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Evaluating the effect of a novel cognitive training program on PTSD symptoms

A dissertation submitted in partial fulfillment of the requirements for the degree

of Doctor of Philosophy

in

Clinical Psychology

by

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2014



The dissertation of Jessica Bomyea is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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## ABSTRACT OF THE DISSERTATION

Evaluating the effect of a novel cognitive training program on PTSD symptoms

by

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Doctor of Philosophy in Clinical Psychology

University of California, San Diego, 2014  
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Post-traumatic stress disorder (PTSD) is a chronic and debilitating disorder that affects millions of people each year (Kessler, Chiu, Demler & Walter, 2005). Although effective psychosocial and pharmacological treatments exist for this disorder, estimated non-response rates as high as 50% point to the need for development and evaluation of novel interventions

(Schottenbauer, Glass, Arnkoff, Tendick, & Gray, 2008). Biological and cognitive mechanisms associated with re-experiencing symptoms may be directly implicated in the development and maintenance of PTSD (McFarlane, Yehuda, & Clark, 2002). Recent cognitive models and empirical data suggest that diminished ability to control proactive interference, may account for the persistent recurrence of re-experiencing symptoms for some individuals (e.g., Wessel, Overwijk, Verwoerd, & de Vrieze, 2008). The present study tested a novel PTSD treatment approach designed to modify cognitive mechanisms theoretically implicated in the development and maintenance of the disorder. Thirty seven women with PTSD were randomly assigned to an 8-session computerized cognitive training (high interference control requirements) or a control condition (low interference control requirements). Primary dependent outcomes included PTSD re-experiencing symptom severity assessed using the Clinician Administered PTSD Scale and proactive interference control performance assessed using an Operation Span task. Secondary measures included self-reported anxiety and depression as well as cognitive generalization to an alternate task of proactive interference control (CVLT interference index) and a thought suppression task. Results indicated that in both groups PTSD re-experiencing symptoms and Operation Span performance improved, with a larger effect size in the cognitive training group. General distress symptoms also improved over time in both groups. However, CVLT performance and thought suppression ability did not improve from pre- to post assessment. Collectively, results suggest that cognitive training of this

type may hold promise as a novel intervention for reducing PTSD symptoms. However, the mechanism of action and implications for models of inhibitory control in PTSD require future study.

## **Introduction**

Posttraumatic stress disorder (PTSD) occurs in response to a traumatic or life threatening event such as combat, natural disasters, or physical or sexual assault. According to the DSM-IV conceptualization, the individual must respond to the event with marked fear, helplessness, or horror (American Psychiatric Association; 2000). However, this requirement was removed in the DSM-V revision (e.g., Brewin, Lanius, Novac, Schnyder, & Galea, 2009; McNally, 2009). Symptoms of PTSD in DSM-IV had been categorized into three clusters including re-experiencing of the traumatic event, avoidance of stimuli associated with the traumatic and event emotional numbing, and hyper-arousal. Modifications to the DSM-V include reorganization of symptoms into four clusters: re-experiencing, avoidance, negative alterations in cognition and mood (e.g., negative beliefs about the self, emotions such as guilt), and alterations in arousal and reactivity (American Psychiatric Association, 2010).

Epidemiological investigations indicate that rates of exposure to at least one traumatic event (defined by the APA "Criterion A" from DSM-IV or earlier) range from 55 to 89% (Breslau et al., 1998; Kessler, Sonnega, Bromet, & Hughes, 1995; Stein, Walker, Hazen, & Ford, 1997). In the general population, PTSD occurs in approximately 7.7 million Americans, or roughly 8%, with higher rates in women than in men (Kessler et al., 2005). PTSD results in significant social and economic burden and puts individuals at increased risk for physical health problems as well as other mental health difficulties including depression and suicide (e.g., Hidalgo & Davidson, 2000). Though most individuals

experience PTSD-like symptoms in the immediate aftermath of a traumatic stressor (e.g., distressing memories), only a minority goes on to develop the chronic, debilitating symptoms that comprise PTSD (Kessler et al., 1995; McNally, Bryant & Ehlers, 2003). Individual differences in factors present before, during, or after a traumatic event may be important in understanding why some individuals go on to develop PTSD while others recover naturally.

