). Third, individuals with higher self-reported state anxiety were predicted to report more intrusions following the Worry Induction Task (c path). The indirect effect of state anxiety and intrusions, controlling for worry span score, was expected to be significant. Such a finding would provide support that working memory performance, using the worry span task, explains in part the relationship between state anxiety and the number of intrusions in this model. See Figure 4.

A second parallel analysis was also investigated using the reading span in place of the worry span as an index of working memory abilities. It was similarly hypothesized that the reading span would mediate the relationship between state anxiety and reported intrusions post worry induction. See Figure 5.

Method

Participants

172 individuals were recruited through the undergraduate participant pool at Idaho State University. All participants who consented to the study received compensation for their participation in the form of course credit.

Study exclusion criteria were intended to control for individual differences in motivation, basic understanding of the task, and domain proficiency in English, given the linguistic nature of the tasks used in this study. Data were excluded for 15 participants

unable to meet the industry standard performance threshold on the reading span practice task (i.e., three out of the last four practice trials successfully passed; Turley-Ames & Whitfield, 2003). Data were excluded for 22 participants whose first language or primary language (in the case of multilinguals) was not English.

Of the remaining 135 participants, four participants' data were removed for the following reasons: one participant left the study prematurely and three participants' data were removed due to missing data on critical self-report measures. A total of 131 participants' data were included in the final analyses.

Materials

Self-report measures. Participants completed self-report measures to assess trait anxiety, state anxiety, worry proneness, and metacognitive attitudes about worry (described below). Some self-reports measures were completed at the beginning of the study; some were completed at key time points during the study; and some were completed at the end of the study. Upon entry into the study, participants completed a brief demographic questionnaire, the *Spielberger State Anxiety Inventory* (see Appendix A), and the *Penn State Worry Questionnaire* (see Appendix B). They were also asked to provide a list of three topics that they were most worried about (see Appendix C). This list was used during the Worry Induction Task (e.g., Hayes, Hirsch, & Mathews, 2010; Ruscio & Borkovec, 2003). Participants completed the state version of the *Spielberger State-Trait Anxiety Inventory* following the reading span task, the worry span task, the Nelson Denny Reading Test, and the Worry Induction Task. At the end of the study, participants completed the *The Metacognitive Questionnaire-30* and a worry sentence questionnaire. Self-report questionnaires used in the study are described below.

The *Spielberger State-Trait Anxiety Inventory* (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983; see Appendix A) is a well-validated 40-item self-report measure comprising 20 items assessing current level of anxiety (i.e., state anxiety) and 20 items assessing anxiety in general (i.e., trait anxiety). The STAI has demonstrated high internal consistency ($\alpha = 0.92$; Ramanaiah, Franzen, & Schill, 1983). Scoring is based on a Likert scale ranging from 1 (Not at all) to 4 (Very much so). Scores on the trait and state scales each range from 20 to 80. Only the state version of this measure was used in the current investigation.

The *Penn State Worry Questionnaire* (PSWQ) is a 16-item inventory that assesses an individual's proneness to engage in worry. The PSWQ has demonstrated predictive validity for high worriers and high internal consistency ($\alpha = 0.93$; Fresco, Mennin, Heimberg, & Turk, 2003; see Appendix B). Scoring is based on a Likert scale ranging from 1 (Not very typical of me) to 5 (Very typical of me). Scores on the trait and state scales each range from 16 to 80.

The *Metacognitive Questionnaire-30* (MCQ-30; Wells & Cartwright-Hatton, 2004) is a 30-item instrument that was modified from the original 65-item *Metacognitive Questionnaire* (Cartwright-Hatton & Wells, 1997). The instrument measures individual differences in judgements, beliefs, and cognitive monitoring tendencies relevant to metacognitive theories of psychological disorders. The questionnaire yields scores on the following five subscales: *Positive Beliefs about Worry;* (e.g., "Worrying helps me to solve problems"), *Uncontrollability and Danger of Worry* (e.g., "My worrying is dangerous for me"*)*, *Poor Cognitive Confidence* (e.g., "I do not trust my memory"), *Need to Control Thoughts* (e.g., "I should be in control of my thoughts at all times), and

Cognitive Self-Consciousness (e.g., "I pay close attention to the way my mind works"). Of relevance to the current study, subscales on this measure have been found to correlate strongly with pathological worry (Wells & Cartwright-Hatton, 2004; Wells & Papageorgiou, 1998), trait anxiety (Wells & Cartwright-Hatton, 2004), and to distinguish GAD patients from those with other anxiety disorders (Wells & Carter, 2001). A four-point Likert response scale is used to score this measure. Each subscale consists of 6 items. Therefore, total MCQ-30 scores range from 30 to 120, and subscale scores range from 6 to 24. Though no direct hypotheses were made regarding participants' metacognitive beliefs about worry or working memory in this study, the MCQ-30 was included to potentially qualify interpretations of findings.

Working memory assessments. Working memory was assessed using two computerized dual span tasks: the reading span task and the worry span tasks. Each included a processing component (e.g., sentences to respond to) and a storage component (e.g., to-be-remembered words). Unlike entirely automated versions of similar assessments (Unsworth, Heitz, Schrock, & Engle, 2005), the experimenter remained in the room during the entire task and recorded the participant's responses (Turley-Ames & Whitfield, 2003). Directly preceding each assessment, participants completed a brief practice session to ensure that they understood the task requirements. As indicated previously, only participants who correctly completed three out of four critical practice trials on the reading span task were included in the study.

Reading span. The reading span task used in this study was modified after the computerized operation span task used in previous studies in this study's parent lab (Bud, Whitney & Turley, 1995; Conway, Kane, Bunting, Hambrick, & Wilhelm, 2005;

Daneman & Carpenter, 1980; Turley-Ames & Whitfield, 2003). Participants were presented with alternating series of sentences (e.g., "Jane walked the dog in the park") and to-be-remembered (TBR) words (e.g., rake). Participants were directed to read sentences presented in the center of a computer screen aloud and to verify whether the sentences were valid (e.g., "Jane walked the dog in the park") or invalid (e.g., "Jane the walked dog in the park") via key press (e.g., 1 for 'yes', 2 for 'no'). After the presentation of a sentence, a TBR word appeared in the center of the screen. Participants were given a total of eight seconds to read the sentence aloud, respond to the sentence, and read the TBR word aloud. At the end of one trial, constituting two to six pairs of alternating sentences and TBR words, participants were asked to write as many of the TBR words that they viewed in the previous trial in a test booklet. In total, participants viewed 60 sentence-word pairs, which were organized into 15 trials of three set sizes, ranging from two to six sentences-word pairs. Trials were presented in ascending set size order. For scoring, participants were awarded one point for correctly identified words in sentences also correctly identified as valid or invalid. This scoring method was used to ensure processing of both the sentence and the words. Reading span scores ranged from 0 to 60. See Appendix E and Appendix G.

Worry span. The worry analogue dual span task was modeled after the reading span task above, and after a dual span task used in a recent study focusing on PTSD in which trauma-related sentences were used (Schweizer & Dalgleish, 2011). Worry span sentence stimuli were designed to reflect the worry construct described previously. Specifically, sentences were self-relevant and suggestive of uncertain negative outcome (e.g., "If I make a mistake while talking to a crowd, everyone might laugh at me.")

A total of sixty worry sentences were constructed. Sentences pertained to topics previously identified as those most frequently worried about in both the general population and in individuals with GAD (i.e., family/interpersonal, work/school, finances, illness/injury/health, and other; Clark, 2003; Borkovec, Shadick, & Hopkins, 1991). Furthermore, some topics have been found to be more frequently worried about than others (i.e., family/interpersonal = 35%; work/school = 25%; finances = 20 %; illness/injury/health = 13 %; other = 7%; Borkovec, Shadick, & Hopkins, 1991). The relative proportion of the sixty worry sentences reflected this frequency (e.g., 35% of worry span sentences centered on family/interpersonal topics). Concrete and emotionally neutral TBR words were selected and matched for length and frequency with TBR stimuli used in the operation span task by Turner and Engle (1989). TBR words were randomly paired with worry sentences. See Appendix F and Appendix G.

In the worry span task, one worry sentence was presented in the center of the computer screen at a time. Participants were asked to read the sentence aloud and indicate whether the sentence represented something they might personally worry about via key press (i.e., 1 for 'yes' and 2 for 'no'). This decision was intended to encourage deeper processing of the sentence stimuli (e.g., Craik & Tulving, 1975). Indeed, manipulating depth of processing of threatening stimuli has resulted in relevant cognitive effects in individuals with anxiety. Specifically, Hirsh and colleagues (2001) demonstrated that semantic processing of words (i.e., identifying the emotional valence of threatening and nonthreatening words) resulted in attentional bias favoring threat and also increased worry in anxious individuals when compared to processing the same words at a structural level (i.e., identifying upper case versus lower case words; Hirsch, MacLeod, Mathews,

Sandher, Siyani, & Hayes, 2011). It was reasoned, therefore, that requiring participants to make a forced-choice decision regarding the self-relevance of worry sentences would increase the likelihood for deeper processing analogous to worry.

Content validity of this new measure was prioritized in the present study. Of note, the sentences used in the worry span task differ on a number of factors from the reading span (i.e., self-relevance, negative affect, and depth of processing), and these factors were all selected based on theoretical and empirical research on the worry construct. Therefore, the results of this investigation are considered in this context, and future studies are required in order to parse out which specific factors, or which combination of factors, are responsible for differences in task performance.

Just as in the reading span task, the worry span task contained five sets of three trials, presented in ascending set size order with each set containing two to six sentence-word pairs. Participants were given a total of eight seconds to read each worry sentence and the TBR word aloud. At the end of each set, participant were asked to recall TBR words from the previous set via writing them in a test booklet. Worry span scores ranged from 0 to 60.

Nelson-Denny Reading Test – Forms G and H. The Nelson-Denny Reading Test (ND; Brown, Fischco, & Hanna, 1993) is a multiple choice test that measures an individual's reading abilities, including reading comprehension (38 items; 20 minutes) and vocabulary (80 items; 15 minutes). Test-retest reliability for this test is good (r = .81 to .90; Brown, Fischco, & Hanna, 1993). This task was included to establish criterion validity of the worry span as a measure of working memory (i.e., predictive of reading

comprehension) as well as discriminant validity with a test of domain vocabulary knowledge. See Appendix D.

Worry induction task. A thought monitoring and worry induction task was used to evaluate the number of reported worry intrusions before and after a period of intentional worry. This procedure was devised from previous research investigating thought monitoring before and after worry induction (e.g., Hayes, Hirsch, & Mathews, 2010; Ruscio & Borkovec, 2004). The procedure comprised three phases (i.e., A, B, & C).

During Phase A, participants were asked to focus their attention on their breath for five minutes. They were told that they might experience negative intrusive thoughts during this time and that if this occurred they should refocus their attention on their breath. Participants were given a hand tally counter and presented with the list of three worry topics they generated at the beginning of the study. They were instructed to use the counter to record any time they experienced a negative, intrusive thought during the five minute period. The following instructions were read by the experimenter:

> **"Please close your eyes. For the next five minutes, you will be asked to focus your attention on your breathing. Try to focus on your breath as much as possible during this time. However, it is very likely that your mind will wander and you might think about other things. Specifically, you may experience negative thoughts, such as thinking about one of these topics you indicated was worrisome for you at the beginning of the study. When you have a negative intrusive thought, please use this counter to mark the thought each time it occurs. After recording the negative thought with the clicker, redirect your attention back to your breath. Think about your breathing as much as you can for the next five minutes but count your negative thoughts when they occur. You may begin focusing on your breathing now."**

In Phase B, participants were directed to view the list of the three currently worrisome topics they identified at the beginning of the study. They were then asked to

select which topic is currently most worrisome for them and to intentionally worry about it for five minutes. The experimenter instructed them as follows:

> **"Please study the list of worries in front of you and choose the one that is the most troubling to you right now. Which one is a negative topic for you that you tend to think about a lot? You will spend the next few minutes trying to intentionally focus as much of your attention as possible on this difficult topic. Think about all the ways in which this topic troubles you—all of the things that might go wrong and the reasons you might worry. You will be asked to worry about this topic intentionally for the next five minutes. You may close your eyes and begin worrying now."**

In Phase C, participants were given the same instructions as in Phase A (i.e., focus on your breath but record negative intrusions when they occur). As in Phase A, participants were asked to count the number of negative intrusions that occurred during the entire five minute monitoring period. It was expected that there would be a significant increase in negative intrusions following the worry induction phase (i.e., Phase B). Therefore, as a manipulation check for the worry induction, intrusions during phase A were compared to intrusions during phase C. The number of intrusions after the worry induction (i.e., Phase C) were used in all other analyses.

Procedure

Directly after consenting to the study, participants completed self-report measures, including measures of state anxiety (STAI-S, baseline) and trait worry (PSWQ). They also provided a list of their three most currently worrisome topics. Participants then completed the reading span and the worry span tasks (order counter-balanced). Next, participants completed the Nelson Denny Reading Test. Finally, participants completed the three-part Worry Induction Task. At the end of the study, participants completed three final self-report questionnaires: a final measure of state anxiety (STAI-S, post worry); a questionnaire assessing attitudes about worry (MCQ-30);

and a questionnaire asking them to respond to the same worry sentences they viewed during the worry span task.

State anxiety (STAI-S) was assessed repeatedly throughout the study at the following time points: beginning of the study (baseline), following the dual span tasks, following the Nelson Denny Reading Test, and post worry. State anxiety measured most proximally to the relevant task was used in all primary analyses. See Figure 3 for flow chart summarizing the study procedures.

Results

Preliminary Analyses

Distribution of variables. Skewness and kurtosis for worry span scores, reading span scores, self-report measures (i.e., STAI and PSWQ), Nelson Denny Reading Comprehension scores, Nelson Denny Vocabulary scores, and post worry induction intrusions were examined. Variables were found to be normally distributed with the exception of post worry intrusions, revealing skewness of 7.79 [*SE* = 0.21] and kurtosis of 74.04 [*SE* = 0.42]. A log transformation was performed on this variable, resulting in a skewness of 0.47 [*SE* = 0.21] and kurtosis of 1.90 [*SE* = 0.42]. This log-transformed variable was included in all analyses of post worry induction intrusions.

Demographics. Of the 131 participants in this study, 71.8% identified as female, 27.5% identified as male, and one participant identified as neither male nor female [0.8%]. Ethnicity was represented in the sample as follows: 80.2% Caucasian, 6.1% Hispanic/Latino, 1.5% African American, 1.5% Native American, 1% Asian American, and 9.9% other. Participants ranged in age 17 to 55 years old [*M* = 24.01, *SD* = 8.62].

Zero-order bivariate relationships were investigated between demographic variables and worry span scores, reading span scores, self-report measures, Nelson Denny Reading Comprehension, and Nelson Denny Vocabulary, and log transformed post worry induction intrusion scores. No significant relationships were revealed, with the exception of a significant positive correlation between age and Nelson Denny Vocabulary scores [$r = 0.36$, $p < .01$]. Therefore, age was included as a covariate for analyses examining Nelson Denny Vocabulary scores. Of note, gender was not found to significantly correlate with any self-report measures of anxiety or worry. Therefore, gender was not included as a covariate in any of the following analyses.

Changes in state anxiety. State anxiety (STAI-S) was monitored following each task in this study. STAI scores are presented in Tables 1 and 2.

The order of the worry span and reading span tasks was counter-balanced such that 52 participants completed the reading span task first and 79 participants completed the worry span task first. State anxiety for participants who completed the reading span first was compared to state anxiety for participants who completed the worry span first at each time point in the study. Order of span task was not found to make a statistically significant difference in state anxiety at any time point. Therefore, task order was collapsed for all subsequent analyses. See Figures 6 and 7.

In general, participants reported a significant increase in state anxiety from baseline [$M = 34.68$, $SD = 9.01$] compared to after completing the worry span task [$M = 42.06$, $SD = 10.94$; $t\ (130) = 8.15$, $p < .001$]. They also reported an increase in state anxiety from baseline [$M = 34.68$, $SD = 9.01$] compared to following the reading span task [$M = 43.39$, $SD = 11.33$; $t(130) = 9.30$, $p < .001$]. Unexpectedly, a trend was

revealed suggesting that participants were marginally more anxious after completing the reading span task [M = 43.39, SD = 11.33] compared to after completing the worry span task [M = 42.06, SD = 10.94]; however, this trend did not reach significance [t (130) = 1.91, p = .06].

Participants demonstrated a significant decrease in state anxiety after their final span task [M = 42.27, SD = 11.65] compared to after the Nelson Denny Reading Test [M = 35.71, SD = 9.59; t(130) = 7.65, p <.001]. Finally, as expected, participants demonstrated a significant increase in state anxiety from before completing the Worry Induction Task [M = 35.71, SD = 9.59] compared to after the Worry Induction Task [M = 41.45, SD = 12.69; t(130) = 5.67, p < .001]

Worry sentence endorsements during worry span and at the end of the study. A manipulation check was performed to verify participants processed sentence stimuli during the worry span task. To do this, a written questionnaire was administered at the end of the study containing the same 60 sentences participants viewed during the worry span task (e.g., "I can't stop thinking about my uncertain financial situation.") Participants were asked to indicate on a Likert scale of 1 (Not at all like me) to 5 (Very much like me) the degree to which the worry sentence applied to them. Agreement between this questionnaire and the number of worry sentences endorsed during the worry span task was assumed to suggest that participants did indeed process the sentence stimuli in the context of the dual span task similarly to the way they would outside of this task.

As expected, participants' worry endorsements of sentences during the worry span task strongly correlated with their endorsements of the same worry sentences at the end of the study [$r = .74$, $p < .001$].

Change in intrusions following worry induction. As an additional manipulation check, pre worry induction intrusions (baseline) were compared to post worry induction intrusions. As discussed above, a log-transformed variable for pre and post worry induction intrusions was used for this analysis, but means and standard deviations of intrusions are also reported as follows. In general, participants reported significantly more intrusions after the worry induction [$M = 8.79$, $SD = 6.53$] compared to before the worry induction [$M = 6.57$, $SD = 14.32$; $t(130) = 3.39$, $p < .01$].

Tests of Main Hypotheses

Zero-order bivariate correlations are presented in text below and summarized in Table 3. All other relationships were tested using a model comparison approach with simultaneous multiple regression (Judd, McClelland, & Ryan, 2009), and predictor variables were centered to the sample mean for these analyses.

Worry span as a measure of working memory.

Hypothesis 1: Worry span expected to correlate positively with standard working memory assessment (i.e., reading span). The worry span task was predicted to tap basic attention control processes in both non-anxious and anxious individuals. Therefore, performance on the worry span task was expected to predict performance on an industry standard measure of working memory (i.e., the reading span task). In general, worry span scores strongly and positively predicted reading span scores [$r = .60$, $p < .001$]. See Table 3 and Figure 8.

Anxiety, worry, and working memory.

Hypothesis 2: State anxiety and trait worry expected to correlate negatively with worry span and reading span. Previous research has found that individuals higher in both state anxiety and worry tend to perform more poorly on tasks that tap working memory abilities (e.g., Ashcraft & Kirk, 2001; Moran, 2016). In the current study, higher state anxiety and trait worry were expected to predict poorer performance on the worry span task, as well as on a neutral dual span task (i.e., reading span). Relationships between performance on each span task and state anxiety (both before and after the span tasks) are presented first. Next, relationships between worry and performance on each span task are presented.

Although multiple analyses introduce the possibility for Type 1 error, state anxiety and trait worry are each theoretically distinct constructs. Further, each have been approached independently in relevant literature and have been shown to be related to anxiety-relevant attentional processing (e.g., state anxiety: Bomyea & Amir, 2011; Mogg, Bradley, de Bono, & Painter, 1997; worry: Hayes, Hirsch, & Mathews, 2010; Hirsch et al., 2011). Baseline state anxiety and trait worry were found to significantly covary in this study [$r = .37$, $p < .001$]. Therefore, interpretations of the following analyses were made considering state anxiety and worry as unique but overlapping anxiety-related constructs.

State anxiety, pre reading span scores, and pre worry span scores. Higher pre-task state anxiety was expected to predict poorer performance on both the reading span task and the worry span task. This pattern was not revealed in the current study. In general, no relationship between pre reading span state anxiety and reading span

performance was found [r = -.08, p = .35]. Similarly, no relationship between pre worry span state anxiety and worry span performance was found [r = -.08, p = .39].