In particular, biological and cognitive mechanisms associated with intrusive recollections may be directly implicated in the development and maintenance of PTSD (McFarlane, Yehuda, & Clark, 2002). By this account, the presence of re-experiencing symptoms may facilitate the development of neural networks pertaining to trauma-related stimuli. Over time, the affective and semantic meaning associated with these memories (e.g., fear, rumination about the cause or consequences of the event) becomes integrated into this trauma-related neural network. Repeatedly accessing trauma memories via these types of symptoms guides and progressively strengthens the development of specific neural circuits that process potentially trauma-related cues at the expense of those that process more neutral information. This process then creates pathological, biased processing within cognitive systems, including those related to “top down” executive functioning, and catalyzes specific bio-behavioral changes that lead to the symptoms of PTSD (e.g., avoidance). Individual differences in these changes lead to variability in the development of PTSD (c.f., natural recovery) for specific individuals.

Consistent with this account, empirical work evaluating the onset of PTSD symptoms suggests that early symptom presentation consists primarily of intrusive symptoms with other symptom clusters emerging later (Creamer, Burgess, & Pattison, 1992). This suggests then that the re-experiencing of trauma memories may modulate specific cognitive processes that later influence other symptoms of the disorder. Thus, evaluating the relationship between cognitive processes associated with intrusive thoughts and PTSD symptomatology holds promise for advancing our understanding of this disorder, as well as for developing novel treatments.

### **Current approaches to PTSD treatment**

Empirically supported treatments for PTSD utilize cognitive-behavioral principles. One widely studied PTSD treatment is Prolonged Exposure (PE; Foa & Rothbaum, 1998), a time-limited, manualized, exposure-based therapy. PE is based on emotional processing theory (Foa & Kozak, 1986), which posits that individuals with PTSD possess extensive, overly inclusive mental representations pertaining to trauma related stimuli (i.e., fear structures). These fear structures, which include information about the feared stimuli, associated responses, and the meaning of the stimuli and responses, maintain PTSD by increasing an individual's subjective sense of threat and facilitating avoidance of feared cues. PE seeks to modify these fear structures by use of in vivo and imaginal exposure exercises, with the goal of increasing habituation to feared stimuli (i.e., decoupling fear from the memory), decreasing avoidant tendencies (i.e., decoupling fear from related situations),

and modifying maladaptive cognitions pertaining to the traumatic event.

Numerous studies indicate that PE is effective for multiple trauma types and populations (for reviews see Ponniah & Hollon, 2009; Powers, Halpern, Ferenschak, Gilihan, & Foa, in press).

Other PTSD interventions include cognitive therapies that emphasize the modification of maladaptive thought patterns that appear to be implicated in the etiology and maintenance of the disorder. Although a number of specific types of cognitive therapy exist, this type of treatment generally aims to modify distorted or unhelpful cognitions (e.g., attributions, beliefs, expectations) that cognitive models posit contribute to PTSD symptoms (Brewin, Dalgleish, & Joseph, 1996; Ehlers & Clark, 2000; Foa & Kozak, 1986). One specific form of cognitive therapy that has garnered significant empirical support is Cognitive Processing Therapy (CPT; Resick & Schnicke, 1992), which focuses on reconciling and integrating an individual's pre-existing beliefs about themselves and the world with the new information generated by the traumatic event. That is, individuals are assisted with developing beliefs about the world that incorporate the details of the trauma without adhering strictly to old beliefs or modifying these beliefs in an over-generalized manner. Extant literature indicates that various forms of cognitive therapy effectively treat PTSD (e.g., Chard, 2005; Ehlers et al., 2003; Monson et al., 2006; Resick et al., 2008; Resick, Nishith, Weaver, Astin, & Feuer, 2002; Resick & Schnicke, 1992).