One potential concern with this analysis is that the order of the reading span task and worry span task was counterbalanced in this study. Because state anxiety was found to increase after the span tasks, an increase in anxiety might have contributed to performance on the second span task. Therefore, separate analyses were performed to examine baseline state anxiety for participants who completed the reading span first and the worry span first. State anxiety at baseline did not correlate with reading span performance for the 52 participants who completed reading span task first [r = .08, p = .60]. State anxiety at baseline did not correlate with worry span performance for the 79 participants who completed worry span task first [r = .001, p = .99].

Given a demonstrated increase in state anxiety following the first span task, relationships between post-initial span task state anxiety and second span task performance were also examined. For the 52 participants who completed the reading span first, post reading span state anxiety was not found to predict performance on the subsequent worry span task [r = -.19, p = .18]. For the 79 participants who completed the worry span task first, post worry span anxiety was not found to predict subsequent reading span performance [r = -.13, p = .26].

Taken together, this pattern suggests that state anxiety *prior* to performing either working memory task did not predict performance on either of the working memory tasks.

State anxiety, post reading span scores, and post worry span scores. The relationship between working memory span scores and post-span task anxiety was also

examined. In general, poorer performance on both the reading span and the worry span tasks was expected to predict higher state anxiety after completion of the tasks. Indeed, lower reading span scores predicted higher state anxiety following the reading span task [r = -.19, p = .03]. Furthermore, lower worry span scores predicted higher state anxiety following the worry span task [r = -.21, p = .01].

This pattern suggests that poorer performance on both working memory tasks predicted higher state anxiety directly *following* the task. As working memory performance decreased, state anxiety was found to significantly increase.

Worry, reading span scores, and worry span scores. Higher trait worry was also expected to predict poorer performance on both the reading span and the worry span tasks. However, PSWQ scores were not found to predict performance on the reading span task [r = .001, p = .98] nor performance on the worry span task [r = -.07, p = .42].

Hypothesis 3: Worry span scores were hypothesized to be lower than reading span scores and this difference was expected to further increase for participants reporting higher state anxiety and trait worry. Anxiety and worry have been found to impact attentional processing (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007) and working memory abilities when tasks contain threatening materials compared to neutral materials (Amir & Bomyea, 2011; Schweizer & Dalgleish, 2011). Therefore, reading span scores were expected to be higher than worry span scores. However, this difference was expected to further increase as a function of participant state anxiety and trait worry such that those reporting higher state anxiety and trait worry would demonstrate even poorer performance on the worry span task compared to the reading span task.

Multiple regression analyses were used to investigate the degree to which state anxiety and trait worry predicted the difference between participants' worry span and reading span scores. State anxiety following the span tasks, state anxiety following the Worry Induction Task, and trait worry were tested as potential predictors of the difference in performance on the worry span and reading span tasks. See Table 4, Model 1.

In the first analysis, the criterion variable was calculated as worry span score minus reading span score. Difference in span scores was regressed on state anxiety post final span task. In general, worry span scores were significantly higher than reading span scores. This difference was not found to be significantly greater as a function of state anxiety after the final span task [$F(1, 130 = 2.13, p = .15$], though a trend suggested that higher post-span anxiety resulted in relatively lower worry span scores compared to reading span scores.

In a second analysis, the difference in worry span scores and reading span scores was regressed on state anxiety following the Worry Induction Task. See Table 4, Model 2. It was expected that participants who reported higher state anxiety following a period of induced worry would perform more poorly on the worry span task relative to the reading span task. Indeed, while participants generally tended to score higher on the worry span task than the reading span task, this was significantly less true for participants who reported higher state anxiety after a period of induced worry [$F(1, 130) = 6.04, p < .05$].[1] A post-hoc investigation of reading span and worry span scores for individuals reporting high state anxiety versus low state anxiety suggests that this effect may have been driven by generally high worry span scores (i.e., ceiling effect). See Figure 10.

A similar regression analysis was used to investigate the degree to which trait worry (i.e., PSWQ scores) predicted the difference between worry span scores and reading span scores. The difference in worry span scores and reading span scores was not found to depend on self-reported trait worry [$F(1, 130) = .79$, $p = .38$]. See Table 4, Model 3.

Worry span concurrent and divergent validity.

Hypothesis 4: Worry span and reading span expected to correlate positively with Nelson Denny – Reading Comprehension. Tasks that tap working memory abilities correlate with measures of higher cognitive functioning, such as reading comprehension (e.g., Daneman & Merikle, 1996; Turley-Ames & Whitfield, 2003). Therefore, it was expected that performance on the reading span and worry span would correlate with performance on a measure of reading comprehension (i.e., Nelson Denny Reading Test-Reading Comprehension).

As has been found in previous studies, performance on the reading span task was strongly and positively correlated with performance on the Nelson Denny Reading Test – Reading Comprehension [$r = .41$, $p < .001$]. As was expected, performance on the worry span task also significantly and positively correlated with performance on the Nelson Denny Reading Test – Reading Comprehension [$r = .38$, $p < .001$].[2] See Figure 11.

Hypothesis 5: Correlations between working memory task performance (i.e., worry span and reading span) and Nelson Denny Reading Comprehension expected to be stronger than correlations between working memory tasks and Nelson Denny Vocabulary. To test divergent validity, relationships between working memory task performance and reading comprehension were expected to be stronger than the

correlations between working memory task performance and a measure of vocabulary knowledge. In general, controlling for age, Nelson Denny – Reading Comprehension scores were strongly and positively correlated with Nelson Denny – Vocabulary scores [$r = .65$, $p < .001$]. Reading span scores were strongly and positively correlated with both Nelson Denny – Reading Comprehension scores [$r = .41$, $p < .001$] and Nelson Denny – Vocabulary scores [$r = .41$, $p < .001$]. These correlations were not found to be significantly different from each other [*Fisher's Z* = .09, $p = .46$].

Similarly, worry span scores were strongly and positively correlated with both Nelson Denny - Reading Comprehension scores [$r = .38$, $p < .001$] and Nelson Denny – Vocabulary scores [$r = .37$, $p < .001$]. These correlations were also not found to be significantly different from each other [*Fisher's Z* = .09, $p = .46$.]

Hypothesis 6: State anxiety and trait worry expected to moderate the relationship between worry span performance and higher cognitive functioning (i.e., Nelson Denny – Reading Comprehension). It was expected that worry span scores would correlate positively with reading comprehension scores and that this relationship would be stronger for individuals who reported higher state anxiety and higher worry. Furthermore, this relationship was expected to remain after controlling for performance on the reading span task.

A multiple regression analysis was used to investigate the potential moderation of state anxiety after completion of the span tasks on the relationship between worry span score and Nelson Denny Reading Test – Reading Comprehension scores, controlling for reading span score. Nelson Denny Reading Test - Reading Comprehension scores were regressed on worry span scores, state anxiety (post span tasks), the interaction of worry

span scores X state anxiety, and reading span scores.[3] See Table 5, Model 1. The full model accounted for significant variance in reading comprehension scores [$F(4,126) = 7.83$, $p < .001$]. On average, as reading span scores increased, reading comprehension scores significantly increased [$F(1, 126) = 8.32$, $p < .01$]. Similarly, on average, as worry span scores increased, reading comprehension scores also significantly increased [$F(1, 126) = 4.48$, $p < .05$]. No significant relationship was found between state anxiety post span task and reading comprehension scores [$F(1,126) = .67$, $p = .42$]. Furthermore, state anxiety did not strengthen or weaken the relationship between worry span scores and reading comprehension, controlling for reading span scores [$F(1,126) = .27$, $p = .60$].

A second multiple regression analysis was used to investigate the potential moderation of state anxiety after the worry induction task on the relationship between worry span score and Nelson Denny Reading Test – Reading Comprehension scores, controlling for reading span score. Nelson Denny Reading Test - Reading Comprehension scores were again regressed on worry span scores, state anxiety (post worry induction), the interaction of worry span scores X state anxiety, and reading span scores. See Table 5, Model 2. This model accounted for significant variance in reading comprehension scores [$F(4,126) = 8.85$, $p < .001$]. As above, as reading span scores increased, reading comprehension scores significantly increased [$F(1, 126) = 5.94$, $p < .05$]. Again, as worry span scores increased, reading comprehension scores also significantly increased [$F(1, 126) = 5.68$, $p < .05$]. Although slightly stronger than the relationship between post span task state anxiety and reading comprehension scores, no significant relationship was found between state anxiety post worry induction and reading comprehension scores [$F(1,126) = 2.59$, $p = .11$]. State anxiety did not strengthen or

weaken the relationship between worry span scores and reading comprehension, controlling for reading span scores [F (1,126) = 1.71, p = .20].

A third multiple regression analysis was used to investigate the potential moderation of trait worry on the relationship between worry span performance and Nelson Denny Reading Test – Reading Comprehension scores, controlling for reading span scores. Nelson Denny Reading Test - Reading Comprehension scores were regressed on worry span scores, PSWQ scores, the interaction of worry span scores X PSWQ scores, and reading span scores. See Table 5, Model 3. This model accounted for significant variance in reading comprehension scores [F(4,126) = 7.65, p <.001]. As above, reading span scores [F(1, 126) = 8.39, p <.01] and worry span scores [F(1, 126) = 4.10, p <.05] each positively predicted reading comprehension scores. No significant relationship was found between trait worry and reading comprehension scores [F(1,126) = .07, p = .79]. Trait worry did moderate the relationship between worry span scores and reading comprehension, controlling for reading span scores [F(1,126) = .27, p = .61].

In general, this pattern of findings suggested that both reading span scores and worry span scores positively predicted reading comprehension scores. However, state anxiety (after the span tasks and after the worry induction task) and trait worry did not predict reading comprehension scores in this sample. Furthermore, there was no evidence that anxiety or trait worry moderated the relationship between worry span performance and reading comprehension, controlling for performance on the reading span task.

Worry span as a predictor of worry intrusions.

Hypothesis 7: Worry span and reading span expected to correlate negatively with post worry intrusions. Previous research has demonstrated a relationship between working memory and the ability to inhibit proactive interference (Rosen & Engle, 1998) and intrusive negative thoughts (Wegner, Schneider, Carter, & White, 1987). Therefore, both worry span scores and reading span scores were expected to negatively correlate with the behavioral index of intrusive worry used in this study. Log transformed post worry induction intrusions were used in all subsequent analyses.

A non-significant trend revealed a positive zero-order relationship between reading span scores and the number of intrusions post worry induction [$r = .15$, $p = .09$]. Similarly, a non-significant trend revealed a positive relationship between worry span scores and intrusions post worry induction [$r = .16$, $p = .07$]. In general, as working memory scores increased, participants reported more intrusive thoughts after a period of induced worry; however, these unanticipated trends did not reach statistical significance. See Table 3.

Hypothesis 8: State anxiety and trait worry expected to correlate positively with post worry intrusions. Previous research has demonstrated that individuals higher in anxiety and worry experience difficulty inhibiting intrusive worry (Becker, Rinck, Roth & Margraf, 1998). Therefore, state anxiety and worry were expected to positively correlate with the number of intrusions reported in the behavioral index of intrusive worry used in this study.

In general, state anxiety at baseline [$r = .27$, $p < .01$], state anxiety after completing the span tasks [$r = .31$, $p < .001$], and state anxiety after completing the

Worry Induction Task [$r = .58$, $p < .001$], were all significantly and positively predictive of the number of intrusions reported by participants during the Worry Induction Task. In addition, trait worry was also positively predictive of post worry induction intrusions [$r = .29$, $p < .01$]. See Table 3.

Hypothesis 9: State anxiety and trait worry expected to moderate the relationship between worry span score and intrusions. Worry span performance was hypothesized to correlate negatively with the number of intrusive worries reported following the Worry Induction Task in general. However, this relationship was expected to be stronger for individuals who reported higher anxiety and trait worry. Furthermore, these interactions were expected to remain after controlling for performance on the reading span task.

State anxiety and intrusions. A multiple regression analysis was used to investigate potential moderation of state anxiety on the relationship between worry span score and the number of post worry induction intrusions, controlling for reading span score. Log transformed intrusions were regressed on worry span scores, state anxiety (post Worry Induction Task), the interaction of worry span scores X state anxiety, and reading span scores. See Table 6, Model 1.

This full model accounted for significant variance in intrusions [$F(4,126) = 18.21$, $p < .001$]. On average, as worry span scores increased, intrusions significantly increased [$F(1, 126) = 5.34$, $p < .05$]. No significant relationship was revealed between reading span scores and the number of reported intrusions after controlling for anxiety and worry span scores [$F(1, 126) = .07$, $p = .43$]. Furthermore, the more state anxiety participants reported after the worry induction task, the more intrusions they reported [$F(1, 126) =$

65.94, p <.001]. However, state anxiety was not found to significantly strengthen or weaken the relationship between worry span scores and reported intrusions, controlling for reading span scores [$F(1,126) = .56$, $p = .46$].

In general, this pattern indicated that both worry span scores and state anxiety each independently predicted the number of intrusions reported by participants during the worry induction task, controlling for reading span scores, and controlling for each other. Reading span scores, however, were not found to predict the number of reported intrusions, after controlling for state anxiety and worry span scores.

Trait worry and intrusions. A multiple regression analysis was used to investigate the potential moderation of trait worry (i.e., PSWQ scores) on the relationship between worry span performance and the number of post worry induction intrusions, controlling for reading span scores. Log transformed intrusions were regressed on worry span scores, PSWQ scores, the interaction of worry span scores X PSWQ scores, and reading span scores. See Table 6, Model 2.

This full model accounted for significant variance in intrusions [$F(4,126) = 4.35$, p <.01]. Higher trait worry was associated with a significantly greater number of intrusions post worry induction [$F(1, 126) = 12.14$, $p < .01$]. After controlling for trait worry, no significant relationship was observed between worry span scores [$F(1,126) = 1.76$, $p = .19$] or reading span scores [$F(1, 126) = .47$, $p = .50$] and post worry intrusions. Trait worry was not found to significantly strengthen or weaken the relationship between worry span scores and reported intrusions, controlling for reading span scores [$F(1,126) = .39$, $p = .53$].

In general, this pattern suggested that trait worry positively predicted reported intrusions post worry induction. After controlling for this relationship, neither worry span scores nor reading span scores were found to predict the number of reported intrusions.

Hypothesis 10: Worry span expected to mediate the relationship between state anxiety and intrusive worry. Working memory (as measured by the worry span task) was expected to mediate the relationship between state anxiety (post worry span) and the number of intrusive thoughts tallied after a five-minute period of intentional worry.

A mediational analysis was conducted using the products-of-coefficients approach (MacKinnon et al., 2007), which is an alternative strategy to the causal steps approach (Baron & Kenny, 1986), and which tests if the mediated effect (*a***b*) is significant. Within this approach, the standard Sobel test has been found to have low statistical power, and does not account for the non-normality of the mediated effect (calculated by the products of *a* and *b* paths; MacKinnon et al., 2002). Therefore, the test of the asymmetric confidence interval was used to assess for significance of the indirect path using the ProdClin Program (MacKinnon et al., 2007). If the 95% confidence interval does not include zero, then the mediated effect is statistically significant.

To test the direct relationship (c path), a linear regression was conducted in which intrusions (log transformed) was regressed on state anxiety (i.e., post worry span) scores. This test revealed a significant positive relationship, such that higher state anxiety (i.e., post worry span) predicted more intrusions [$B = .009$; $F(1, 129) = 13.51$, $p < .001$]. By adopting the products-of-coefficients approach both *a* and *b* paths were run to determine if an indirect mediation existed. Higher state anxiety post worry span task was found to

predict lower worry span scores [*a* path; *B* = -.15*; SE = .06; F*(1, 129) = 6.37, *p* < .05]. Furthermore, intrusions were regressed on worry span scores, controlling for state anxiety (i.e., post worry span; b and c' paths), and this test was found to be significant [*B* =.01, SE = .004, *F*(1, 129) = 7.92, *p* <.01]. A calculation of the asymmetric confidence interval indicated that the mediated effect of worry span on the relationship between state anxiety (i.e., post worry span and intrusions) was also significant [95% CI = -.0029 to -.00023]. However, it is noted that the Sobel test, a more conservative estimate, revealed only marginal evidence of mediation [Sobel test = -1.78, *SE* = .0009, *p* = .075].

A second parallel analysis was also investigated using the reading span in place of the worry span as an index of working memory abilities. It was similarly hypothesized that the reading span would mediate the relationship between state anxiety (i.e., post worry span) and reported intrusions post worry induction.

A second mediational analysis was conducted to test performance on the reading span task as a potential mediator of the relationship between state anxiety and log transformed intrusions. Higher state anxiety post worry span task was not associated with lower reading span scores [*B* = -.09*; SE* = .07, *p* = .19]. However, higher reading span scores predicted more intrusions following worry induction when controlling for state anxiety [*B* = .007*; SE = .003*, *p* <.05]. A calculation of the asymmetric confidence interval indicated that the mediated effect of reading span on the relationship between state anxiety (i.e., post worry span and intrusions) was not significant [95% CI = -.0015 to .00034]. The Sobel test also revealed no evidence of mediation [Sobel test = -1.13, *SE* = .00054, *p* = .26].

Results Summary

The main findings of the present study are summarized briefly below. They will be discussed in detail subsequently.

Worry span as a measure of working memory. Overall, high endorsements were found between post-study worry sentence endorsements and worry sentence endorsements during the worry span, suggesting that participants processed the worry sentences during the worry span task in a similar manner to how they would process these sentences outside of the dual span task context.

Correlations were strong and positive between performance on the reading span task and performance on the worry span task, providing support for the worry span task as a measure of working memory. Furthermore, performance on the reading span task and worry span task were significantly and positively predictive of performance on the Nelson Denny Reading Test – Reading Comprehension test.[2] This suggests that like other dual span tasks, the worry span may be predictive of higher cognitive functioning. Reading span scores and worry span scores were not more highly correlated with Nelson Denny Reading Comprehension compared to Vocabulary scores, providing no evidence for divergent validity (of either of these tasks) in this study.

State anxiety, worry, and working memory. In general, state anxiety was found to increase after the reading span task, after the worry span task, and after the worry intrusion task, compared to baseline. This finding may imply that tasks that tap working memory increase state anxiety.

In general, state anxiety *prior* to reading span and worry span was not correlated to performance on either task. However, state anxiety *after* the reading span task

negatively correlated with reading span performance. Similarly, state anxiety *after* the worry span task negatively correlated with worry span performance. Trait worry was not related to performance on the reading span task nor the worry span task.

Participants scored higher on the worry span task than the reading span task in general. However, this was less true for participants reporting higher state anxiety after the worry induction task. A post hoc investigation of reading span and worry span task scores suggests that this interaction may have been driven by a ceiling effect of high worry span scores. An alternative interpretation is that participants' reactivity to the worry induction may have resulted in a facilitative effect on reading span performance but not on worry span performance. These interpretations are discussed further below. Trait worry was not found to moderate the difference between worry span score and reading span score.

Independent effects of working memory on reading comprehension, controlling anxiety and worry. As reading span scores increased, reading comprehension scores significantly increased, and this effect remained after controlling for worry span scores, state anxiety post span tasks, state anxiety post worry induction. Similarly, as worry span scores increased, reading comprehension scores also significantly increased, and this effect remained after controlling for reading span scores, state anxiety post span tasks, and state anxiety post worry induction.

No significant relationship was found between reading comprehension and state anxiety (at any time point) or trait worry in this study. State anxiety and trait worry did not strengthen or weaken the relationship between worry span scores and reading comprehension, controlling for reading span scores.

These results indicate that the working memory tasks used in this study each predicted unique variance in reading comprehension; however, state anxiety and worry did not predict performance on reading comprehension in this sample.

Independent effects of working memory on intrusions, controlling anxiety and worry. An increase in worry intrusions was found after the worry induction task compared to before the worry induction task. Furthermore, as working memory scores increased, participants appeared to report *more* intrusive thoughts after a period of induced worry; however, this unanticipated trend did not reach statistical significance.

Self-reported measures of anxiety all appeared to have a strong positive correlation with reported post-worry induction intrusions. Specifically, state anxiety at baseline, state anxiety after completing the span tasks, and state anxiety after completing the Worry Induction Task were all significantly and positively predictive of the number of intrusions reported by participants after the worry induction. In addition, trait worry was also positively predictive of post worry induction intrusions.

Interestingly, after controlling for post worry state anxiety and reading span, worry span scores became significantly predictive of post worry intrusions. However, reading span was not found to be predictive of intrusions after controlling for state anxiety and worry span. After controlling for trait worry, neither worry span nor reading span significantly predicted post worry intrusions. Finally, there was no evidence that either worry span performance or reading span performance mediated the relationship between state anxiety post worry span and post worry intrusions.