#### **Future directions for treatment outcome research**



In spite of empirical support for extant PTSD treatments, further intervention research is still needed. Current approaches require substantial time and effort from patients both during sessions and while completing home-based exercises. Research indicates that dropout rates may be as high as 54% (Schottenbauer, Glass, Arnkoff, Tendick, & Gray, 2008), suggesting that these interventions may not be feasible for or well-received by all patients. Surveys of clinician attitudes about empirically supported treatments suggest that trauma-focused therapy is used infrequently; many clinicians feel uncomfortable with the emotionally demanding nature of trauma-focused treatment or unqualified to do such treatment protocols (e.g., Becker, Zayfert, & Anderson, 2004; Van Minnen, Hendriks, & Olf, 2010). Moreover, these approaches are not effective for every individual who completes them. Estimates indicate that non-response rates range from 33% (Bradley, Greene, Russ, Dutra, & Westen, 2005) to almost 50% (Schottenbauer et al., 2008). In summary, this body of literature suggests that many individuals do not access or complete the current empirically supported approaches and that, even among those who do complete therapy, they are not universally effective.

Identification of new intervention targets may advance our ability to treat PTSD. Ideally, new targets would be factors hypothesized to be involved in the etiology and maintenance of the disorder and derived from theoretical models of PTSD. Existing psychosocial treatments derived from cognitive models focus on the *content* of trauma-related cognitions – that is, the types of negative beliefs and expectations an individual has about trauma-related

stimuli and cues. However, an alternative approach is to focus on the basic underlying *processes* that regulate the emergence and recurrence of thoughts. Specifically, this approach would *aim to alter the functioning of basic cognitive systems hypothesized to govern the regulation of thoughts*, particularly the re-experiencing symptoms (e.g., intrusive thoughts and memories, flashbacks) that are the hallmark of PTSD.

### **The role of executive functioning in intrusive symptoms**

Recent theoretical accounts posit that the persistence of re-experiencing symptoms and other forms of intrusive thoughts and memories in clinical disorders like PTSD stems from deficits in basic cognitive systems that regulate the inhibition of information (e.g., Anderson & Levy, 2009; Joormann, Yoon, & Siemer, 2010; Verwoerd, de Jong, & Wessel, 2008). Specifically, these cognitive theories suggest that individual differences in executive functioning processes may lead to differential ability to regulate and control unwanted cognitions. Executive functioning refers to domain-general control mechanisms that govern cognitive sub-processes used in higher order cognition, such as updating and monitoring information, inhibition of unwanted information, and shifting between mental sets (Miyake, Friedman, Emerson, Witzky, & Howerter, 2000). Components of executive functioning have taken a variety of names based on different cognitive models (e.g., attention control, central executive, cognitive control; see Wessel, Overwijk, Verwoerd, & de Vrieze, 2008). For the sake of simplicity we will refer to domain-general cognitive abilities as *executive functioning*, and use *inhibitory control* to refer to

the specific sub-function designed to inhibit irrelevant information or remove thoughts from awareness. From this theoretical perspective, individuals with poor *inhibitory control* are predicted to be less able to prevent unwanted thoughts from entering consciousness and less able to rid themselves of these thoughts once they enter into mind. Two lines of evidence support this model. First, PTSD is associated with deficits in executive functioning, including inhibitory control. Second, analogue research indicates that performance on executive functioning tasks relying on inhibitory control is associated with intrusive thoughts and re-experiencing symptoms after experiencing stress.

**Executive functioning deficits in PTSD.** A number of studies demonstrate that specific deficits in executive functioning performance differentiate individuals with and without PTSD (Aupperle, Melrose, Stein, & Paulus, 2012; Polak, Witteveen, Reitsma, & Olff, 2012). For example, individuals with PTSD demonstrate deficits on learning and memory tasks (e.g., Yehuda, Keefe, Harvey, & Levengood, 1995; Yehuda, Golier, Halligan, & Harvery, 2004) and poorer working memory performance (e.g., Leskin & White, 2007; Stein, Kennedy, & Twamley, 2002) relative to healthy individuals (for a review of cognitive processing differences see Buckley, Blanchard, & Neil, 2000; Constans, 2005; Mathews & MacLeod, 2005). These findings are consistent with neuroimaging studies indicating that individuals with PTSD are characterized by diminished cortical activation in brain areas associated with executive functioning and over-activation of areas regulating emotional reactivity relative to healthy individuals. Specifically, research consistently

indicates that individuals with PTSD demonstrate hypoactivation in the prefrontal cortex (including the anterior cingulate cortex) and the parietal cortex, as well as hyperactivation in the amygdala relative to controls across a variety of cognitive tasks using neutral and trauma-relevant stimuli (e.g., Shin et al., 2001; for reviews see Etkin & Wager, 2007; Francati, Vermetten, & Bremner, 2007). Taken together, results from these studies suggest that individuals with PTSD exhibit neurobiologically-based deficits in performance on executive functioning tasks.

Consistent with theoretical accounts linking inhibitory control with intrusive symptoms, specific inhibitory control deficits are also observable in PTSD. Theoretical models suggest that inhibitory control is made up of distinct subcomponents (e.g., Friedman & Miyake, 2004). These subcomponents include *response inhibition*, where the individual must prevent executing a previously learned response tendency, and *interference resolution*, where an individual must ignore distracting stimuli to complete behavior consistent with an alternate goal (including distracter interference and proactive interference). Individuals with PTSD appear to experience difficulty with both domains of inhibitory control functioning.

Data from empirical studies show dysfunctional patterns of pre-potent response inhibition in PTSD samples. For example, individuals with PTSD demonstrate dysregulated performance on tasks that require response inhibition of learned behaviors (e.g., go/no-go task; Carrion, Garrett, Menon, Weems, & Reiss, 2008; Casada & Roache, 2005; Falconer et al., 2008). One

paradigm frequently used to assess this form of inhibition is the emotional Stroop color and word task (or color-name interference task; Friedman & Miyake, 2004). In a traditional Stroop task (Stroop, 1935), participants are presented with a list of color words presented in different colored ink and must say the ink color aloud. The pre-potent tendency while completing this task is to read the color written in the text of the word (rather than the color of the ink). In the emotional Stroop task, the words printed are emotionally evocative or trauma related (e.g., rape). Theoretical accounts of the emotional Stroop effect suggest that the presence of threat words activates the tendency to read the word, which negatively impacts the ability to name the color of the word (Williams, Mathews, & MacLeod, 1996). Research indicates that PTSD samples demonstrate delayed time to complete the emotional Stroop task when trauma-relevant stimuli are included, relative to healthy samples (for a review see Constans, 2005).

Individuals with PTSD also demonstrate decrements in performance requiring interference control. More specifically, extant studies suggest that individuals with PTSD have difficulty controlling *proactive interference* – that is, difficulty remembering recently learned stimuli when they are similar to other, previously learned stimuli. Tasks that tap proactive interference control typically ask participants to remember multiple stimuli, then assess for the intrusion of formerly learned stimuli onto newer learning. Evidence for this type of inhibitory difficulty in PTSD comes from directed forgetting paradigms. In these tasks, participants are instructed to remember specific verbal stimuli

while ignoring and forgetting others. This body of research suggests that individuals with PTSD experience difficulty retaining to-be-remembered words due to interference from irrelevant task information in this type of paradigm (Cottensin et al., 2006; McNally, Metzger, Lasko, Claney, & Ptiman, 1998; although see Zoellner, Sacks, & Foa, 2003).

Similarly, a number of additional studies have assessed proactive interference control using performance on the Auditory Verbal Learning Test or California Verbal Learning Test in PTSD samples (Eren-Kocak, Kilic, & Hizli, 2009; Uddo, Vasterling, Brailey, & Sutker, 1993; Yehuda, Golier, Tischler, Stavitsky, & Harvey, 2005). In this test, participants are asked to memorize a short list of words (i.e., List 1). This process of learning and recalling the words from List 1 is repeated five times. On the sixth trial, participants are given new words to recall (i.e., List 2). The difference between initial learning of List 1 and List 2 is considered a measure of interference of the first list onto learning of the second (Kaplan & Delis, 1991). Results from these three studies indicate that individuals with current or lifetime PTSD consistently demonstrate relatively greater difficulty inhibiting proactive interference on this type of task.