Discussion

Through the use of cognitive methodology, researchers have uncovered robust relationships between anxiety, worry, and working memory. However, the precise nature of these relationships is currently widely debated (Morgan, 2016). Furthermore, clinical scientists have developed innovative treatment interventions to treat anxiety disorders through the use of modified computerized tasks initially used to measure these relationships. The purpose of the current investigation was twofold. First, this study sought to clarify basic relationships between state anxiety, trait worry, and working memory abilities. Second, this study sought to develop a measurement of the impact of worry-like processing on working memory and to provide initial validation for this potentially useful research and clinical tool.

A number of informative patterns were revealed in the current investigation. In the following section, I will provide a detailed discussion of the current findings, including interpretations and theoretical implications. In order to clarify relationships between anxiety, worry, and working memory, a number of manipulation checks were conducted. Given that these form the basis for the specific hypotheses under investigation, I will begin with a detailed description of the observed changes in state anxiety during the study protocol; evidence for worry-processing during the worry span task; and evidence for increased reported worry intrusions following the worry induction task.

Next, I will provide detailed description and discussion regarding the specific hypotheses under investigation in the current study. Here, I will discuss findings supporting worry span as a measure of working memory; findings suggesting a qualified

relationship between anxiety and trait worry on working memory processes in this non-clinical sample; and findings regarding predictive qualities of the worry span with regard to other relevant cognitive processes (e.g., higher cognitive functioning and intrusive worry.)

I will conclude with a summary of the broad patterns observed in this study and their implications. I will also address potential limitations of this study and provide suggestions for future research. Indeed, this study represents an important preliminary step toward better understanding the relationships between anxiety, worry, and working memory. Additionally, this study offers the worry span task as a potentially useful clinical and research tool for measuring the impact of worry on working memory.

Discussion of Preliminary Analyses

State anxiety during the study protocol. State anxiety was measured at several key time points during this study (i.e., baseline, post reading span, post worry span, post Nelson Denny Reading Test, and post Worry Induction Task). In general, state anxiety was found to significantly increase after completing the worry span and reading span tasks, compared to baseline. Furthermore, state anxiety was found to significantly decrease after participants completed the Nelson Denny Reading Test, yielding state anxiety scores that were not significantly different from baseline state anxiety. Finally, state anxiety was found to significantly increase again after participants completed the Worry Induction Task.

In general, tasks intended to tap working memory were associated with an increase in state anxiety in the current investigation. While a trend suggested marginally elevated levels of anxiety following the reading span compared to the worry span, this

trend did not reach significance. Thus, the worry span was not associated with a greater increase in state anxiety than reading span, contrary to predictions from other studies incorporating threatening materials into basic cognitive tasks (e.g., Amir & Bomyea, 2011; Schweizer & Dalgleish, 2011; discussed more below). State anxiety was found to decrease after the Nelson Denny Reading Test. This task is similar to many multiple choice tests taken routinely by college students. One interpretation of this pattern is that novel tasks that tap executive processes may increase state anxiety more than multiple choice tests routinely encountered by college students.

Our findings also imply that the Worry Induction Task successfully increased participant anxiety, relative to baseline, and relative to state anxiety following the Nelson Denny Reading Test. This finding is consistent with previous research using a similar task which concluded that a five minute period of intentional worry is sufficient to significantly increase state anxiety while not so long as to allow anxiety to decline (Ruscio & Borkoveck, 2004).

In summary, participant anxiety increased both after completing novel, cognitively demanding dual span tasks, and after engaging in a 5-minute worry induction procedure. This pattern suggests that tasks that tap working memory may, in and of themselves, increase participant anxiety, regardless of the use of threatening materials, in non-clinical college students. Similarly, instructing participants to worry intentionally also resulted in subsequent increase in state anxiety. However, given a lack of experimental control in this study, we can only speak to observed patterns in state anxiety over time for all participants who completed the same tasks during the protocol.

Randomizing participants to control tasks would be required to make definitive causal statements regarding these relationships.

Worry-like processing during worry span. Our findings suggest that the worry span task may be a good analogue for the impact of worry on working memory. As described previously, the worry span task is a dual-span task designed to measure the ability to remember words while also processing worry-like sentences. Construction of the worry sentences used in this task was based on both theory regarding the worry construct (Borkovec, Robinson, & Dupree, 1983) and on previous research investigating worry in both clinical and non-clinical populations (Borkovec, Shadick, & Hopkins, 1991; Clark, 2003). Worry sentences were self-referential, negatively valanced, and suggestive of negative potential future outcomes (e.g., "The international news makes me concerned about a possible war in the future.")

During the worry span task, participants were asked to read these sentences aloud and respond via forced-choice keypress ('yes' or 'no') as to whether the worry sentence applied to them. Scores on this task were based solely on the number of unrelated words remembered, and participants could have potentially chosen to use a response set to bypass processing the sentences at a deeper level (e.g., invariably selecting either 'yes' or 'no'; responding randomly). Therefore, a manipulation check was performed to verify that participants processed the worry sentences during the worry span task in a manner comparable to how they would process these sentences outside of the cognitively demanding dual span task context. High agreement between participants' responses to the post-study worry sentence questionnaire and their endorsement of worry sentences during the worry span task was revealed in this study. This finding suggests that

participants generally processed the worry sentences while performing the worry span task in a manner comparable to how they would process the same sentences outside of the task.

The finding that participants appeared to consider whether the sentence applied to them during the worry span task supports the potential for online worry-like processing during this task. However, it is conceded that worry-like processing evoked in this task may differ from worry that occurs outside of the laboratory. For instance, whereas protracted worry tends to include chains of repeated themes, idiographic to an individual, the sentences used in this study were thematically independent of each other and standardized across all participants in the study. While presenting standardized worry sentences was necessary for this preliminary investigation, future studies may consider using sentence stimuli constructed for individual participants based on current, idiographic worry themes. Such a change may increase the generalizability of findings in future investigations of the worry span task, potentially allowing clinicians to adapt this tool for use in clinical settings.

Increase in tallied intrusions following worry. Consistent with prior research (Hayes & Hirsch, 2010; Ruscio & Borkovec, 2004), we found an increase in both state anxiety and intrusions after the Worry Induction Task. Recall that this task included three phases. During the first phase, participants were asked to attend to their breath while counting worry intrusions with a handheld counter. During the second phase, they were asked to intentionally worry for a five minute period. During the third phase, they were asked to again attend to their breath while counting worry intrusions. A significant increase in intrusions after worrying compared to before worrying suggested that the

worry induction successfully increased participants' reported worry intrusions relative to their baseline. Furthermore, after completing the task, participants also reported an increase in state anxiety, suggesting that this task increased anxiety, as would be expected after increasing intrusive worry.

The observed increase in reported worry in this study is consistent with findings from earlier studies using similar worry induction techniques in clinical samples. In a study by Ruscio and Borkovec (2004), high trait worriers and individuals with GAD were asked to engage in a five minute period of focused breathing, followed by five minutes of focused worry, and concluding with five minutes of focused breathing. They were asked to indicate whether they were distracted by negative thoughts or focused otherwise (e.g., focused on their breath, distracted by neutral thoughts, or distracted by positive thoughts) at four time intervals during the two focused breathing periods. In general, these participants reported a significant increase in worry following the worry induction. In a later study using the same task (Hayes & Hirsch, 2010), high trait worriers were similarly asked to report whether they experienced negative thoughts at 12 time intervals during each breathing-focused periods. This study also found a significant increase from baseline in reported negative thoughts following a five-minute period of worry. Findings from the current investigation, using a non-selected sample, replicated the results of these studies, suggesting that a five minute period of intentional worry can result in increased worry in non-clinical participants.

While participants' reported worry intrusions during this task are presumed to reflect true instances of worry-related intrusions, this cannot be directly verified. Because worry is a private, cognitive phenomenon, converging methodological

techniques are required to support findings that participants are generally accurate in their ability to count intrusions that occur during periods of thought monitoring. In one study investigating intrusive worry in participants with GAD, intrusions were measured via 'think aloud' methodology. Participants were asked to verbalize their thoughts for a sustained period and to also count the number of intrusive negative thoughts that occurred with a mouse click (Reinecke, Hoyer, Rink, & Becker, 2010). Verbalized thoughts were audio-recorded and later reviewed by independent raters who quantified occurrences of verbalized intrusions. Using this methodology, strong agreement between independent raters' tally of verbalized intrusions and participants' ratings of intrusions was observed, suggesting that participants were able to accurately record intrusions when they occurred. While this study supports the presumption that participants can accurately quantify negative intrusive thoughts, it is similarly methodologically limited, as worry that occurs in nature is typically subvocalized. Indeed, explicit verbalization could change the nature of the worry phenomenon.

In general, our finding that reported worry intrusions increased after a period of worry induction is consistent with previous literature using similar methodology. However, because worry is a private behavior that cannot be directly observed, we also concede that participants may not have responded accurately when asked to count intrusions in this study. For instance, participants may have responded to demand characteristics of the study, perhaps expecting that worry should increase following the worry induction. While an increase in reported worry intrusions is consistent with previous research and suggests an increase in intrusions, these important caveats are considered when interpreting main findings of post-induction worry intrusions below.

Discussion of Primary Hypotheses

Worry span as a measure of working memory.

Hypothesis 1: Worry span expected to correlate positively with standard working memory assessment (i.e., reading span). The worry span task is a dual span task designed to tap basic attention control processes. Therefore, performance on the worry span task was expected to predict performance on the reading span task, an industry standard measurement of working memory capacity. Results suggested that as worry span scores increased, reading span scores also increased in this study. Furthermore, worry span scores accounted for 36% percent of the variance in readings span scores, suggesting a large effect (Cohen, 1997; Judd, McClelland, & Ryan. 2009) and providing solid initial support for the worry span as a task that measures working memory processes.

Of note, several differences between reading span and worry span may account for remaining variance not accounted for by this relationship. By design, the reading span and worry span differed on a number of factors. While sentences were to be judged as grammatically valid or invalid in the reading span task, participants were asked to decide whether worry-like sentences applied to them in the worry span task. Worry span sentences were threat-related and self-referential. Therefore, participants' general metacognitive and meta-emotional awareness may have been tapped in the worry span task but not in the reading span task. Reading span sentences required participants to identify the grammatical validity of the sentence itself, likely calling upon different cognitive processes. While both types of processing may increase cognitive load, the degree to which they do so, and mechanisms by which they do so, may differ. To parcel

out which specific working memory processes were tapped by the worry span task, future studies may consider including other tasks presumed to rely on specific executive processes.

In addition, unexplained variance in the two span tasks may have resulted from different scoring strategies. During the reading span task, participants earned one point for every correctly remembered word paired with a sentence correctly indicated as valid or invalid. In the worry span task, participants indicated whether or not they agreed with the worry sentence, but received a point for every correctly recalled word memorandum regardless of their response to the worry sentences. It is possible that this scoring difference may have weakened the observed relationship between these two working memory tasks.

While worry span scores and reading span scores were each normally distributed, reading span scores were observed to be lower than worry span scores. This finding was contrary to expectations, as including threatening material has been found to disrupt performance in cognitive tasks in individuals with anxiety (e.g., Amir & Bomyea, 2011; Schweizer & Dalgleish, 2011). The inclusion of threatening materials may not have impacted participants in the current study, who were within normal limits on measures of anxiety and trait worry (discussed more below). However, as mentioned, other differences between the worry span and reading span tasks may be responsible for mean differences found on these tasks. For instance, reading span scoring may have yielded lower scores, as participants had to demonstrate correct performance on both the storage and processing component. Controlling for this difference in a future study may help to clarify the observed mean differences in task performance (and potentially increase

variance explained between the reading span and worry span). For example, a future study may alter the worry span to include worry-like sentences that are either grammatically valid or invalid, and require participants to judge their validity, rather than evaluate whether they would worry about the sentence. While this future study would sacrifice some content validity regarding the worry construct, it would allow for a clearer understanding of the impact of including threatening and otherwise worry-like materials in the worry span task.

Although differences between the two span tasks are noted, the strong positive relationship between them supports the hypothesis that the worry span task tapped working memory processes in the current study. However, differences between the worry span and reading span tasks are considered in interpretations of other findings presented below.

Anxiety, worry, and working memory.

Hypothesis 2: State anxiety and trait worry expected to correlate negatively with worry span and reading span. Previous research has found that, in general, individuals higher in state anxiety and worry tend to perform more poorly on tasks that tap working memory abilities (e.g., Ashcraft & Kirk, 2001; see Moran, 2016). The results of the current study suggest that state anxiety, but not trait worry, was related to performance on two working memory tasks in an unselected sample of undergraduate participants. However, this relationship was only observed when examining working memory task performance and state anxiety *after* completing the working memory tasks. No relationship was revealed between pre-task state anxiety and working memory task performance.

While robust relationships between state anxiety, worry, and working memory have been observed in previous studies and reported in a recent meta-analysis, the precise nature of these relationships is complex and currently debated (see Moran, 2016). Adding to this complexity, different dimensions of anxiety, worry, and working memory have been examined in previous studies. For instance, dimensions that vary across studies include the methodological approach to measuring anxiety (e.g., physiological arousal versus self-reported anxiety), experimental manipulation of anxiety and worry, and the use of different assessments of working memory. Critically, the relationship between anxiety and impaired working memory is stronger in anxious samples (Moran, 2016). Furthermore, the direction of the relationship between anxiety, worry, and working memory is also controversial. For example, some research suggests that impaired attention control is a risk factor for developing anxiety (e.g., MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2003; Mathews & MacLeod, 2005), whereas other studies suggest that anxiety directly impairs attention control abilities (e.g., Eysenck, Derakshan, Santos, & Calvo, 2007). The findings in the current study may provide some clarification regarding the nature of anxiety, worry, and working memory in non-anxious participants.

As mentioned above, state anxiety and worry have been addressed as independent but related constructs in previous literature, and will be discussed separately here. State anxiety is defined as the subjectively distressing experience of arousal in response to perceived or anticipated threat (e.g., Ohman, 2008). In the current study, state anxiety was measured in a non-selected sample of undergraduate participants using the *Speilberger State Anxiety Scale* (STAI-S) self-report questionnaire at several time points

during the protocol. State anxiety at baseline was not found to predict performance on working memory tasks in this study. However, it is noted that baseline anxiety scores at the beginning of this study (*M* = 34.68, *SD* = 9.01) were comparable to other non-clinical samples (*M* = 36, *SD* = 12) and significantly lower than individuals with GAD (M = 57, SD = 13; Kennedy, Schwab, Morris & Beldia, 2001). Given non-clinical levels of state anxiety at baseline, finding no relationship between baseline anxiety and working memory performance in the present study may be due to statistical reasons (e.g., restricted range at baseline), but may also be due to a relatively weak relationship between baseline state anxiety and working memory in non-anxious participants. To observe a deleterious effect of anxiety on cognition in non-anxious samples, state anxiety may need to be experimentally manipulated.

Indeed, in other studies investigating anxiety and working memory abilities in non-anxious samples, a relationship between state anxiety and working memory performance has been revealed when anxiety is experimentally elevated. In studies using the 'threat-of-shock' technique, participants are randomly assigned to receive electrical shock while performing a working memory assessment or to a control condition (no shock) while performing the same assessment. Increasing state anxiety via threatening shock during the task has been found to reduce working memory capacity in non-clinical populations (Pyke & Agnew, 1963; as cited by Moran 2016). Additionally, studies examining 'ego-threat' have similarly manipulated participant anxiety. These studies have found diminished performance on tasks requiring working memory (e.g., digit span) after random assignment to receive negative feedback or no feedback regarding previous task performance (Hodges & Speilberger 1969; Moldawsky & Moldawsky 1952; Moran,

2016). Taken together, it is possible that baseline state anxiety did not impact working memory performance in the current study because anxiety was generally low in this non-clinical sample at baseline, and it was not experimentally manipulated prior to the working memory assessments.

However, in line with previous studies, a negative relationship was observed between working memory task performance and state anxiety directly *after* the working memory tasks were completed. In general, as span task performance decreased, state anxiety subsequently increased. As discussed above, state anxiety itself was also generally found to increase after the span tasks, compared to baseline. Although not a hypothesis proposed directly in this study, a post-hoc analysis revealed that while anxiety increased generally over this time period, the increase in state anxiety was significantly stronger for participants scoring lower on the working memory tasks [i.e., reading span, $F(1, 129) = 2.99$, $p = .09$; worry span, $F(1, 129) = 11.80$, $p > .001$]. To interpret this finding, one might consider the STAI-S as a measure of both general arousal (e.g., "I feel tense") and anxiety (e.g., "I feel nervous"). One possible interpretation of this pattern is that the working memory tasks used in the present study increased arousal generally, and that this increase in arousal was interpreted more negatively (e.g., as anxiety) for individuals who performed more poorly in the working memory tasks.

This hypothesis is consistent with a previous study investigating the interaction of physiological arousal, working memory, math anxiety, and performance on a novel math task (Mattarella-Micke, Zokak, Foster & Beilock, 2011). In this study, cortisol was found to increase generally after completing the difficult math task. Interestingly, in high spans, increases in cortisol were found to have a detrimental effect on math performance,

but only for those high spans who reported higher math anxiety. Increases in cortisol were found to have a facilitative effect on performance for high spans lower in math anxiety. The authors argued that it is not physiological arousal, per se, but rather how arousal is *interpreted* that impacts performance on cognitively demanding tasks. In the current study, an increase in state anxiety was found between baseline and working memory task completion, consistent with this previous study. It may be that individuals who performed more poorly on the working memory tasks interpreted the resulting physiological arousal they experienced during the task more negatively (e.g., as anxiety) due to poor task performance, resulting in significantly higher STAI-S scores. Moreover, increased anxiety during the task may have also exacerbated poorer performance during the working memory tasks. Unfortunately, given the corollary nature of this study's design, parsing directionality in this pattern is beyond the scope of the current investigation.

These patterns suggest that both the reading span and worry span were similarly correlated with an increase in post-task anxiety, and that poorer working memory performance also predicted a greater increase in anxiety following the task. Furthermore, given that baseline anxiety was not related to working memory task performance, these findings suggest that anxiety may need to be "online" in order to exert its deleterious effects on working memory in non-anxious participants.

Worry was the central construct under investigation in this study. However, our results did not reveal a relationship between the dispositional tendency to worry across contexts (trait worry, i.e., *Penn State Worry Questionnaire*, PSWQ, scores) and working memory performance. Although problematic worry is experienced in the general

population, it may be that the relationship between trait worry and working memory was not strong enough to be observed in this non-clinical sample. Indeed, PSWQ scores in this sample (M = 49.62, SD= 13.47) were also comparable to other non-anxious samples (M= 44.9, SD = 10.98; Meyer, Miller, Metzger & Borkovec, 1990) and considerably lower than PSWQ scores observed in individuals with GAD (M = 68.11, SD = 7.33; Fresco, Mennin, Heimberg, & Turk, 2003). It may be that worry, like anxiety, must be activated in order to exert its proposed deleterious effects on working memory in non-clinical samples.

Several studies have found a negative impact of worry on working memory in high worriers and individuals with GAD (e.g., Hayes, Hirsch, & Mathews, 2008). However, previous studies investigating the impact of trait worry (i.e., PSWQ scores) on working memory in non-anxious samples have found mixed results. In one study, trait worry (measured by the *Worry Domains Questionnaire*; Tallis, Davey, & Capuzzo, 1994) was found to uniquely account for variance in a simultaneous dual span task and a reversed spatial span task (controlling for state anxiety) in non-anxious individuals, such that higher trait worry yielded lower task performance. However, in this same study, trait worry was not found to predict performance on other working memory tasks, such as digit span forward, reversed digit span, spatial span, or the visual patterns test (Crowe, Matthews, & Walkenhorst, 2007). The authors concluded that trait worry only predicted performance on tasks specifically tapping central executive functioning. However, an alternative explanation may have been that worry was not activated (or was variably activated) during task performance in these healthy participants. Along these lines, other studies in non-clinical participants have found that active engagement in worry interferes

with working memory. For instance, in one study, PSWQ scores were found to correlate with working memory abilities in non-clinical participants only during concurrent attempts to control worry but not during concurrent attempts to control neutral thoughts (Hallion, Ruscio, & Jha, 2014). Similarly, in a seminal study investigating the impact of worry on working memory, engaging in tasks utilizing the central executive (e.g., random digit generation and random key press) was found to inhibit worry itself (in both high worriers and low worriers; Rapee, 1993).

In the current study, trait worry was not found to predict poorer working memory performance in the reading span nor the worry span tasks. Although interpreted cautiously, findings from other studies support the hypothesis that this may have been due to a weak relationship between trait worry and working memory in this non-clinical sample.