In summary, results from clinical samples indicate that individuals with PTSD demonstrate significant impairment in executive functioning, including performance on tasks thought to tap inhibitory control. These deficits appear both when individuals are asked to inhibit a dominant cognitive or behavioral response and also when attempting to control proactive interference from previously learned stimuli. There is some evidence that these deficits may be

related to re-experiencing symptoms seen in PTSD. When surveying findings from neuropsychological assessment studies of PTSD, Vasterling, Brailey, Constans, and Sutker (1998) noted that “cognitive intrusions” (made up of commission errors, false positives, and intrusion errors) were significantly correlated with re-experiencing symptoms when controlling for arousal and avoidance symptoms. However, it is unclear whether these deficits are pre-existing risk factors for PTSD development or a consequence of the disorder. Also, these studies do not inform us as to whether these deficits are a maintenance factor in PTSD.

**Relationship between inhibitory control and intrusive thoughts in non-clinical samples.** Extant literature using analogue samples suggests performance on executive functioning tasks that rely on inhibitory control predicts one’s ability to inhibit unwanted thoughts. Moreover, these analogue studies provide information about the relationship between subtypes of inhibitory control and intrusive thoughts. One approach that has been used extensively to evaluate this relationship involves exposing healthy individuals to an in-laboratory stressor such as a distressing film to induce transient cognitive and emotional effects similar to that of a naturalistic trauma (for a review of this distressing film paradigm see Holmes & Bourne, 2008). A number of studies used this paradigm to specifically examine the relationship between basic inhibitory control processes measured prior to film exposure and intrusive thoughts after the film. In general, these studies find that greater ability to control proactive interference is associated with fewer intrusive

memories (e.g., performance on the paired-associates task; Verwoerd, Wessel, & de Jong, 2009, Wessel et al., 2008, CVLT-II interference index, Verwoerd, Wessel et al., in press). Based on this evidence, these researchers conclude that intrusive symptoms may reflect a breakdown in this specific component of inhibitory control and that the inability to resolve proactive interference may be associated with a greater number of intrusive symptoms in clinical disorders such as PTSD.

Analogue research also suggests that control over proactive interference is related to the ability to deliberately suppress unwanted information and memories (Brewin & Beaton, 2002; Brewin & Smart, 2005). In these two studies, the authors first administered a working memory capacity (WMC) assessment to participants. WMC refers to the amount of information that can be kept in working memory, the temporary mental storage used to hold and manipulate information during complex cognitive tasks (e.g., Conway et al., 2005). Because performance on WMC tasks depends partially on one's ability to control memories from prior trials during the task, it is thought to tap proactive interference control ability (Bunting, 2006; Friedman & Miyake, 2004; Lustig, May & Hasher, 2001; May, Hasher, & Kane, 1999). After completing the WMC task, participants in these studies then completed a thought suppression task. During this task, they were asked to verbalize their stream of consciousness during three 5-minute phases. In the first and third phase, participants recorded anything that came to mind. In the second phase, participants were asked to try to suppress either a pre-selected neutral thought



(Brewin & Beaton, 2002) or a negative personally relevant thought (Brewin & Smart, 2005). Results revealed that higher WMC was associated with fewer intrusions during the thought suppression condition and with a smaller “rebound” in number of thoughts in the third phase. In addition, Bomyea, Amir, and Lang (2012) found that, in a non-clinical sample of individuals with trauma exposure, WMC was uniquely associated with PTSD re-experiencing symptoms. Thus, findings from these studies also support the link between proactive interference control and regulation of intrusive cognitions.

### **Summary and future directions for inhibitory control research in PTSD**

In summary, extant literature using clinical samples with PTSD as well as analogue samples suggests that: 1) PTSD is associated with inhibitory control deficits, including difficulty with inhibiting pre-potent responses and controlling proactive interference, and 2) difficulty controlling proactive interference is associated with difficulty regulating intrusive thoughts and memories, after experiencing a traumatic event, after an analogue traumatic stressor, and during deliberate thought suppression. Post-trauma, most individuals experience intrusive memories of the event that are vivid and laden with negative emotion. By theoretical accounts emphasizing the importance of executive functioning in PTSD, individuals with relatively better inhibitory control may be able to inhibit unwanted thoughts. With repeated practice of accessing and then inhibiting these thoughts, these individuals successfully recover from the traumatic event by laying down the appropriate neural networks to regulate trauma-relevant memories (for a review of how neural

networks might be modified in the course of this process see McFarlane et al., 2002). However, individuals with relative deficits in executive functioning, particularly inhibitory control, are likely to experience more difficulty regulating such thoughts. Repeatedly accessing aversive traumatic memories in the aftermath of the event may lead to escalating and maladaptive attempts to control thought content and associated emotional responses, particularly in individuals with poor inhibitory control (e.g., Wessel et al., 2008). Thus, poor inhibitory control and deliberate attempts to suppress thoughts may paradoxically increase the frequency of intrusive thoughts and associated emotional distress (Moore, Zoellner, & Mollenholt, 2008).

While the extant literature examining inhibitory control and intrusive cognitions suggests the two are related, this literature is limited by correlational study designs. This current evidence cannot speak to causal relationships between inhibitory control and thought regulation ability. If performance on cognitive tasks tapping inhibitory control is related to inhibitory control over the content of cognition, then improving this cognitive ability should lead to decreased frequency of intrusive memories. Thus, examining the malleability of these cognitive processes may have clinical utility for PTSD.

### **Executive functioning training programs**

Several studies indicate that it is possible to improve executive functioning using training programs. The effectiveness of these programs has been demonstrated across such diverse populations as children with attention deficit hyperactivity disorder (e.g., Klingberg et al., 2005), older adults

(Buschkuehl et al., 2008), individuals with schizophrenia (Dickinson et al., 2010; McGurk, Twamley, Sitzler, McHugo, & Mueser, 2007; Wykes et al., 2007), and healthy participants (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Olesen, Westerberg, & Klingberg, 2004). Furthermore, there is evidence in some cases to suggest that gains made during such training programs are not an artifact of practice effects or learning the specific training task, but rather reflect increased cognitive ability in the trained domain (e.g., Klingberg et al., 2004; Jaeggi et al., 2008). Changes in performance can be observed via neural activity during task performance, and suggest that modification of shared biological circuitry may be the mechanism of generalizability of training procedures (lateral prefrontal and parietal cortices; Kane & Engle, 2002; Olesen et al., 2004). In addition, several studies indicate that computer-based programs designed to modify cognitive biases such as attentional allocation are effective in anxious populations and decrease clinical symptoms (Amir, Beard, Burns, & Bomyea, 2009). Thus components of executive functioning appear malleable using computer-based training programs.

### **Pilot study: The effect of inhibitory control training on intrusive memories**

A preliminary study was conducted to evaluate the feasibility and effectiveness of a novel proactive interference control training program. The first aim of the study was to evaluate whether this computer-based training program would improve cognitive performance. The second aim was to examine the causal effect of this training program on intrusive memory

regulation ability. To do so, Bomyea and Amir (2010) randomly assigned unselected individuals to complete a single-session training condition or a control condition and evaluated the effects of the conditions on cognitive performance and thought suppression ability.

**Training program.** Given that proactive interference appears to be related to ability to regulate intrusive cognitions (e.g., Wessel et al., 2008), the training and control conditions consisted of two modified WMC tasks designed to differ only on this variable. The WMC tasks selected for this program was a Reading Span task (Daneman & Carpenter, 1980, adapted by Lustig et al., 2001). In this task, participants were asked to memorize semantically unrelated words while simultaneously processing sentences. Participants were first shown a sentence (e.g., “Jane walks her dog in the park”). When the participant indicated that they had finished reading the sentence, they were asked to verify whether or not the sentence makes sense (e.g., “Jane walked her car in the park”, correct answer: “no”). After the participant made this decision, a word (e.g., “arm”) appeared on the screen for 500ms. Then the next trial began with another sentence and word, until the end of the set. Sets typically range from sizes two to six (i.e., participants see two to six sentences and words; Engle, Tuholski, Laughlin, & Conway, 1999). When the set is finished, participants are shown a recognition screen showing 12 words and asked to identify which (two to six) words were shown during the trial in the correct serial order.