Hypothesis 3: Worry span scores were hypothesized to be lower than reading span scores and this difference was expected to further increase for participants reporting higher state anxiety and trait worry. Anxiety has been found to differentially impact working memory abilities when tasks contain threatening materials compared to neutral materials (Amir & Bomyea, 2011; Schweizer & Dalgleish, 2011). Therefore, reading span scores were expected to be higher than worry span scores. Further, the difference in span scores was expected to be greater for individuals higher in state anxiety and trait worry, such that those reporting higher state anxiety and trait worry would demonstrate even poorer performance on the worry span task compared to the reading span task.

As discussed above, we unexpectedly found that reading span scores were lower than worry span scores. With regard to the degree to which the difference between span scores changed as a function of participant anxiety, the linear regression analysis generally supported our hypothesis. While worry span scores were unexpectedly higher than reading span scores, this difference was significantly reduced for participants reporting higher state anxiety after a period of induced worry. A post hoc investigation of mean differences suggested that this interaction was likely driven by generally high worry span scores compared to reading span scores, with those participants reporting higher state anxiety after a 5-minute period of intentional worry also demonstrating (marginally) higher scores on the reading span task [$F(1,129) = 3.04$, $p = .08$][1]. See Figure 10.

One alternative interpretation, however, is in line with our predictions, as well as the Yerkes-Dodson principle. According to the Yerkes-Dodson principle, moderate levels of anxiety have a facilitative effect on cognitively demanding task performance, whereas increasing anxiety past this optimal point reduces task performance (Diamond, Campbell, Park, Halonen & Zoladz, 2007; Yerkes & Dodson, 1908). Therefore, a general susceptibility to state anxiety (as measured after the anxiety-inducing worry induction task) may have facilitated performance on the reading span task. Yet, introducing threatening materials into the worry span task may have resulted in an *additional* increase in anxiety in these already anxiety-susceptible individuals. This additional increase in anxiety past the optimum point may have resulted in less facilitation on worry span performance. One implication of this interpretation is that the inclusion of worry-like materials in the worry span task may have differentially impacted working memory

abilities in our non-clinical participants who were more susceptible to anxiety following a period of induced worry. This explanation is consistent with previous studies demonstrating that the inclusion of threatening materials has been shown to reduce performance on similar cognitive tasks in anxious individuals (e.g., Amir & Bomyea, 2011; Schweizer & Dalgleish, 2011). Taken together, a facilitative effect of mildly elevated anxiety on working memory performance may have been reduced by the inclusion of threatening materials.

However, this interpretation is presented cautiously for two reasons. First, this interpretation assumes that the inclusion of threatening materials in the worry span task would have provoked anxiety, and thus yielded higher state anxiety following the worry span task compared to state anxiety following the reading span task. No evidence was found to suggest this was the case. In fact, our results indicated marginally higher state anxiety after completing the reading span compared to the worry span. Unfortunately, there is a potential confound in that poorer performance was correlated with higher post-task state anxiety, and that the dual span tasks may have differed in difficulty. Second (and relatedly), we found that worry span scores were generally higher than reading span scores, so a ceiling effect may account for observed differences on post-worry induction state anxiety on reading span scores versus worry span scores. Taken together, the ambiguity of these findings underscore the aforementioned argument that future investigations must equate the worry span task and the reading span task in all aspects with the exception of the inclusion of threatening, worry-like materials.

In summary, the finding that worry span performance was significantly reduced compared to reading span performance for participants reporting higher anxiety following

a period of worry is potentially informative. Compared to the reading span task, the worry span task may demonstrate incremental sensitivity to the impact of anxiety after a period of worry on working memory.

Worry span concurrent and divergent validity

Hypothesis 4: Worry span and reading span expected to correlate positively with Nelson Denny – Reading Comprehension. Working memory is the ability to maintain and process information (e.g., Baddeley & Hitch, 1974) and is typically measured with dual span tasks that contain memorandum interleaved with a processing task (e.g., math problem, evaluating sentences; Daneman & Carpenter, 1980; Dunning & Holmes, 2014; Turley-Ames & Whitfield, 2003; Turner & Engle, 1989). Previous work has demonstrated that dual span tasks, such as these, demonstrate superiority over simple span tasks (e.g., digit span) at predicting higher cognitive functioning, such as mathematical problem-solving (e.g., Beilock & DeCaro, 2007), following directions (Engle, Carullo, & Collins, 1991), and reading comprehension (e.g., Daneman & Carpenter 1980). Critically, these findings suggest that dual span tasks measure a domain general executive process critical for higher cognitive processing.

To provide further validation of the worry span as a measure of working memory, the current study evaluated the extent to which performance on the worry span task predicted reading comprehension, one index of higher cognitive functioning. In the current study, both the reading span and the worry span strongly correlated with Nelson Denny Reading Test – Reading Comprehension with comparable magnitude. This finding provides further support for the worry span task as a working memory task that taps domain general processes.

Hypothesis 5: Correlations between working memory task performance (i.e., worry span and reading span) and Nelson Denny Reading Comprehension expected to be stronger than correlations between working memory tasks and Nelson Denny Vocabulary. To potentially assess divergent validity, it was expected that the correlations between working memory task performance and reading comprehension would be stronger than the correlations with a measure of domain specific knowledge (i.e., vocabulary knowledge; e.g., Nelson Denny Vocabulary). However, this pattern was not observed in the current study. Both the reading span scores and worry span scores were found to positively predict Nelson Denny Reading Test – Reading Comprehension scores and Vocabulary scores with comparable magnitude.

Importantly, no difference was observed in the correlations between reading span scores and reading comprehension scores [r = .41], and reading span scores and vocabulary scores [r = .41]. Moreover, strong correlations between reading comprehension scores and vocabulary scores [r = .65] suggest that both tests may tap similar processes. Therefore, this null finding may imply that the vocabulary test used in this study may not have been an appropriate test of divergent validity for the purposes of the current investigation.

An ideal test of divergent validity for evaluating the worry span as a measure of working memory abilities, specifically, would be a task shown to rely less heavily on working memory and more heavily on other cognitive processes (e.g., long-term memory). While originally selected due to its face validity as a measure of domain specific vocabulary knowledge, our results imply that the Nelson Denny Vocabulary test may have drawn more strongly on working memory processes than originally expected.

This may be due to its time restriction as part of the standardized administration of this test, as the working memory system holds and manipulates information for only a limited amount of time prior to decay. During the vocabulary test used in this study, participants were given 20 minutes to answer 80 multiple choice vocabulary questions and many participants ran out of time before completing the test. Removing the time-requirement of the Nelson Denny Vocabulary test may have reduced reliance on working memory during the test, and instead allowed participants sufficient time to search long-term memory stores. In general, no evidence for divergent validity was observed in this study, leaving a potential gap to be addressed in future investigations.

Hypothesis 6: State anxiety and trait worry expected to moderate the relationship between worry span performance and higher cognitive functioning (i.e., Nelson Denny – Reading Comprehension). The worry span task was expected to be a superior tool for assessing the impact of worry on working memory compared to a standard measure of working memory (e.g., reading span). Because previous research and theory suggest that anxiety and worry reduce working memory efficiency (Eysenck, Derakshan, Santos, & Calvo, 2007), it was expected that correlations between the worry span task and a measure of higher cognitive functioning would strengthen as individuals reported higher state anxiety and trait worry. Therefore, it was expected that the relationship between worry span and reading comprehension would be stronger as state anxiety and trait worry increased, and that this relationship would persist over and above reading span performance.

Our results did not confirm a moderating effect of state anxiety or trait worry on the relationship between working memory and reading comprehension. Moreover, the

results of our multiple regression analyses revealed that neither state anxiety (post worry induction and post working memory tasks) nor trait worry explained variance in Nelson Denny Reading Comprehension scores, controlling for performance on the reading span and worry span tasks. Furthermore, an investigation of zero-order bivariate correlations confirmed no significant association between Nelson Denny – Reading Comprehension scores and anxiety at any time point in the study (i.e., baseline, r = -.14, p = .11; post span tasks, r = -.05, p = .54; and post Nelson Denny Reading Test, r = -.06, p = .50). No significant relationship was revealed between Nelson Denny – Reading Comprehension scores and trait worry either (i.e., PSWQ, r = -.03, p = .73). Overall, anxiety and worry did not appear to be related to reading comprehension in our sample of non-clinical undergraduates.

Dual span tasks purportedly measure a domain general executive process critical for higher cognitive processing. According to the predictions of Attentional Control Theory (ACT), the domain general executive process assessed by dual span tasks should theoretically also be interrupted by worry, resulting in poorer performance on tasks that require higher cognitive processing (Eysenck, Derakshan, Santos, & Calvo, 2007). This prediction is consistent with observations from other studies in which individuals higher in anxiety have demonstrated impaired performance for mathematical problem-solving (Ashcraft & Krause, 2007) and reading comprehension (Calvo et al., 1992). Our results, however, did not reveal a relationship between anxiety or trait worry and reading comprehension. One interpretation of this finding is that the impact of anxiety on reading comprehension was not observed in our study due to sampling characteristics of our participants. Our participants were undergraduates, voluntarily engaged in higher

education, and presumably faced with similar multiple choice reading comprehension tests on a routine basis. As follows, it is likely that our participants were habituated to tests like the Nelson Denny. Consistent with this interpretation, we observed a significant *decrease* in anxiety following this multiple choice test.

Overall, our results supported no relationship between anxiety or worry and reading comprehension, and this is unexpected given previous research suggesting poor academic outcomes for individuals with anxiety (Ashcraft & Krause, 2007; Calvo et al., 1992; Moran, 2016). However, our study included non-clinical college students, potentially precluding any observation of the effect of state anxiety or trait worry on reading comprehension. Given that no effect of anxiety on reading comprehension was revealed in this study, it is not surprising that anxiety was not found to moderate the relationship between worry span and reading comprehension in our sample of non-anxious undergraduates.

Interestingly, simultaneous multiple regression analyses also revealed that reading span and worry span scores each predicted unique variance in Nelson Denny Reading Comprehension scores. Specifically, after controlling for both state anxiety and worry span, reading span scores were still found to positively correlate with Nelson Denny Reading Comprehension scores. Likewise, after controlling for state anxiety and reading span, worry span scores remained a positive predictor of Nelson Denny Reading Comprehension scores. This pattern suggests that the worry span and reading span tasks may tap unique working memory processes required for reading comprehension. For instance, given the differences between the two tasks, the reading span task may uniquely tap specific linguistic processes required for reading comprehension above those

processes tapped by worry span. Conversely, the worry span task may uniquely tap metacognitive processes used in timed multiple choice tests (e.g., awareness of one's pace; any mental calculus regarding time remaining and questions remaining; tracking one's place in a reading passage, etc.). Furthermore, given its use of threatening materials, the worry span may have tapped emotional inhibition processes required to shield an individual from distraction from his or her own internal processes for the sake of understanding the passages (i.e., the primary task). Although these are reasonable speculations, future studies are needed to parse out what components of worry span versus what components of reading span are uniquely associated with reading comprehension.

Worry span as a predictor of worry intrusions.

Hypothesis 7: Worry span and reading span expected to correlate negatively with post worry intrusions. Previous research has demonstrated a relationship between working memory and both the ability to inhibit proactive interference (Rosen & Engle, 1998) and inhibition of intrusive negative thoughts (Brewin & Smart, 2004; Wegner, Schneider, Carter, & White, 1987). Therefore, both worry span scores and reading span scores were expected to negatively correlate with the behavioral index of intrusive worry used in this study. In the current study, our results indicated that as working memory scores increased, participants reported *more* intrusive thoughts after a period of induced worry; however, this unanticipated trend did not reach statistical significance. Given its potential theoretical implications, however, this null result is discussed and interpreted below, albeit with caution.

On the surface, the finding that working memory was associated with an increase in intrusions appears to contrast with previous research. For instance, basic cognitive research has revealed that higher working memory is associated with both the ability to inhibit proactive interference and cognitive intrusions. In their seminal study, Rosen and Engle (1998) compared participants who scored in the lowest quartile on the operation span task (i.e., low spans) to participants who scored in the highest quartile on the task (i.e., high spans) on their ability to learn and recall lists of word pairs (i.e., paired-associates task). Specifically, participants were asked to memorize three lists of word pairs. In experiment 1, low spans required more learning trials to reach criterion for the second list compared to high spans, and these effects were significantly greater in the high interference condition (when the second list contained the same initial words from the pairs on the first list). Additionally, low spans produced significantly more between-list intrusions than high spans, suggesting that second list learning was impaired for them due to interference from the first list. These findings suggest that inhibiting proactive interference was enhanced in individuals with higher working memory capacity. Furthermore, in experiment 2, suppression was examined by measuring latency to recall first-trial word pairs from the first list when only accuracy, but not speed, was emphasized. Participants were instructed not to repeat responses. High spans in the high interference condition took significantly longer to recall words from the first list than high spans who learned the same list but had learned two previous independent lists of word pairs. In contrast, low spans in the high interference condition exhibited the opposite pattern; they were faster than low spans in the low interference condition. The patterns revealed across experiment 1 and 2 indicate that high spans, who were able to

learn second list words faster than low spans despite proactive interference from the first word list, were later significantly slower recalling words from the first list. This suggests that high spans may be both superior to low spans at inhibiting proactive interference and at strategically suppressing intrusive information. Overall, this early study suggested that working memory abilities may facilitate the inhibition of interfering information, resulting in sustained suppression of this information. Importantly, this study also revealed that high spans were sensitive to task directions in experiment 2, using more time to accurately respond to the task as needed when speed was not emphasized.

Later studies have similarly demonstrated that higher working memory is associated with the ability to volitionally suppress both unwanted neutral thoughts and unwanted personally relevant thoughts. For example, Brewin and Beaton (2002) found that operation span scores correlated strongly with participants' success at suppressing neutral thoughts about white bears (White Bear paradigm; Wegner, Schneider, Carter, & White, 1987). In a different study, a similar pattern was uncovered such that higher operation span task performance was found to predict volitional suppression of personally relevant intrusive thoughts, controlling for negative mood (Brewin & Smart, 2004).

Considering these findings, one interpretation of our unexpected results is that the Worry Induction Task may not have been an adequate indicator of inhibitory control over worry. While theoretically this task was intended to measure the ability to inhibit worry intrusions, it may have actually functioned more like a working memory dual task, requiring participants to complete two different cognitive operations simultaneously. Specifically, participants were instructed to both focus on their breathing and to count

intrusions when they occurred. They were not instructed to volitionally suppress worry-related thoughts. Consistent with Rosen and Engle's (1998) study reviewed above, individuals higher in working memory may have demonstrated superiority in attending to the task directions and carrying out both elements of the task, and they may have, thus, more accurately tallied their intrusions.

In summary, the finding that individuals higher in working memory abilities reported (marginally) more intrusions after a period of induced worry was opposite than was predicted. This finding calls into question what processes are specifically measured by the Worry Induction Task which may measure complex cognitive functioning that depends on working memory (e.g., following task directions; metacognitive and meta-emotional awareness). This will be discussed more below.

Hypothesis 8: State anxiety and trait worry expected to correlate positively with post worry intrusions. Previous research has demonstrated that individuals higher in anxiety and worry experience difficulty inhibiting cognitive intrusions (Becker, Rinck, Roth & Margraf, 1998). Therefore, state anxiety and worry were expected to positively correlate with the number of intrusions reported in the behavioral index of intrusive worry used in the present study. In general, state anxiety at baseline, state anxiety after completing the span tasks, and state anxiety after completing the Worry Induction Task, were all significantly and positively predictive of the number of intrusions reported by participants after the worry induction. In addition, trait worry was also positively predictive of post worry induction intrusions.

This pattern is largely consistent with previous research showing a positive relationship between anxiety, trait worry, and intrusions in clinical samples. As reviewed

above, individuals with GAD have been found to report more negative thought intrusions when asked to focus on their breath following a worry induction task compared to high worriers without GAD (Ruscio & Borkovec, 2004). Uncontrollable worry is a cardinal symptom in GAD (American Psychiatric Association, 2013); however, intrusive worry is also experienced in individuals with other anxiety and affective disorders, and in the general population (Ruscio, Borkovec, & Ruscio, 2001). Our findings suggest that even in non-clinical participants, higher state anxiety and trait worry are associated with more intrusive thoughts after a period of induced worry.

The finding that self-reported anxiety and trait worry were strongly and positively associated with the number of tallied intrusions after a period worry may simply reflect the fact that these tasks are essentially self-report measures of similar anxiety-related constructs. However, as discussed above, previous research using the 'think aloud' technique has demonstrated strong agreement between the number of self-tallied verbalized worry intrusions and the number of verbalized intrusions tallied by independent raters (Reinecke, Hoyer, Rink, & Becker, 2010), providing some converging support for participant accuracy in tallying instances of these cognitive phenomena.

Our findings suggest that the number of post-induction intrusions reported during Worry Induction Task was strongly related to state anxiety at several time points in this study, and related to self-reported worry. In consideration of the above finding suggesting that individuals higher in working memory abilities also reported more intrusions after a period of induced worry, these results imply that multiple processes may have resulted in increased intrusions in this task. In other words, anxiety and

working memory may each have independently contributed to the number of reported worries during this task. This interpretation is considered below.

Hypothesis 9: State anxiety and trait worry expected to moderate the relationship between worry span score and intrusions. Based on previous research and theory suggesting that anxiety and trait worry are negatively associated with working memory (Eysenck, Derakshan, Santos, & Calvo, 2007; Moran, 2016), worry span performance was originally hypothesized to correlate negatively with the number of post worry intrusions, and this effect was expected to be significantly stronger in individuals reporting higher state anxiety and trait worry. Furthermore, the worry span task was expected to be a superior tool for assessing the impact of worry on working memory abilities, compared to the reading span. Therefore, the interaction of anxiety/worry on worry span and intrusions was expected to remain after controlling for performance on the reading span task.

Overall, our results did not confirm a moderating effect of state anxiety (post worry induction) on the relationship between worry span performance and intrusions following the Worry Induction Task. Consistent with the aforementioned patterns observed in this study, the results of our multiple regression analyses revealed that after controlling for state anxiety and reading span score, worry span scores were positively predictive of post worry induction intrusions. Controlling for reading span and worry span performance, higher state anxiety (post worry induction) also remained a strong and positive predictor of intrusions. However, after controlling for anxiety and worry span score, no significant relationship was revealed between reading span scores and the number of reported intrusions.

State anxiety was not found to significantly strengthen or weaken the relationship between worry span scores and reported intrusions, controlling for reading span scores. Instead, our findings indicated that both worry span scores and state anxiety each *independently* predicted the number of intrusions reported by participants during the worry induction task, controlling for reading span scores and controlling for each other. This pattern suggests that worry span score and post worry state anxiety each accounted for unique variance in the number of reported intrusions. This begs the question: What processes are being measured by the thought monitoring component of the Worry Induction Task? More centrally to this investigation, why does worry span account for variance in the number of reported intrusions, above that accounted for by both state anxiety and reading span?

One hypothesis accounting for patterns observed throughout this study is that the worry span task may measure a particular facet of working memory that is not tapped by the reading span task. Specifically, the worry span task may measure a cognitive-emotional monitoring and gating function of working memory that is required for managing worry in the face of a second task. Support for this hypothesis is discussed below.

Worry span may measure the ability to monitor and gate emotional-cognitive interference (e.g., worry) that is a key component of the working memory system not measured by standard dual span tasks. One finding that supports this hypothesis is that individuals higher in working memory surprisingly reported more worries during the thought monitoring component of the Worry Induction Task (see discussion of *Hypothesis 7…*). As discussed above, the Worry Induction Task may have functioned

like a dual task. During this task, participants were asked to complete two cognitive operations (i.e., focus on their breath and tally negative thoughts that occur). This description of the Worry Induction Task is consistent with previous research, suggesting that individuals higher in working memory are superior at managing multiple components of tasks, shielding and expanding attentional scope strategically, and are generally more sensitive to task directions than individuals lower in working memory (Conway, Cowan, & Buntin, 2001; Engle, Carullo, & Collins, 1991; Rosen & Engle, 1998).

Therefore, the number of reported intrusions may have been partially determined by the ability to manage both components of the Worry Induction Task—i.e., working memory. Specifically, individuals higher in working memory may have been better able to observe internally generated emotional information (e.g., worry intrusions) and to dismiss this information as directed in order to return attention to the primary task (i.e., focus on their breath). Indeed, this task did not measure the duration of protracted worry episodes (i.e., pathological worry), but simply the number of intrusions observed. Individuals high in working memory abilities may have been better able to both "observe" their intrusions and better at shifting their attention back to the primary task (e.g., focusing on their breath), as directed. This particular emotional monitoring and gating function of working memory may have been more aptly measured by the worry span task compared to the reading span task. Indeed, while zero-order correlations revealed that those with both higher reading span and worry span scores reported (marginally) more negative thoughts after the worry induction, only worry span was

predictive of the number of intrusions after controlling for reading span in the multiple regression analysis.

The hypothesis that the worry span may measure an emotional-cognitive gating function of working memory is consistent with other patterns revealed across this investigation, as well. As reviewed earlier, worry span and reading span were highly correlated, providing initial support for worry span as a measure of working memory. Like reading span, worry span was also predictive of reading comprehension, lending further support for worry span as a measure of working memory that predicts higher cognitive functioning. However, multiple regression analyses revealed that reading span and worry span each predicted unique variance in reading comprehension, suggesting that these working memory tasks may have accounted for different working memory processes required to understand literary passages. Given task differences between the reading span and worry span, it was suggested that the worry span may have accounted for metacognitive (and/or meta-emotional) processes needed for reading comprehension (see discussion of *Hypothesis 6…*). Taken together, these results suggest that worry span is a measure of working memory, and that it predicts unique variance in reading comprehension, controlling for working memory processes measured by the reading span task. This pattern supports the proposal that the worry span may account for an emotional-cognitive gating function of working memory.

The hypothesis that worry span may measure an emotional monitoring and gating function of working memory is also consistent with our pattern of findings regarding anxiety (see discussion of *Hypothesis 2…*). We found that anxiety increased after the worry span and reading span tasks, relative to baseline. Above this, a post-hoc analysis

revealed that individuals who performed more poorly on these tasks showed a more dramatic increase in subsequent anxiety. If working memory includes monitoring and gating emotional information, then taxing this function during span task may be predicted to increase arousal in general, as was observed for all participants. Furthermore, if taxing working memory increases arousal and additional attentional effort is required to shift attention back to the operations needed to perform the span tasks (e.g., away from worry), then task performance may suffer due to exhausting limited executive resources (consistent with predictions of ACT; Eysenck, Derakshan, Santos, & Calvo, 2007). Thus, poor resulting performance on the span tasks may account for the further increase in anxiety observed for participants who performed particularly more poorly on these tasks.

Moreover, higher state anxiety after the worry induction task was associated with a relative increase in reading span scores compared to worry span scores (see discussion of *Hypothesis 3*…). Although it is interpreted with caution, this finding is not inconsistent with the hypothesis that worry span may tap an emotional-cognitive monitoring and gating function of working memory above that measured by the reading span task. In summary, taxing an emotion monitoring and gating function of working memory may result in increased anxiety, accounting for increase in anxiety following the working memory tasks as well as the increase in anxiety following a period of worry. Consequently, these effects would theoretically be more sensitively detected by the worry span task compared to the reading span task—one potential interpretation of our observations.

Of note, no evidence for a moderating effect of trait worry on the relationship between worry span score and intrusions was revealed in the current investigation. Our

multiple regression analyses revealed that, after controlling for reading span and worry span, higher trait worry was significantly predictive of more intrusions post worry induction. Interestingly, after controlling for trait worry, no significant relationship was observed between worry span scores or reading span scores and post worry intrusions. See Table 6, Model 2.1. One possible interpretation of this finding is that because trait worry accounted for a smaller percentage of variance in intrusions than state anxiety (R^2 = .08 versus R^2 = .33), this might have slightly reduced the ratio of variance explained by worry span and reading span. Indeed, results from a post hoc analysis found that once state anxiety (post worry) was reintroduced to the model including trait worry, both reading span [F(1, 126) = 6.10, p < .05] and worry span [F(1, 126) = 5.01, p < .05] explained significant variance in intrusions once again.

Overall, our multiple regression analyses suggested that worry span and state anxiety each independently predicted variance in intrusions, above that explained by reading span. Centrally, this finding is considered in light of patterns of findings in the present investigation, leading to the proposition that worry span measures a facet of working memory responsible for the monitoring and gating of cognitive-emotional information. This proposed function may be critical for managing intrusive worry.

Hypothesis 10: Worry span was expected to mediate the relationship between state anxiety and intrusive worry. While self-reported state anxiety was expected to predict difficulty controlling worry (i.e., higher reported intrusions during the Worry Induction Task), this relationship was originally expected to depend, in part, on basic attention control abilities (i.e., working memory, measured by performance on the worry span task and reading span tasks). As discussed above, we found that worry span was

positively related to the number of reported intrusions. Our study revealed mixed findings regarding a potential mediation of working memory on the relationship between state anxiety (i.e., post worry span) and the number of reported intrusions. While the test of asymmetric distribution of products revealed evidence of mediation of the worry span on this relationship, the Sobel test (a more conservative estimate) did not. This mixed finding may be due to low sample size, as the Sobel test is a less powerful statistical test. Reading span performance was not found to mediate the relationship between state anxiety (i.e., post worry span) and the number of reported intrusions using either the asymmetric distribution of products test or the Sobel test.

Taken together, patterns revealed that worry span and state anxiety each predicted the number of intrusions reported by participants after a period of induced worry and provide preliminary support that working memory (as measured by the worry span task) may mediate the relationship between anxiety and intrusive worry. Furthermore, the findings are consistent with the proposal presented above: the worry span task may measure a facet of working memory responsible for monitoring and gating cognitive-emotional information.

Conclusions, Limitations, and Future Directions

This study reveals several patterns regarding basic relationships between anxiety, worry, and working memory. Furthermore, this study offers support for the worry span as a measure of worry-like processing and working memory. The study's limitations are summarized in the following section with specific suggestions for future investigations of the worry span. This section concludes with a general discussion of the study's broad findings, implications, and suggested directions for future research.

Limitations. It is conceded that there were limitations with regard to this preliminary study's design and execution. As detailed above, one important limitation of the current study was that the worry span and reading span processing requirements were not equated. In the current investigation, this decision was necessary 1) to maximize content validity of the worry span sentence stimuli, and 2) to establish preliminary data regarding psychometric properties of the worry span sentence stimuli. However, as discussed above, this design decision necessarily limits precise conclusions regarding direct comparisons that can be made between the reading span and worry span tasks. For instance, the finding that worry span scores were higher than reading span scores may be due to number of possible factors, such as scoring differences between the tasks, a possible (unanticipated) facilitation effect of threatening materials on performance in this non-clinical sample, and/or differences in task difficulty. A potential limitation of the preset study was that we did not assess the latter possibility by asking participants to rate which task was subjectively more difficult at the end of the study.

Taken together, with the previous arguments noted above, the next logical step for a future related study would be to modify the worry span processing requirement to match the reading span processing requirement. One method that could be employed in a follow up study would be to design the worry span task such that 50% of sentences would be made grammatically invalid (as is the case with the reading span). The worry span processing requirement would then be for participants to judge the validity of sentences while attempting to remember the same interleaved TBR word stimuli used in the current investigation. Such a modification would allow for a more direct comparison between the standard reading span task and a span task utilizing this study's worry-like stimuli.

An additional limitation of the present study's design was the decision to base exclusionary criteria on only the reading span practice test, coupled with the decision to counterbalance the reading span and worry span tasks. Based on previous research, a performance criterion was required for inclusion in the final analyses based on reading span practice scores to ensure basic motivation and understanding of the task (Turley-Ames & Whitfield, 2003). Participants were required to successfully recall TBR words in three out of the four final practice trials during which they also accurately indicated whether sentences were valid or not. This resulted in approximately 8% of the sample being eliminated. The novel worry span task, however, had no such accuracy criteria for the sentences and no analogous practice criterion. Due to counter-balancing the worry span and the reading span tasks, participants who completed the worry span task first may have benefited from practicing a dual span task prior to completion of the reading span task's practice test. This may have consequently increased their likelihood for inclusion in the final dataset. In consideration of this concern, analyses were conducted after creating a similar worry span practice criterion, which resulted in eliminating an additional 21 participants based on failure to recall TBR words in the final three out of four worry span practice trials. Of note, these analyses revealed a generally similar pattern of results presented above. Yet, this potential limitation of the current study's design is still noted.

The generalizability of our study's findings are also limited. For instance, a large number of participants were excluded from the study due to English not being their first language (13%). Although non-first language English speakers were excluded because of the linguistic nature of the tasks used in this study, our findings can consequently only be

generalized to English speaking individuals. Furthermore, most of our participants were Caucasian, female college students, further limiting our findings to this population.

Critically, our study assessed anxiety, worry, and working memory relationships in high functioning individuals (e.g., college students) whose self-reported baseline state anxiety (STAI-S) and trait worry (PSWQ) were below clinical cut-offs. Therefore, the study provides only a snapshot of anxiety, worry, and working memory relationships for non-clinical individuals.

Finally, the conclusions of this study are limited due to notable measurement concerns. While the study found support for the worry span as a measure of both worry-like processing and working memory, unexpected findings detailed above call into question whether this task measured the theorized negative impact of worry on working memory. For example, contrary to theory and expectations, we found higher worry span scores than reading span scores. Furthermore, we found (marginally) higher state anxiety reported after the reading span task compared to the worry span task. As discussed above, these findings may be due task differences that should be equated in a future study. On the other hand, these findings could be due to failure of the worry span to mimic worry-like processing and to consequently increase worry.

A limitation of the current investigation is that while state anxiety was measured following both the reading span and worry span tasks, no pure measurement of state worry was included. Consequently, we cannot verify that the worry span task successfully increased participants' experience of state worry. Although no established measurement of pure state worry currently exists, two items on the STAI-S do measure state worry (i.e., "I am currently worried about current misfortunes" and "I am worried.")

As discussed above, the STAI-S measures state arousal and anxiety. Again, state anxiety and worry are highly related constructs that are both associated with reduced working memory efficiency when experienced at high levels (Eysenck, Derakshan, Santos & Calvo, 2007; Hirsh & Mathews, 2011; Yerkes-Dodson, 1908), although through potentially different mechanisms (Moran, 2016). Thus, conclusions drawn from the STAI-S in this investigation may confound relationships between state anxiety and state worry on working memory. A future investigation using purer self-report measures of state anxiety and state worry may help to clarify whether the worry span increases state anxiety and state worry, respectively.

Relatedly, while forced-choice endorsements of the worry span task were correlated strongly with endorsements of the same sentences at the end of the study, worry that occurs in nature is ideographic and often protracted, as discussed above. While our study provides some support for worry span sentences capturing the worry construct, using worry-like sentences idiographic to the individual with protracted themes would theoretically increase construct validity of the worry span task.

A final limitation of the current study is that the index of intrusive negative thoughts used may have unintendedly measured multiple processes. Specifically, our results suggest that this index measured both the propensity to experience intrusive thoughts as well as some process related to working memory abilities (e.g., sensitivity to task directions; ability to shift attention between two tasks). While we have interpreted these findings to suggest that the task may index an emotional-cognitive gating function of working memory, this is speculative. In the original version of the worry induction task, participants are not required to both monitor their thoughts for intrusions and focus

attention on their breath. Rather, participants are instructed to focus on their breath during the entire post-worry period. A tone is then sounded at random time intervals cuing participants to complete a thought monitoring sheet that queries if they are focusing on negative thoughts or other thoughts at that point in time (Ruscio & Borkovec, 2004). Thus, the original version of this task may be a purer measure of intrusive worry as it does not require participants to monitor their own thought processes explicitly. It is recommended that future investigations utilize this thought sampling technique rather than the modified version of the task used in the current investigation to index intrusive worry.

Conclusions and Future Directions. Overall, our study suggests a qualified relationship between anxiety and working memory in non-clinical participants. State anxiety was found to increase after two cognitively demanding working memory tasks, to a comparable degree as the increase in anxiety observed after a period of intentional worry—an intentionally stress-inducing task. One limitation of this study is that a lack of experimental control to verify a causal relationship between tasks that tap working memory and subsequent anxiety, however. Randomly assigning participants to complete a working memory task or control task would strengthen this argument by verifying that other factors (e.g., time) were not responsible for increases in participant anxiety. We also found that baseline anxiety and trait worry were not predictive of performance on the working memory tasks, nor performance on a test of reading comprehension. As discussed above, this may be due to our use of non-clinical participants in this study. Yet, we observed that state anxiety increased *during* the working memory tasks in general, and that task performance appeared to diminish as a function of an increase in

anxiety. In line with previous research, anxiety may need to be measured 'online' in order to demonstrate deleterious effects on working memory in non-clinical participants. Therefore, testing these relationships in clinically anxious participants may yield stronger effects, representing an important next step for future research. However, our results do suggest that, even in non-clinical samples, anxiety appears to increase following working memory tasks in general, and increasing anxiety during these tasks also correlates with reduced working memory performance.

Importantly, this study provides preliminary support for the worry span as a measure of the impact of worry-like processing on working memory. The worry span correlated strongly with the reading span, and it predicted unique variance on a measure of higher cognitive functioning (e.g., reading comprehension). Additionally, both reading span and worry span (marginally) positively predicted the number of intrusions reported after a period of intentional worry. However, the worry span predicted the number of intrusions observed by participants after controlling for both anxiety and performance on an industry standard measure of working memory (e.g., reading span). Furthermore, state anxiety after a period of induced worry appeared to differently impact reading span scores compared to worry span scores (though future investigations must equate these two tasks in order to determine the reason for this effect). Together, these patterns support the worry span task as a general measure of working memory, and also one that may tap an individual's ability to monitor and gate emotional information (e.g., worry) for the sake of managing a primary task (e.g., reading comprehension or re-directing focus to one's breath). One general limitation of the present study is a failure to provide divergent validity with a task assessing other cognitive processes (e.g.,

crystalized intelligence or domain knowledge), leaving this as an avenue for future research. Furthermore, it is conceded that this is only the first investigation of a novel task. Assessing for these effects on a new sample is necessary for confirming the patterns observed in this study. Additionally, as discussed above, because this study utilized a non-clinical sample, we cannot generalize our findings to individuals with pathological worry (e.g., GAD). However, anxiety symptomology can be viewed on a continuum and that previous research has found moderate relationships between working memory and anxiety that increase in clinical samples (Moran, 20016). Therefore, we suggest that our findings would not qualitatively change in clinical participants but would rather strengthen.

Our findings also support the proposition that a critical facet of working memory includes the monitoring and gating of emotional information—a hypothesis closely aligned with previous research on attentional bias for threat in anxiety (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007; Hakamata et al., 2010), and models of attention control and worry (Eysenck, Derakshan, Santos, & Calvo, 2007; Hirsch & Mathews, 2013). As reviewed earlier, training attentional bias away from threat has shown ameliorative effects on anxiety symptoms, including reduced anxiety during later stressful situations (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007) and reduction in subsequent worry (Hayes, Hirsch, & Mathews, 2010). One purported mechanism for these effects may be an enhanced ability to inhibit the influence of threatening stimuli in the working memory system in order to efficiently respond to the primary task (i.e., respond quickly to probes). This is consistent with our proposition that a key facet of working memory, implicated in pathological anxiety, is the

monitoring and gating of cognitive-emotional information. This hypothesis also supports predictions from attention control theory (ACT; Eysenck, Derakshan, Santos, & Calvo, 2007), which posits that worry competes for attentional processing and requires executive control to manage. Taken a step further, this hypothesis is consistent with Hirsh and Mathews (2013) model of pathological worry, which states that pathological worry is maintained due to exhausted attentional control occurring with biased information processing and habitual patterns of thought favoring threat-representations in anxious individuals. Indeed, it is implied by these models that a key element of working memory is the monitoring and gating of emotional information. Our study also implies that this function of working memory may be observable in non-clinical participants.

The present study provides preliminary support for the worry span task as a measure of cognitive-emotional monitoring and gating in the working memory system. As such, the worry span may be a helpful tool for assessing the impact of pathological worry on working memory. Therefore, one important avenue for future research is to utilize this working memory assessment task in studies with clinically anxious participants—particularly those struggling with GAD. It would be expected that individuals with GAD would show reduced performance on the worry span task compared to other working memory tasks.

Furthermore, the worry span may be easily adapted into a training tool for improving the ability to manage emotional information in working memory. As reviewed above, there is precedence for modifying cognitive tasks originally used to assess cognitive phenomena associated with anxiety into efficacious interventions that yield symptom reduction. For example, the probe detection task was originally used to

assess attentional bias for threat associated with anxiety and was later modified so as to train attentional control via programming a contingency into the task whereby probes reliably followed only neutral (versus threatening) stimuli (for review see Hakamata et al., 2010). Similarly, the worry span was designed to lend itself to similar modification. For instance, performance on standard dual span tasks can be improved by training participants to utilize explicit strategies, such as verbal rehearsal for to-be-remembered words (Turley-Ames & Whitfield, 2003). Including a rehearsal strategy training in the worry span task may yield similar improvements on this task and may be one vehicle for enhancing executive control over worry. Indeed, using a verbal rehearsal strategy to manage the contents of working memory may be particularly apropos for inhibiting worry, given its verbal nature. In virtue of its design, the worry span task could easily lend itself to this simple training modification in a future study.

Difficulty controlling worry is a key symptom in anxiety disorders (American Psychiatric Association, 2013) as well as a problem for many individuals who do not meet full criteria for anxiety disorders (Ruscio, Borkovec, & Ruscio, 2001). Research implicates robust relationships between impaired attentional control and anxiety symptoms. However, relationships between anxiety and working memory are complex, potentially bi-directional, and still debated (Moran, 2016). Furthermore, there have been few tools available to directly study the impact of worry on working memory. Thus, the current investigation sought to develop and provide preliminary validation for a novel computerized span task, incorporating worry-like sentences interleaved with neutral to-be-remembered words.

Overall, our results support the worry span task as a measure of working memory, due to persistent correlations with the reading span task and with the criterion task assessing higher cognitive functioning. In addition, the worry span task remained a significant predictor of both reading comprehension and the number of tallied intrusions, after controlling for both state anxiety and reading span performance. Our preliminary findings support the worry span task as a measure of working memory that predicts unique variance in higher cognitive functioning (e.g., reading comprehension) and, possibly, the ability to monitor emotional information while engaged in a second task (e.g., focus on breathing). This pattern suggests that the worry span may be a superior measurement of the impact of worry and anxiety on working memory, compared to other standard measures of working memory. While future research is needed to continue developing this instrument, the worry span task shows potential as a useful tool for measuring the impact of worry on working memory, and one that may be later modified for use in clinical settings.

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Footnotes

[1] Alternative analyses were also conducted to investigate the moderation of state anxiety (post worry induction task) on worry span compared to reading span scores. A repeated measures ANOVA was conducted using a 2 task (worry span, reading span) X state anxiety (high, low) with repeated measures on the first factor. Anxiety groups were determined based on a median split of state anxiety post worry induction task. The ANOVA revealed a main effect of task [F (1,129) = 833.80, p < 0.001]. Reading span scores [M = 27.74, SD = 8.32] were found to be significantly lower than worry span scores [M = 45.65, SD = 7.77] on average across anxiety groups. The main effect of anxiety group was not significant [F (1,129) = 1.05, p = 0.31]. Similar to the regression in which difference scores were regressed on state anxiety, the ANOVA revealed a significant interaction of anxiety on task performance [F (1,129) = 3.95, p < 0.05]. Post hoc analyses revealed that participants reporting high and low state anxiety did not differ on worry span task performance [t (129) = 0.04, p = 0.97]. However, individuals in the high anxiety group scored marginally higher on the reading span task [M = 28.97, SD = 7.78]] than individuals in the low anxiety group [M = 26.45, SD = 8.63; t (129) = 1.744, p = 0.08]. As with this ANOVA, a similar pattern was also revealed when standard Z scores were created for worry span and reading span and their difference regressed on state anxiety. These findings parallel the presented results.

[2] Although not a hypothesis in this study, combined Nelson Denny-Reading Test total scores (i.e., 2 x Comprehension + Vocabulary) were also found to significantly and positively correlate with reading span scores [r = .46, p < 0.001] and worry span

scores [r =.41, p <0.001].

[3] Nelson Denny-Reading Test total scores were alternatively regressed on worry span scores, reading span scores, and state anxiety (post worry induction task). This analysis revealed that as worry span scores increased, Nelson Denny Total scores significantly decreased controlling for reading span and state anxiety [$F(1,127) = 5.10$, $p < 0.05$]. Similarly, as reading span scores increased, Nelson Denny Total scores significantly increased controlling for worry span and state anxiety [$F(1,127) = 10.61$, $p < 0.01$]. No relationship was revealed between state anxiety and Nelson Denny Total scores. These findings thus parallel the presented results.

Figure 1. Baddeley's (2000) Multicomponent Model of Working Memory

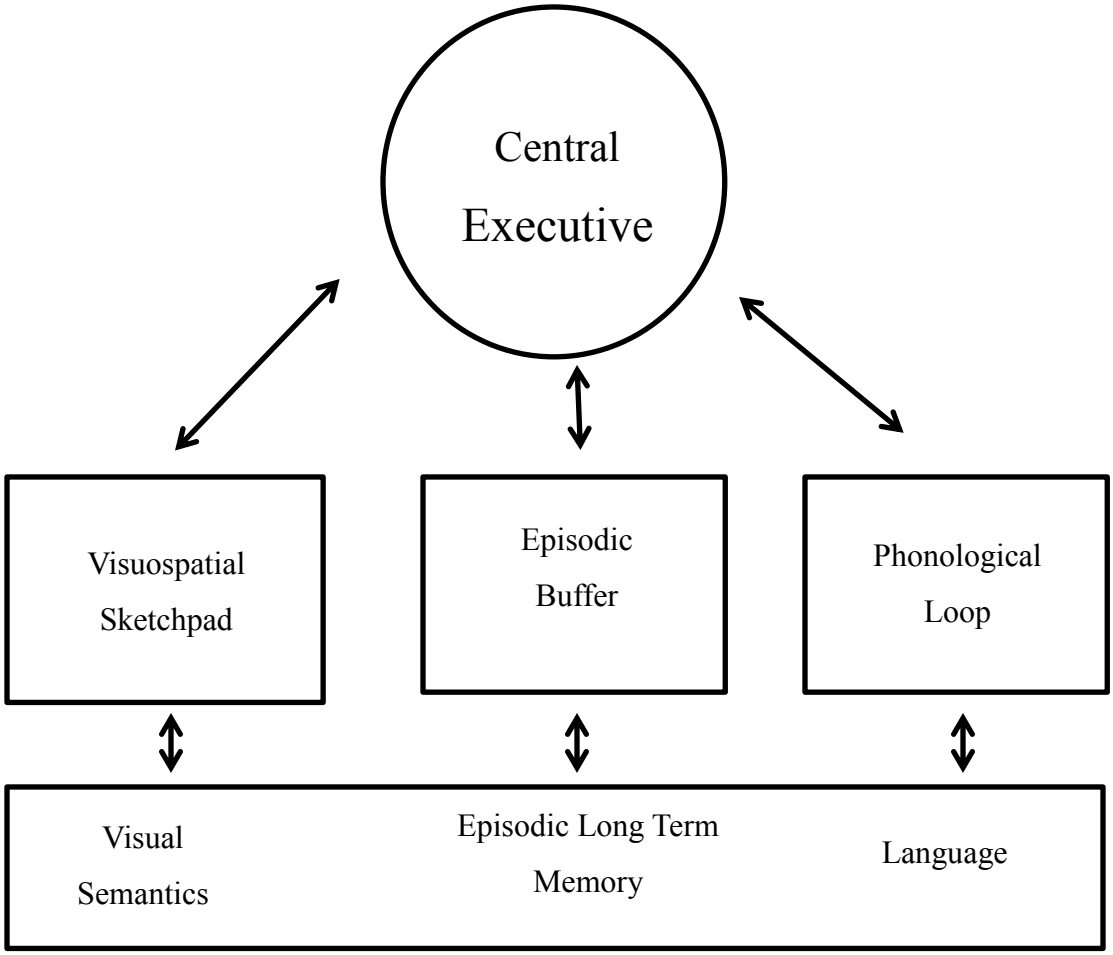

Figure 2. Hirsch and Mathews' (2013) Cognitive Model of Pathological Worry.

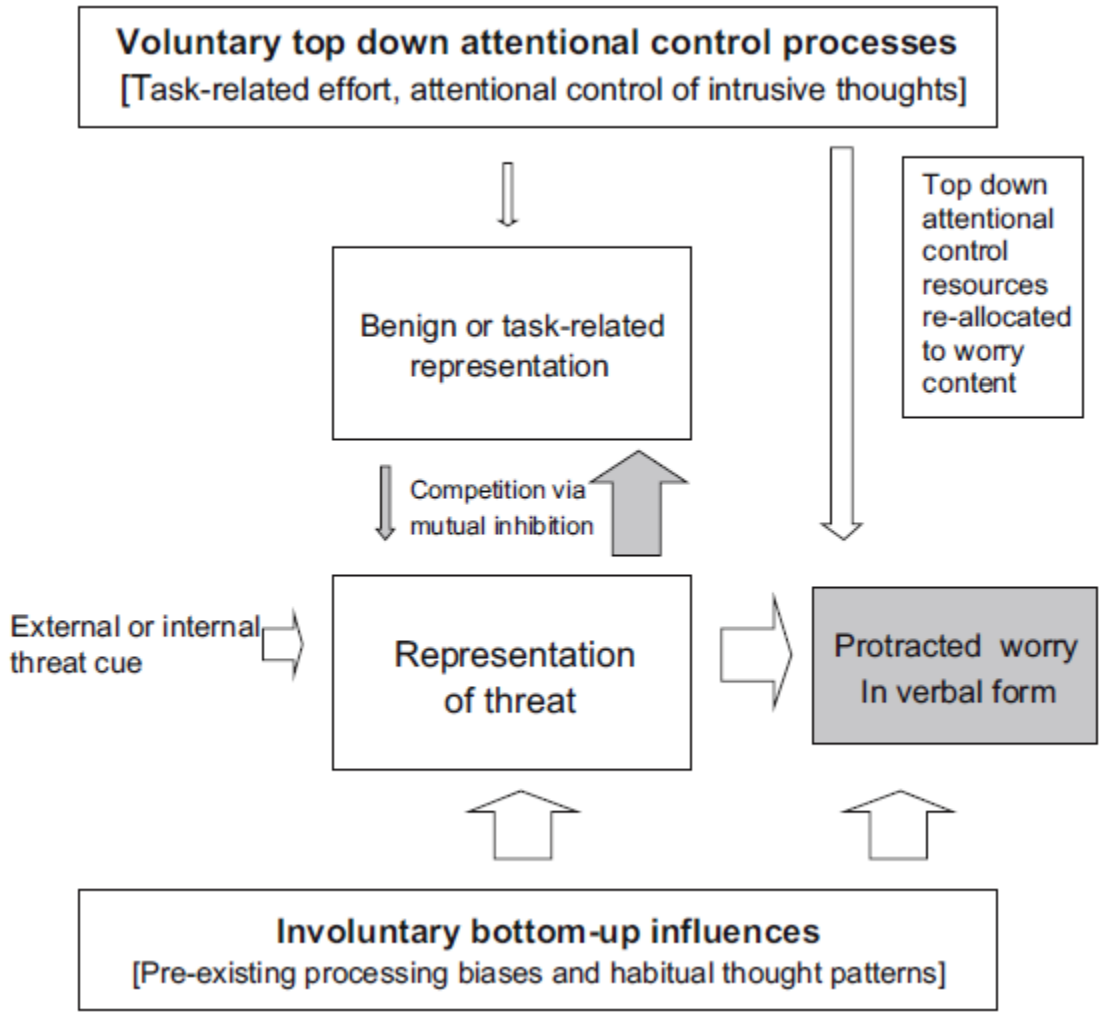

Figure 3. Procedural Flow Chart for the Current Investigation.

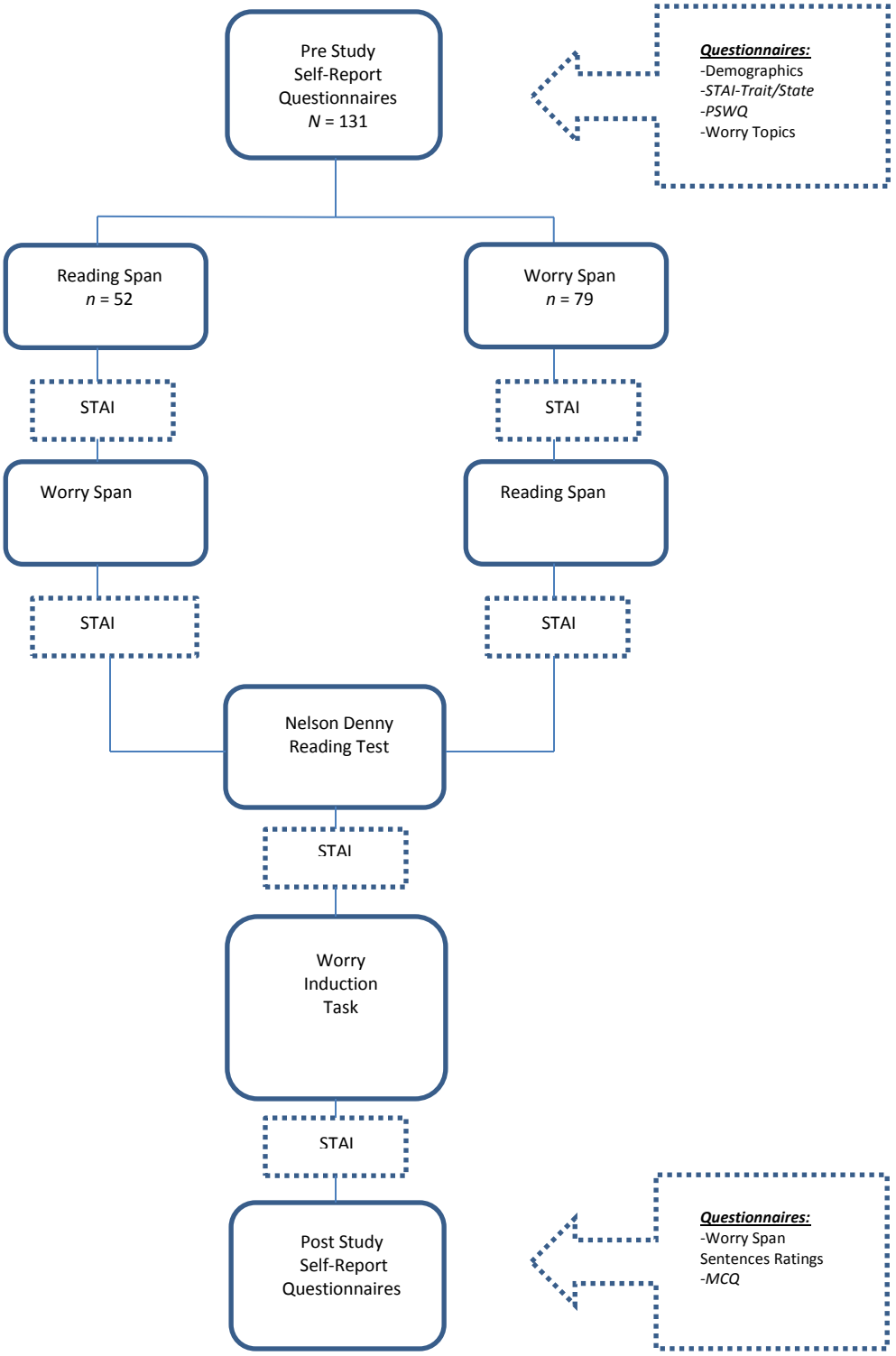

Figure 4. Mediational Model of Hypothesized Relationships between Anxiety, Worry Span Score, and Post Worry Intrusions.

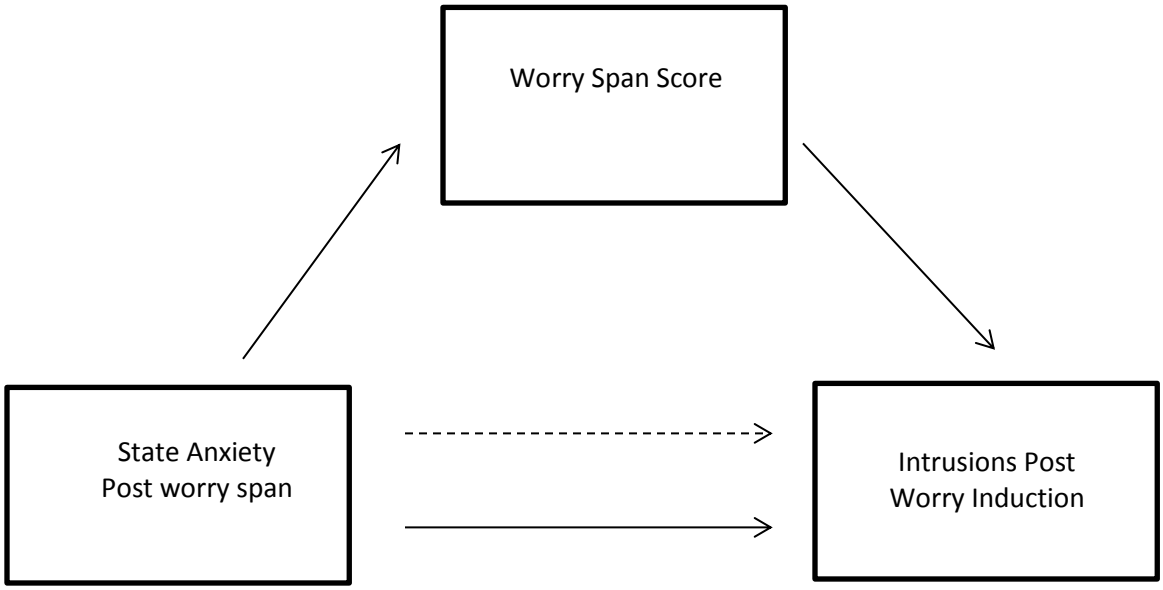

Figure 5. Mediational Model of Hypothesized Relationships between Anxiety, Reading Span Score, and Post Worry Intrusions.

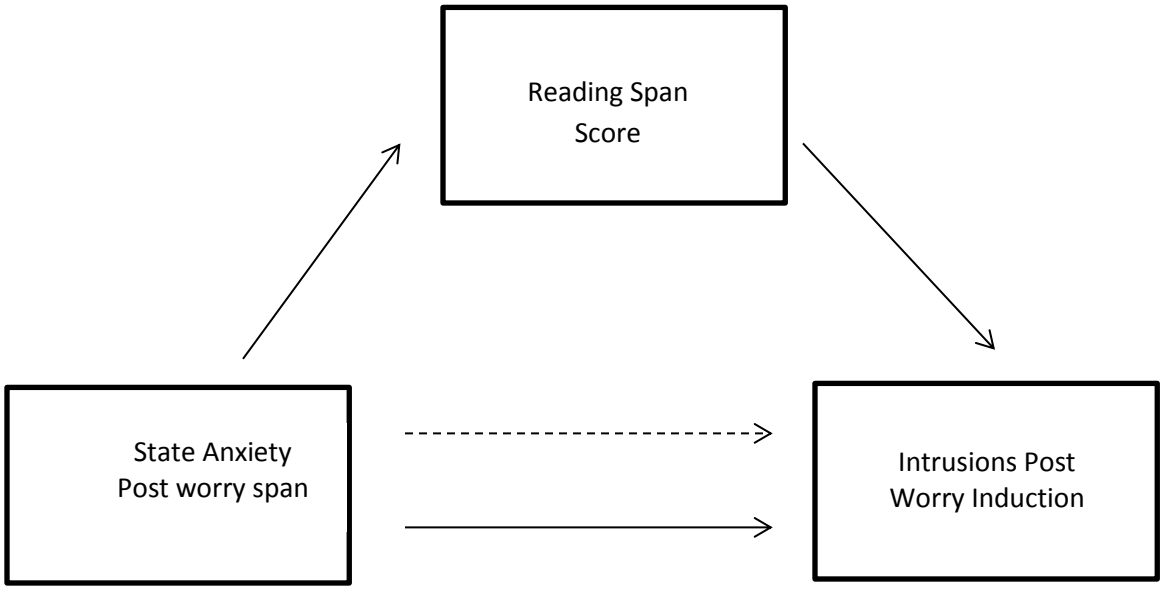

Figure 6. **State Anxiety (STAI-S) at each Time Point during the Procedure.**

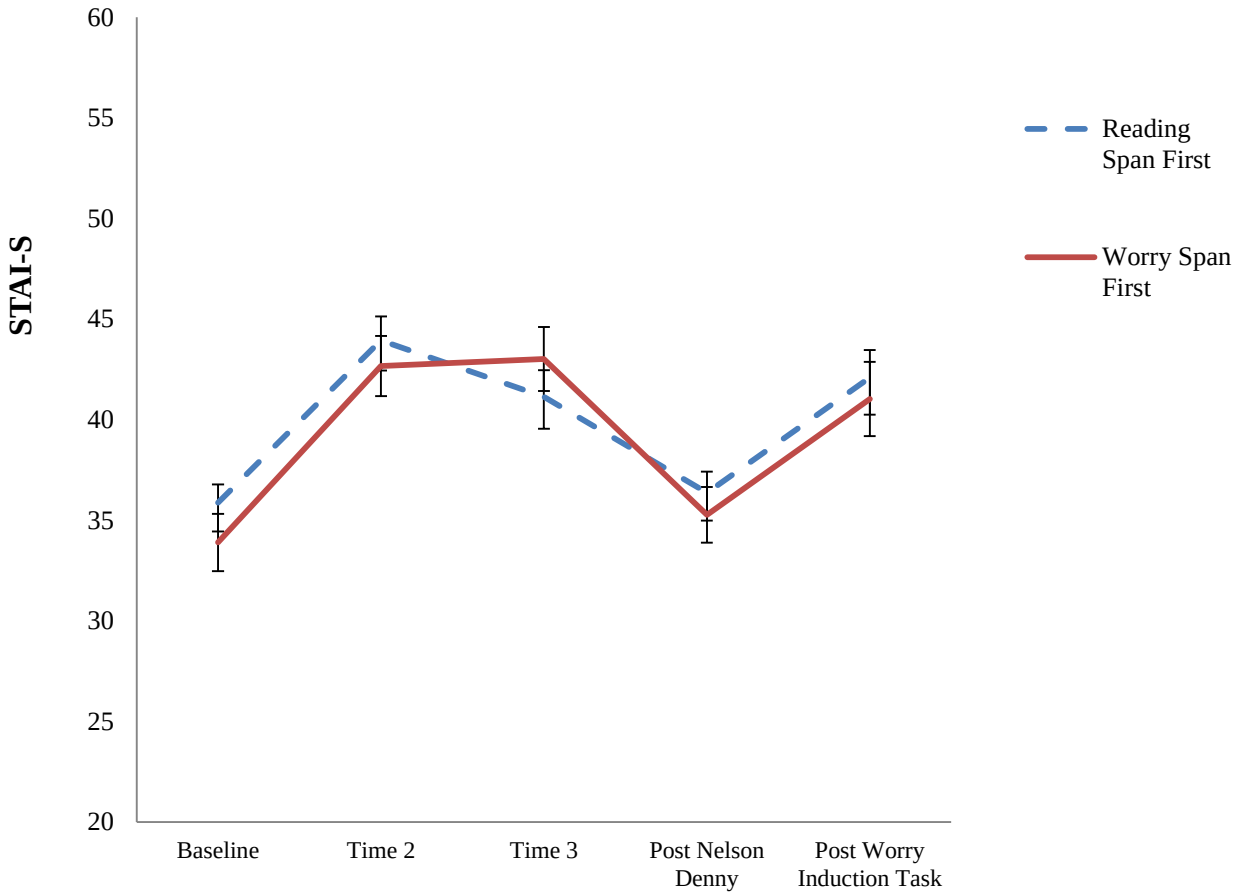

Figure 6. The *Speilberger State-Trait Anxiety Inventory – State Version (STAI-S)* was administered repeatedly during the study. Here, results are presented for groups that completed the reading span versus worry span task first. For example, Time 2 for Reading Span First group was *STAI-S* after the reading span and Time 3 was *STAI-S* after the worry span. Confidence bars represent standard error of the mean.

Figure 7. State Anxiety (STAI-S) following each Task in the Procedure.

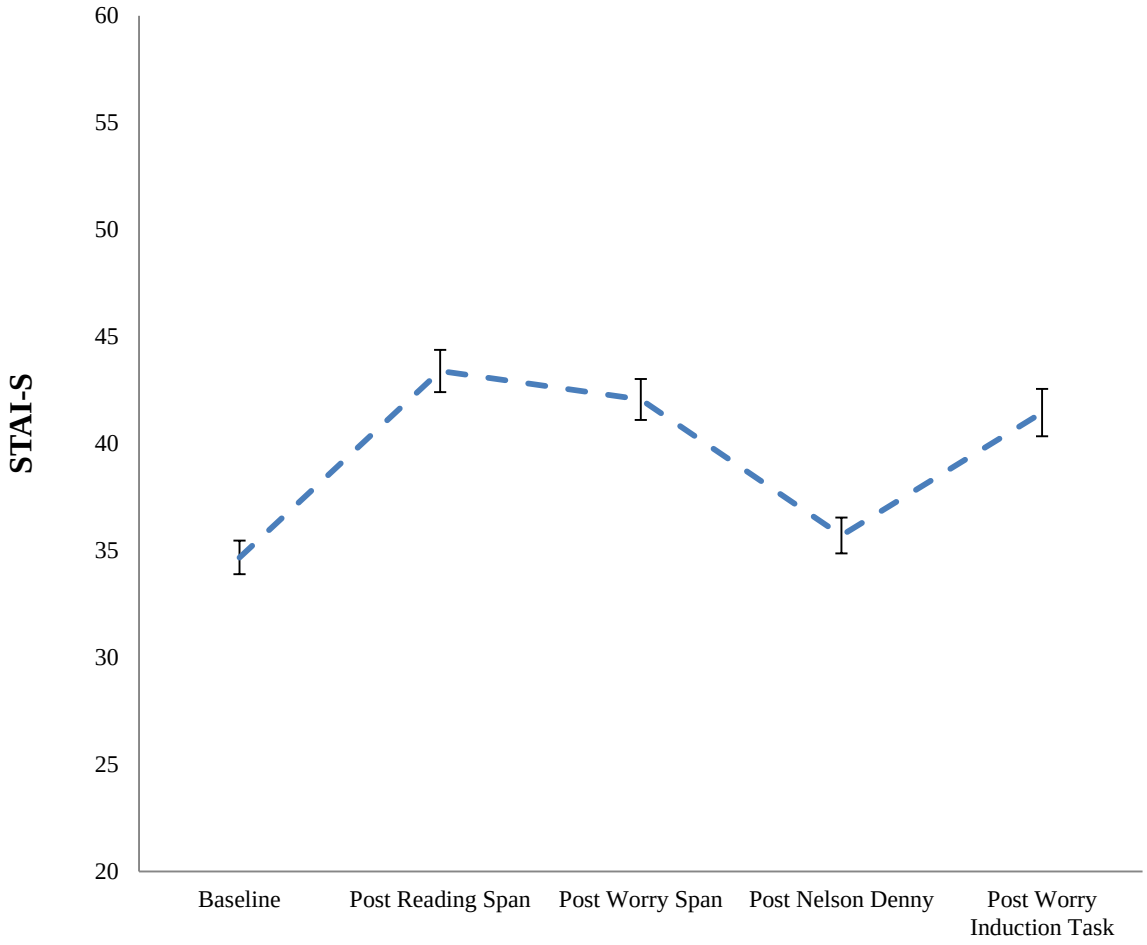

Figure 7. Speilberger State-Trait Anxiety Inventory – State Version (STAI-S) after each task in the study procedure. Reading span and worry span order was counterbalanced. Here, results are collapsed for groups completing the reading span and worry span task first. Confidence bars represent standard error of the mean.

Figure 8. Scatter Plot of Worry Span Scores and Reading Span Scores.

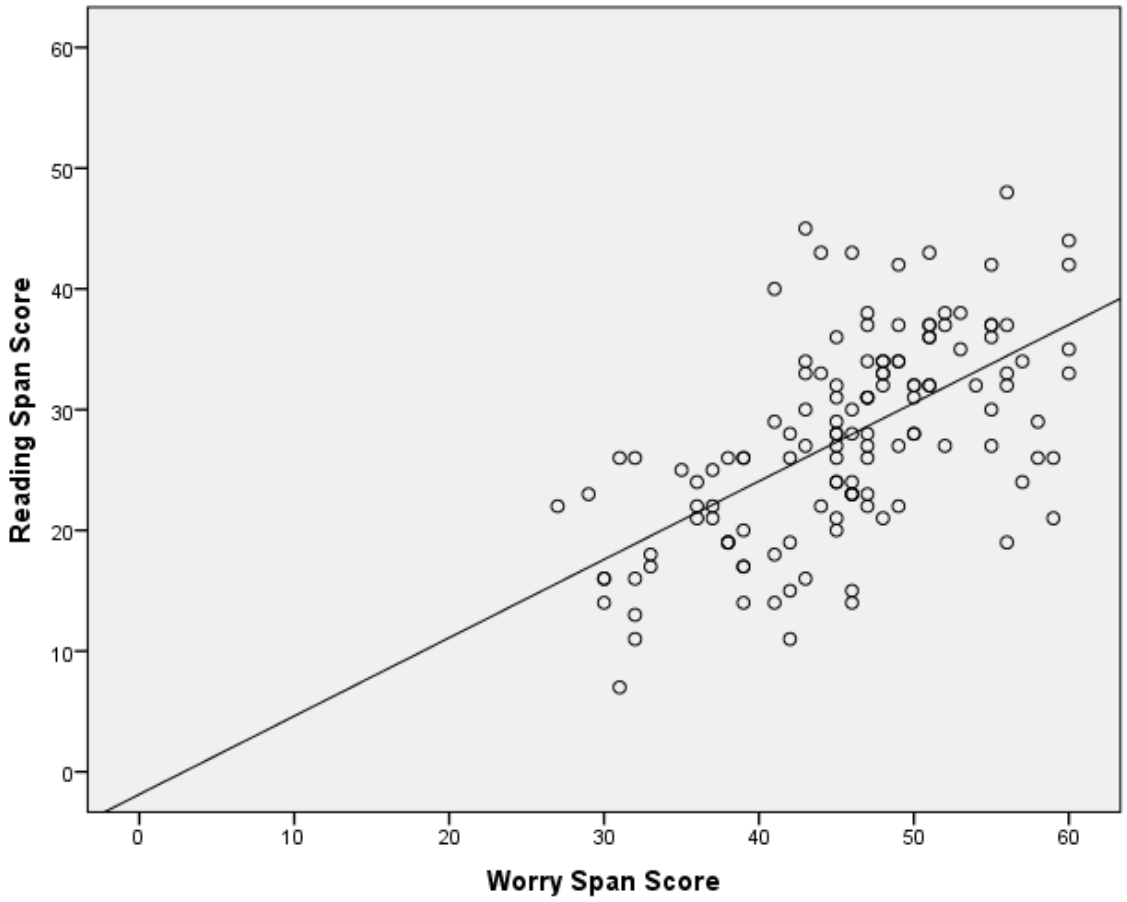

Figure 8. Scatter plot showing the correlation between reading span score and worry span score [$r = 0.60$, $p < 0.001$]. The line represents the bivariate correlation line of best fit.

Figure 9. Scatter Plot of Reading Span and Nelson Denny Reading Test – Reading Comprehension Scores.

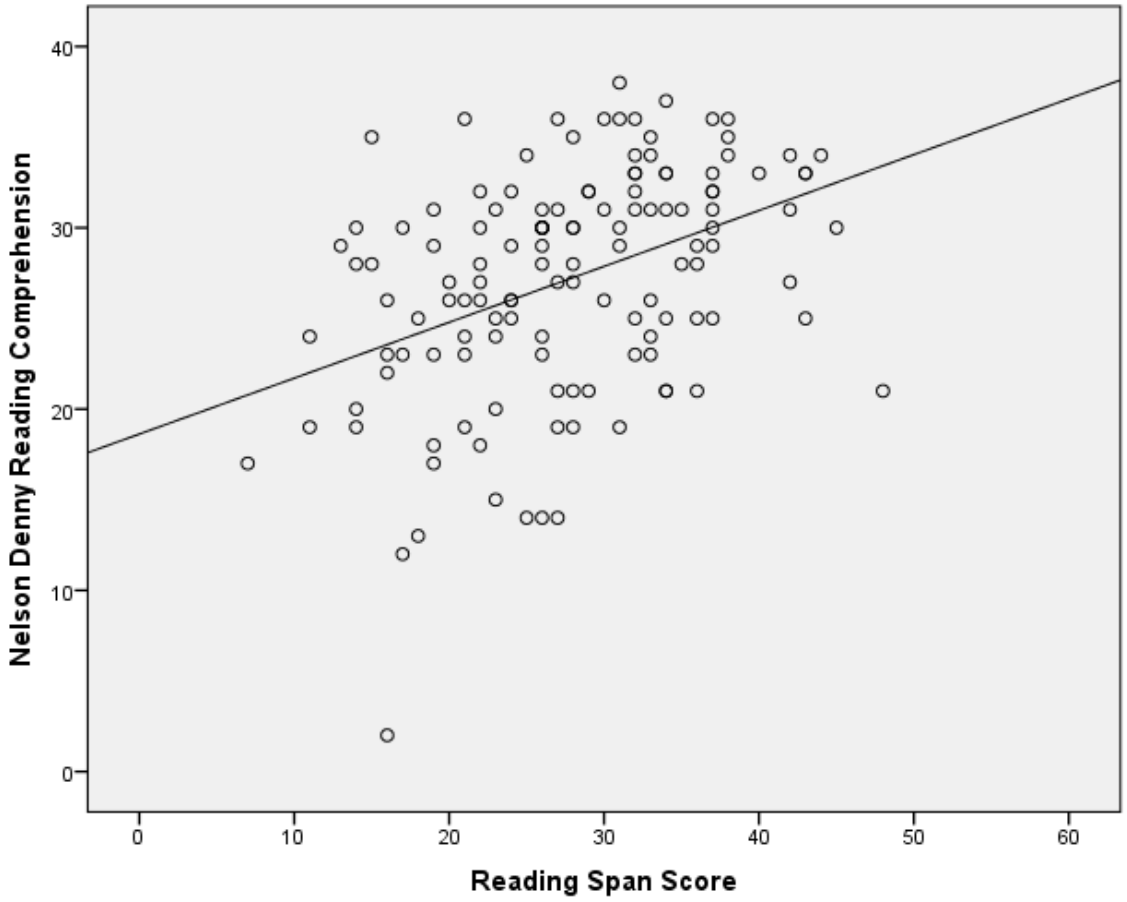

Figure 9. Scatter plot showing the correlation between reading span score Nelson Denny Reading Test – Reading Comprehension score [$r = 0.38$, $p < 0.001$]. The line represents the bivariate correlation line of best fit. A simultaneous multiple regression revealed that as reading span scores increased, reading comprehension scores increased [F (1, 126) = 8.32, p <0.01], controlling for worry span score, and Speilberger State Trait Anxiety – State Version (STAI-S, post span tasks).

Figure 10. Dual Span Task Scores by High and Low State Anxiety Groups.

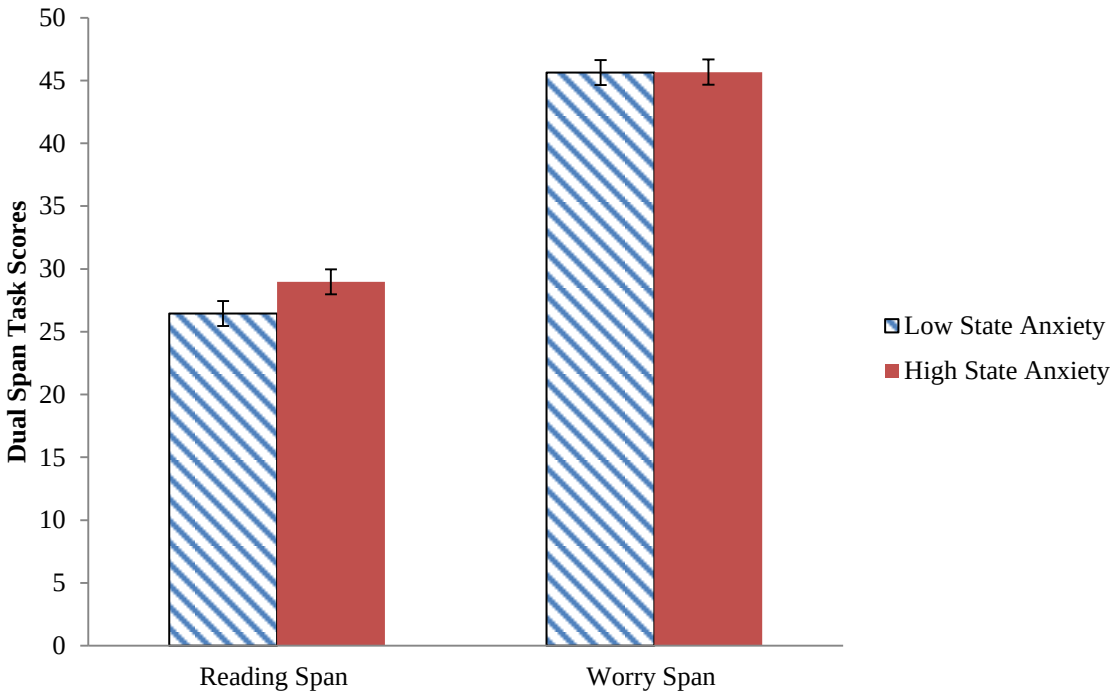

Figure 10. Reading span score and worry span presented by high and low state anxiety post worry task groups. State anxiety groups were defined as one standard deviation above (i.e., High State Anxiety) and one standard deviation below (i.e., Low State Anxiety) the mean of the Speilberger State Trait Anxiety – State Version (STAI-S) post Worry Induction Task. A linear regression analysis found that while participants generally tended to score higher on the worry span task than the reading span task, this was significantly less true for participants who reported higher state anxiety after a period of induced worry [$F(1, 130) = 6.04$, $p < 0.05$]. Confidence bars represent standard deviations.

Figure 11. Scatter Plot of Worry Span and Nelson Denny Reading Test – Reading Comprehension Scores.

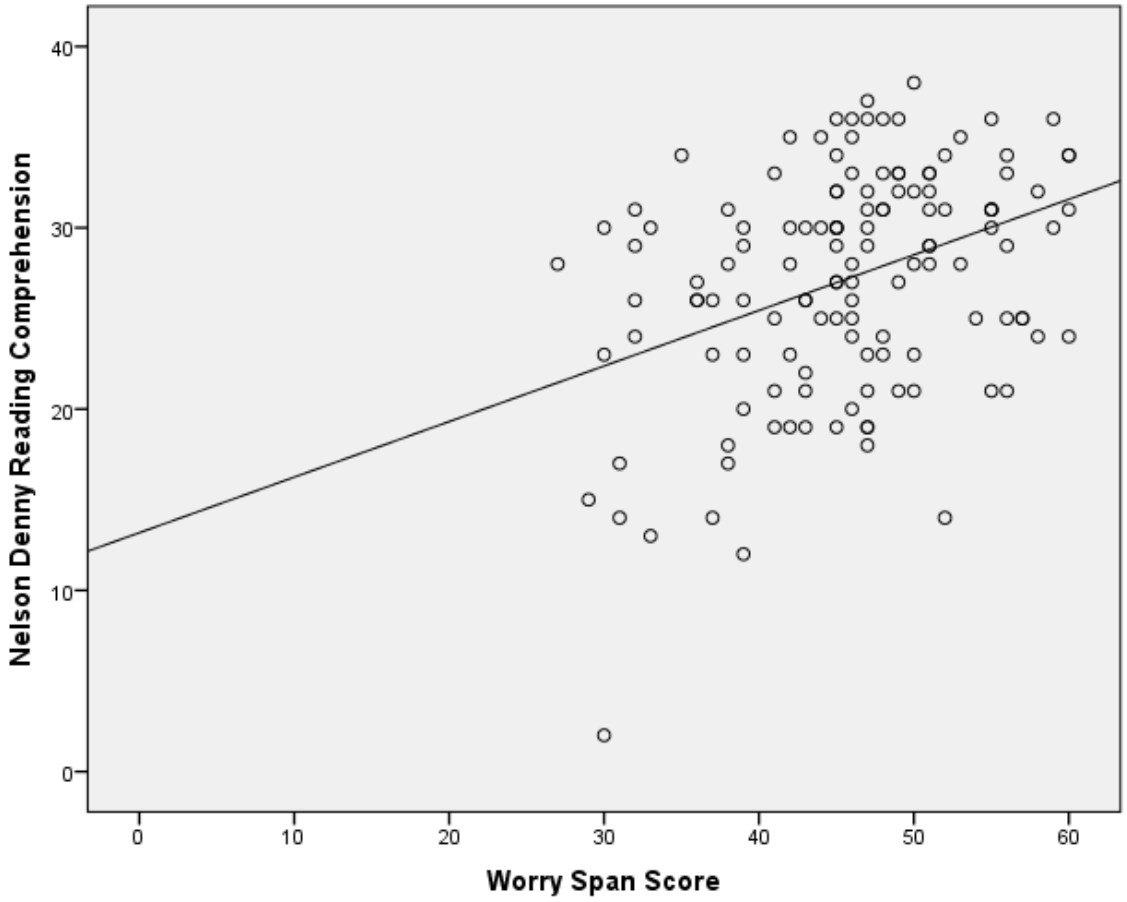

Figure 11. Scatter plot showing the correlation between worry span score Nelson Denny Reading Test – Reading Comprehension score [$r = 0.38$, $p < 0.001$]. The line represents the bivariate correlation line of best fit. A simultaneous multiple regression revealed that as worry span scores increased, reading comprehension scores increased [F (1, 126) = 4.48, p <0.05], controlling for reading span score, and Speilberger State Trait Anxiety – State Version (STAI-S, post span tasks).

Figure 12. Scatter Plot of Worry Span and Intrusions Post Worry (Log Transformed).

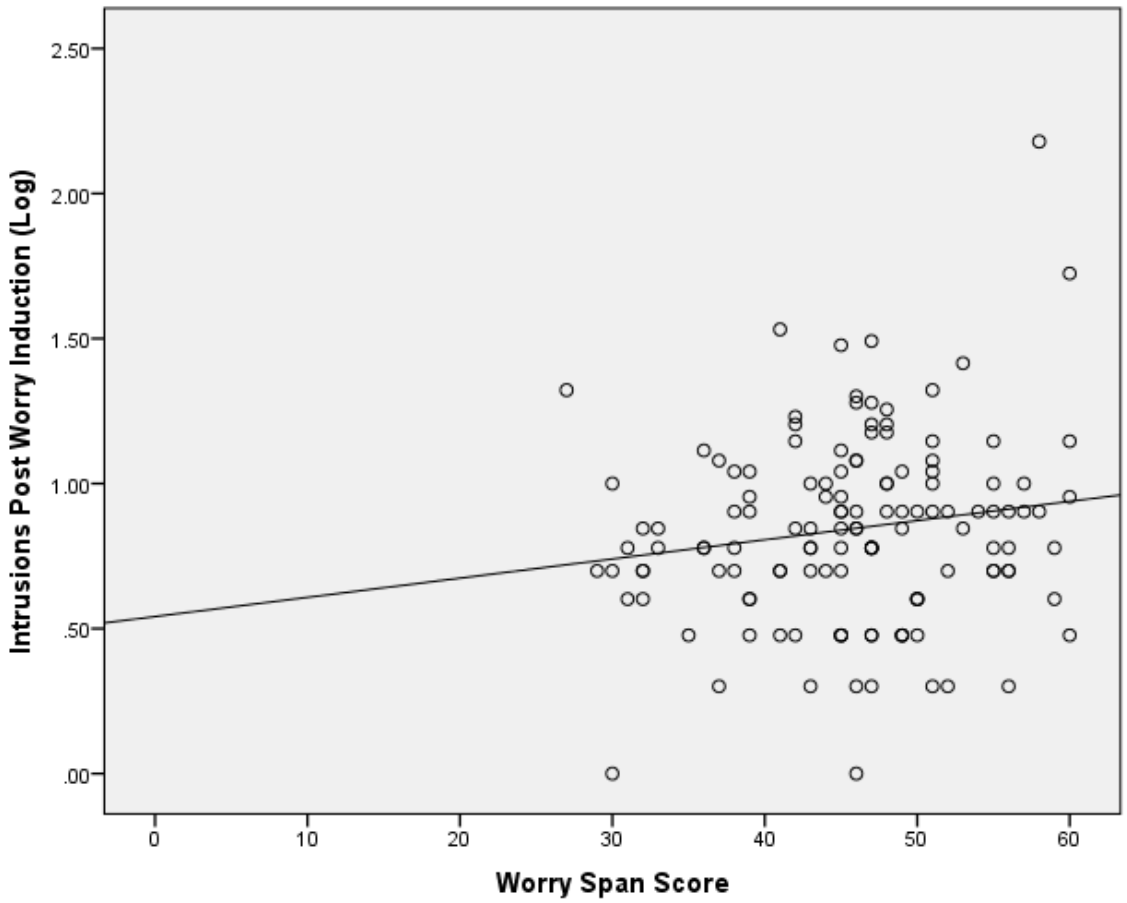

Figure 12. Scatter plot showing the correlation between worry span score and log transformed post worry intrusions [$r = 0.16$, $p = 0.07$]. The line represents the bivariate correlation line of best fit. A simultaneous multiple regression revealed that as worry span scores increased, intrusions significantly increased [F (1, 126) = 5.34, p <0.05], controlling for reading span score, and Speilberger State Trait Anxiety – State Version (STAI-S, post Worry Induction Task).

Table 1

Descriptive Statistics for Speilberger State Trait Anxiety Inventory – State Version by Time

	All Participants	Reading Span First *n* = 52	Worry Span First *n* = 79
State Anxiety			
Time 1	34.68 (9.01)	35.87 (10.23)	33.90 (8.09)
Time 2	43.18 (10.6)	43.94 (10.72)	42.67 (10.60)
Time 3	42.21 (11.65)	41.14 (11.49)	43.02 (11.76)
Time 4	35.71 (9.59)	36.37 (9.98)	35.27 (9.35)
Time 5	41.45 (12.66)	42.09 (13.28)	41.03 (12.30)

Note. Speilberger State Anxiety Inventory – State Version scores were compared at each time point or individuals who completed the reading span task first versus the worry span task first. No significant differences were revealed based on task order. Therefore, STAI scores were collapsed across order.

Table 2

Descriptive Statistics of Study Variables

	Mean	**SD**
Self-Report Questionnaires		
STAI - State		
Baseline	34.68	9.01
Post Reading Span	43.39	11.33
Post Worry Span	42.06	10.94
Post Nelson Denny	35.71	9.59
Post Worry Induction	41.45	12.66
Penn State Worry Questionnaire	49.62	13.48
Working Memory Assessments		
Reading Span Score	27.74	8.32
Worry Span Score	45.65	7.70
Criterion Tasks		
Nelson Denny Reading Test – Comprehension	27.18	6.28
Nelson Denny Reading Test – Vocabulary	59.91	10.77
Nelson Denny Composite Score	115.18	21.38
Post Worry Intrusions ^{log}	0.84	0.32

Note. STAI – State = Speilberger State Trait Anxiety Inventory – State Version; Post worry induction intrusions are presented in log transformed form.

Table 3

Correlation Matrix of Study Variables

	Worry Span	Reading Span	STAI (WS)	STAI (RS)	STAI (WIT)	PSWQ	ND Reading Comp	ND Vocab
Worry Span	-	-	-	-	-	-	-	-
Reading Span	.60**	-	-	-	-	-	-	-
STAI-S Post Worry Span	-.22*	-.12	-	-	-	-	-	-
STAI-S Post Reading Span	-.27**	-.19*	.75**	-	-	-	-	-
STAI-S Worry Induction Task	.02	.17	.56**	.43**	-	-	-	-
PSWQ	-.07	.001	.46**	.36**	.30**	-		
ND Reading Comprehension	.38**	.41**	-.05	-.05	-.16	-.03	-	-
ND Vocabulary	.35**	.37**	-.17	-.17*	.01	-.14	.63**	-
Intrusions Post Worry Induction ^{Log}	.16 $p = 0.07$	.15 $p = 0.09$	.31**	.28**	.58**	.29**	.26*	.19*

Note. Correlations are presented for the following variables: worry span score, reading span score, *STAI* (post worry span, post reading span, and post worry induction task), *PSWQ*, Nelson Denny Reading Comprehension score, Nelson Denny Vocabulary score, and number of intrusions post worry (log transformed.) *STAI -S= Speilberger State-Trait Anxiety Inventory – State Version; PSWQ = Penn State Worry Questionnaire;* ND = *Nelson Denny Reading Test. ** = p <0.01; * = p <0.05*

Table 4

Simultaneous Multiple Linear Regression Models of the Difference between Worry Span Score and Reading Span Score

DV = Worry Span Score – Reading Span Score	*B*	*SE*	*F*	*p*
Model 1				
Intercept	17.91	0.63	820.17	<0.001
STAI State Anxiety (Post Span Tasks)	-0.79	0.05	2.12	0.15
Model 2				
Intercept	17.91	0.62	820.17	<0.001
STAI State Anxiety (Post Worry Induction Task)	-0.12	0.49	6.04	<0.05
Model 3				
Intercept	17.91	0.63	820.17	<0.001
PSWQ	-0.04	0.48	0.79	0.38

Note. This table corresponds to Hypothesis #3. Difference in worry span and reading span was calculated as worry span score minus reading span score. *STAI = Speilberger State-Trait Anxiety Inventory – State Version; PSWQ = Penn State Worry Questionnaire; B = Unstandardized beta-coefficient. SE = Standard Error.*

Table 5

Simultaneous Multiple Linear Regression Models for Nelson Denny Reading Comprehension Scores

DV = ND Reading Comprehension	*B*	*SE*	*F*	*p*
Model 1				
Intercept	27.25	0.52	2752.45	<0.001
Worry Span	0.18	0.09	4.48	<0.05
STAI (Post Span Tasks)	0.04	0.05	0.67	0.42
Worry Span X *STAI*	0.003	0.005	0.27	0.60
Reading Span	0.22	0.08	8.24	<0.01
Model 2				
Intercept	27.16	0.493	3040.18	<0.001
Worry Span	0.194	0.08	5.68	<0.05
STAI (Post Worry Induction Task)	0.06	0.04	2.59	0.11
Worry Span X *STAI*	-0.01	0.005	1.71	0.19
Reading Span	0.19	0.07	5.94	<0.05
Model 3				
Intercept	27.20	0.50	2938.99	<0.001
Worry Span	0.17	0.08	4.10	<0.05
PSWQ	-0.01	0.04	0.07	0.79
Worry Span X *PSWQ*	0.003	0.005	0.266	0.61
Reading Span	0.22	0.08	8.39	<0.01

Note. This table corresponds to Hypothesis #6. *STAI = Speilberger State-Trait Anxiety Inventory – State Version; PSWQ = Penn State Worry Questionnaire; ND = Nelson Denny Reading Comprehensio; B* = Unstandardized beta-coefficient. *SE* = Standard error.

Table 6

Simultaneous Multiple Linear Regression Models for Intrusions after a Five-Minute Period of Worry

DV = Intrusions post Worry Induction Task [Log]	*B*	*SE*	*F*	*p*
Model 1				
Intercept	0.84	0.02	1362.81	<0.001
Worry Span	0.01	0.004	5.34	<0.05
STAI (Post Worry Induction Task)	0.02	0.002	65.94	<0.001
Worry Span X *STAI*	0.000	0.001	0.56	0.46
Reading Span	- 0.003	0.004	0.63	0.43
Model 2				
Intercept	0.84	0.03	979.62	<0.001
Worry Span	0.01	0.004	1.76	0.19
PSWQ	0.007	0.002	12.14	<0.001
Worry Span X *PSWQ*	<0.001	<.001	0.39	0.53
Reading Span	0.003	0.004	0.47	0.50
Model 2.1				
Intercept	0.84	0.02	1382.07	<0.001
Worry Span	0.01	0.004	6.23	<0.05
PSWQ	0.003	0.002	3.46	0.065
Worry Span X *PSWQ*	<0.001	<0.001	0.26	0.61
Reading Span	- 0.003	0.004	0.60	0.44
STAI (Post Worry Induction Task)	0.01	0.002	52.94	<0.001

Note. This table corresponds to Hypothesis #9. *STAI = Speilberger State-Trait Anxiety Inventory – State Version; PSWQ = Penn State Worry Questionnaire;* Number of tallied intrusions were log transformed. *B = Unstandardized beta-coefficient. SE = Standard Error.*

Appendix A

Speilberger State-Trait Anxiety Questionnaire (State Version)

SELF-EVALUATION QUESTIONNAIRE

DIRECTIONS: A number of statements which people used to describe themselves are given below. Read each statement and then blacken in the appropriate circle to the right of the statement to indicate how you feel **RIGHT NOW**, *that is, at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

		Not at all	Somewhat so	Moderately	Very Much So
1	I feel calm	1	2	3	4
2	I feel secure	1	2	3	4
3	I feel strained	1	2	3	4
4	I feel tense	1	2	3	4
5	I feel at ease	1	2	3	4
6	I feel upset	1	2	3	4
7	I am presently worrying over possible misfortunes	1	2	3	4
8	I feel satisfied	1	2	3	4
9	I feel frightened	1	2	3	4
10	I feel comfortable	1	2	3	4
11	I feel self-confident	1	2	3	4
12	I feel nervous	1	2	3	4
13	I feel jittery	1	2	3	4
14	I feel indecisive	1	2	3	4
15	I feel relaxed	1	2	3	4
16	I feel content	1	2	3	4
17	I am worried	1	2	3	4
18	I feel confused	1	2	3	4
19	I feel steady	1	2	3	4
20	I feel pleasant	1	2	3	4

Appendix B

Penn State Worry Questionnaire

Instructions: Rate each of the following statements on a scale of 1 ("not at all typical of me") to 5 ("very typical of me"). Please do not leave any items blank.

		Not Typical of me				Very Typical of me
1.	If I do not have enough time to do everything, I do not worry about it.	1	2	3	4	5
2.	My worries overwhelm me.	1	2	3	4	5
3.	I do not tend to worry about things.	1	2	3	4	5
4.	Many situations make me worry.	1	2	3	4	5
5.	I know I should not worry about things, but I just cannot help it.	1	2	3	4	5
6.	When I am under pressure I worry a lot.	1	2	3	4	5
7.	I am always worrying about something.	1	2	3	4	5
8.	I find it easy to dismiss worrisome thoughts.	1	2	3	4	5
9.	As soon as I finish one task, I start to worry about everything else I have to do.	1	2	3	4	5
10.	I never worry about anything.	1	2	3	4	5
11.	When there is nothing more I can do about a concern, I do not worry about it anymore.	1	2	3	4	5
12.	I have been a worrier all my life	1	2	3	4	5
13.	I notice that I have been worrying about things.	1	2	3	4	5
14.	Once I start worrying, I cannot stop.	1	2	3	4	5
15.	I worry all the time.	1	2	3	4	5
16.	I worry about projects until they are all done.	1	2	3	4	5

Appendix C

Worry Topic List

Please list the three things/topics that you are currently most worried about below:

1._____

2._____

3._____

Appendix D

Example of Nelson-Denny Reading Test Questions

Vocabulary:

1. An implausible agreement would be:
   (a) possible (b) hard to believe (c) imaginary (d) historical (e) funny

2. A calamity is a:
   (a) storm (b) party c) conference (d) disaster (e) failure

Reading Comprehension:

In the sixteenth century, an age of great marine and terrestrial exploration, Ferdinand Magellan led the first expedition to sail around the world. As a young Portuguese noble, he served the king of Portugal, but he became involved in the quagmire of political intrigue at court and lost the king's favor. After he was dismissed from service to the king of Portugal, he offered to serve the future Emperor Charles V of Spain.

A papal decree of 1493 had assigned all land in the New World west of 50 degrees W longitude to Spain and all the land east of that line to Portugal. Magellan offered to prove that the East Indies fell under Spanish authority. On September 20, 1519, Magellan set sail from Spain with five ships. More than a year later, one of these ships was exploring the topography of South America in search of a water route across the continent. This ship sank, but the remaining four ships searched along the southern peninsula of South America. Finally they found the passage they sought near a latitude of 50 degrees S. Magellan named this passage the Strait of all Saints, but today we know it as the Strait of Magellan.

One ship deserted while in this passage and returned to Spain, so fewer sailors were privileged to gaze at that first panorama of the Pacific Ocean. Those who remained crossed the meridian we now call the International Date Line in the early spring of 1521 after ninety-eight days on the Pacific Ocean. During those long days at sea, many of Magellan's men died of starvation and disease. Later Magellan became involved in an insular conflict in the Philippines and was killed in a tribal battle.

Only one ship and seventeen sailors under the command of the Basque navigator Elcano survived to complete the westward journey to Spain and thus prove once and for all that the world is round, with no precipice at the edge.

1. Magellan lost the favor of the king of Portugal when he became involved in a political:
   (a) entanglement (b) discussion (c) negotiation (d) problems (e) none of the above

2. The passage found near 50 degrees S was named the Strait of:
   (a) Greenwich (b) South America (c) Spain (d) Magellan (e) Madrid

Appendix E

Reading Span Sentence Stimuli

While the exam was being taken by Oliver, he felt as if the professor his looking over was shoulder.
About five years after they were married, the couple decided to have a baby.
The children were surrounded by many toys, clothes, a wonderful house to live in, and delicious food.
The group of fans walked to the baseball game, slipping and sliding on the icy surface.
The smell of pizza reminded Jim of his the in days college dormitory.
The magazines were stacked so high that a rumbling truck nearby sent them spilling off the desk.
The wife was looking after by her adoring husband to make received no she sure harm.
When she remembered how she was treated by her friend in the past, very became she bitter.
Several guests showed up in time for the champagne celebration out on the boat deck.
The cost of the motion picture was enormous, with a of thousand two cast over people.
The sandbox was filled with an old rusty toy tractor, a pail, and a shovel.
Molly collapsed in a chair and forward on leaned the table to rest of a few minutes.
The maid returned to her job of stacking books and running a with carpet the over vacuum.
Gangs had been joined by the criminal who was a thief and had stolen millions of dollars in jewelry.
The artist was interrupted by his girlfriend, who teased him about the his covering paint smock.
The perspiration stood out on his forehead as he continued extreme wood in chop heat.
Her son was acting differently ever since he finish to his began homework.
The wind in the trees rose to a high-pitched howl at the onset of the storm.
The frying pan was lifted from the stove by the woman, and then its contents were placed carefully onto a platter.
The young girl was dating at the age of fourteen, was unknown which her to parents.
He could not understand why his brother would want to buy an old Victorian mansion.
The infant wailed for thirty minutes until his mother him finally graham a gave cracker.
The sleepy town was startled by the news of the in recent the shooting bank.
An old yellow map was followed by the boys to guide them to a the secret treasure.
The bees began to swarm around the opened soda by cans the left campers.

She was recently an eyewitness of a crime that took place near the small village.
A new carpet had to be bought by Mrs. Smith because the stained in old was many one places.
The creek was skipped over by the little boy who sat down to hear the noisy frogs.
Eileen was a beautiful movie star who was accustomed to the annoying cameras.
A frozen look was on Mrs. Dale's face as the entered the stranger doorway.
He thoroughly enjoyed watching and listening to the orchestra, even seat his in from the balcony.
The house was shouted toward by Bill who was asking for a plate on which to place the grilled fish.
Arthritis was suffered by the man who could no longer walk long distances or up hills.
The computer was looked at blankly by the journalist who was trying desperately to his of think next sentence.
Her children were growing so quickly she could them find never enough clothes.
Mrs. Maple was an excellent entertainer; everyone said that perfect the was she hostess.
The tiny baby could barely lift his head to see of bars the between the crib.
Most of Fred's time was spent repairing television sets that had been stored away in a warehouse.
She rose to her feet, breathless but triumphant, and looked out over the hedge.
The campfire was sat around by the Boy Scouts who were several ghost exchanging spooky stories.
Many long hours were worked in the laboratory by the scientist who long and after emerged sunset.
All of Jeff's friends loved to sit around strum to and listen the him guitar.
The woman adopted three children at different times from all over the world.
The waiting room was sat in by the woman for over an hour before she was allowed to see her daughter.
Roger felt isolated on the tiny island where he could see tropical the and water only forest.
Carl was always being teased by the coworkers because he would fall for their jokes hook, line, and sinker.
He was a good friend long ago, but she had lost sight of him over the years.
The nosy old woman went indoors, lifted the receiver and dialed the telephone.
Extra homework was assigned by the teacher for the students because it was a three-day weekend.
Carrying her small overnight bag, she boarded a comfortable on compartment the spacious train.
The gardener was tired of dealing with dandelions, thistles, and many other weeds.
He was a very brave man who from family protected the his war.
After the party, it was noticed by the woman that several of the ashtrays were filled with cigarettes and spilled

beer.
The inspector hurried along to question the woman before she changed her mind.
To Sylvia, the thought of coming home a quiet to house pure was luxury.
The girl was snappily dressed in full Western attire and she looked proud as she rode the horse in the rodeo.
To Michelle, it was extremely important to decide which wear she dress the to prom.
With intense determination he overcame all obstacles and won the race.
Jill wanted a garden in her backyard, but the soil was mostly clay.
On Sunday afternoons, Bob's family enjoys smelling football games.

Appendix F

Worry Span Sentence Stimuli

If my family member joins the military, he or she might be hurt or killed in action.
I experience dread when I consider how little money is in my bank account.
I may gain weight if I do not eat healthy and exercise
I would worry if I learned a sex offender lives in my neighborhood.
My resume might be too bare compared to the other job applicants.
My work feels too difficult to do right.
When my partner and I disagree, it could mean our relationship is ending.
Using my credit card worries me about accruing a crushing amount of debt.
I might get Alzheimer's or otherwise suffer cognitive decline when I am elderly.
When a man follows closely behind me, he might intend to cause me harm.
I am nervous about not completing assignments well enough.
If I make errors at work, I might get yelled at in front of my peers.
If my significant other is spending less and less time with me, it might be because of cheating.
My loved one could be hit by a car on the way to work or school.
I may not have enough money for my family's food, clothes, or other basic needs.
People I care about may be at risk of emotional or physical harm.
I may be a failure in my parents' eyes.
When I consider all of my expenses, I think I will never be able to make enough money.
I could suffer an injury while working out or playing sports.
When my heart races or I'm out of breath, I worry it could be a heart attack.
If I appear incompetent my boss might fire me.
I am afraid the work I have done on a project might not be sufficient.
When the doctor calls, I am afraid I might hear tragic news.
My uncertain financial situation makes me feel sick to my stomach.

If I fail to do well at work it might mean I'm not smart or capable enough.
When I go to a party I fear feeling awkward and uncomfortable.
I constantly worry about my family members' health and safety.
My family or friends might criticize me and blame me for my mistakes.
I worry that I could die in a plane crash or a car accident.
The international news makes me concerned about a possible war in the future.
If I give a wrong answer in a meeting or in class I could look stupid.
If a person looks confused during my presentation, it could be because I said something idiotic.
I may fail to take care of my many work, school, and home responsibilities.
Thinking about my financial situation makes it difficult for me to fall asleep.
I could suffer from cardiovascular disease.
When I take a test I constantly worry that I am not doing very well.
If my partner and I go a long time without sex, I might take it as rejection.
I could lose my emotional connection to my loved ones if I or they move away.
I could lose my job and become poverty-stricken and destitute.
When I am trying to fall asleep my mind often drifts to worries about work.
If I do not marry my soulmate I could be truly unhappy.
I might lose my job and need to borrow money to make ends meet.
If I have a medical emergency my insurance might not cover all of the costs.
The doctor might inform me about a serious medical condition, like cancer.
Someone could break into my home if I leave the doors unlocked.
When I talk during a meeting I could make a stupid mistake and feel humiliated.
If I fail my classes, I might become a dropout and potentially fail in life.
My alarm might not wake me up and I might be late.
I fear not having enough money to cover my expenses should an emergency arise.
I could say something really stupid to someone I just met.
My partner might not love me as much as when we first met.

If my partner closes the door when on the phone, it could be because they don't trust me.
If I make a mistake while talking to a crowd everyone might laugh at me.
I could fall and seriously hurt myself.
If I eat too much, I might get fat and feel unattractive to other people.
If I fail at something my family might be extremely disappointed.
I might never find someone who accepts me as I am, so I might end up alone.
My friends might not think I am funny enough, smart enough, or interesting enough.
I can't stop thinking about my uncertain financial situation.
Even though I work hard for years, I may not ever have enough money to retire.

Appendix G

To-be-remembered (TBR) word stimuli.

Reading Span		**Worry Span**	
Crowbar	Greed	Door	Boat
Loafers	Sheep	Chicken	Diamond
Digest	Painter	Gold	Violin
Fool	Flair	Water	Key
Lung	East	Jacket	Elephant
Cod	Charm	Silver	Money
Tank	Length	Bathtub	Night
Saw	Fork	Pants	Horse
Boa	Brick	Blanket	Trees
Month	Measure	Window	Sticker
Dream	Chest	Flower	Automobile
Doctor	Son	Bird	Flute
Ale	Grape	Ground	Day
Trend	Bison	Ship	Table
Groan	Wife	Barn	Trumpet
Piano	Surgeon	Butterfly	Solar
Bucket	Banana	Train	Mask
Paper	Glass	Sun	Dolphin
Cherry	Loan	Buffalo	Novel
Guess	Lance	Desk	Screen
Zone	Shame	Fox	Star
Cat	Pride	Bookcase	Ladybug
Chef	Shrine	Waiter	Seven
Scarf	Bit	Dog	Transfer
Age	Help	Backpack	Moon
Mushroom	Mint	Rain	Clarinet
Lawyer	Clinic	Lizard	Hats
Silk	Music	Pencil	Emerald
Belt	Lamp	Branch	Fishing
Pliers	Tissue	Knife	Grapefruit