Extant literature suggests that modifying memoranda (i.e., to-be-remembered stimuli) to make them more distinct from one another decreases proactive interference during learning (Wickens, Born & Allen, 1963). Thus, WMC tasks like the Reading Span task can be adapted to vary in level of proactive interference by varying memoranda similarity (e.g., Bunting, 2006; Emery, Hale, Myerson, 2008). For example, Bunting (2006) modified a WMC task such that the memoranda alternated between words and numbers across trials. The data from this study indicated that participants performed better on trials when memoranda switched categories (i.e., from numbers to words or vice versa). Moreover, these “proactive release” trials did not correlate with other forms of cognitive assessments (i.e., Ravens Advanced Progressive Matrices), suggesting that the predictive validity of WMC tasks may be dependent on the proactive interference demands of the task. Thus, although the memoranda were easier for participants to remember, the task no longer tapped processes that are critical to higher order cognition.

Based on this literature, the two conditions in this pilot were designed to vary in terms of the type of memoranda shown. The WMC tasks in both conditions contained the same working memory storage requirements but differing levels of proactive interference. The training condition required high interference control (HIC). In this condition, all the memoranda were words. In order to perform successfully on the task, participants were required to repeatedly practice exerting control over proactive interference as trials progressed. The control condition required low interference control (LIC). In

this condition, the memoranda alternated between words and digits (1 through 12) every three trials (Bunting, 2006). In this condition there was relatively less proactive interference inherent in the task because trials with number memoranda would not interfere on trials with word memoranda and vice versa. This condition provided relatively less opportunity to practice this type of inhibitory control relative to the HIC condition. Participants completed three blocks of training in a single session. Within each block, participants were trained on span sizes of 2 to 6, with three repetitions of each span size presented in random order. Thus, during the three blocks the participant completed 45 trials total lasting approximately 30 minutes.

**Assessment of training effects.** Before and after completing the HIC or LIC conditions, participants completed an alternate WMC assessment to evaluate the effect of the training on proactive interference control performance. This was assessed using a computerized Operation Span task (Ospan; Unsworth, Heitz, Schrock, & Engle, 2005). This task is similar to the Reading span task. However participants were required to memorize letters (rather than words), and to decide whether arithmetic problems were correct (rather than verifying sentences; e.g., “ $2 \times 2 + 1 = 5$ ?” correct answer: “Yes”).

After completing the HIC or LIC conditions participants also completed a thought suppression task (Wegner, Carter, Schneider, & White, 1987). They first identified a negative personal memory and wrote about this memory for three minutes. Next, participants were given a definition of intrusive thoughts. They were then instructed to record the number of intrusive thoughts they

experienced about the negative personal memory during three 5-minute phases: 1) a baseline monitoring phase, 2) while trying *not* to think about the memory, and 3) a post-suppression monitoring phase.

**Results.** Results from the WMC assessment indicated that participants in the HIC demonstrated significantly greater performance from baseline to post training, relative to those in the LIC group. During the thought suppression task, individuals in the HIC group experienced significantly fewer thoughts about their negative personal memory during the suppression and post-suppression monitoring phase, relative to those in the LIC condition. In addition, individuals in the HIC condition showed a significant decrease in the number of intrusive thoughts about the memory from the baseline thought monitoring period to the suppression period, while those in the LIC condition did not.

Taken together, results from studies examining executive functioning training suggest that this type of intervention is a potential candidate for increasing proactive interference control over cognitions and decreasing symptoms associated with cognitive deficits in PTSD. The results of Bomyea and Amir (2010) also suggest that proactive interference control may have a causal relationship with intrusive thoughts. Further research is needed to evaluate the potential utility of such procedures in clinical samples, first establishing the efficacy of such training programs on cognitive functioning and then that these training programs impact re-experiencing symptoms. This research would both inform and test inhibitory control accounts of intrusions

while also potentially establishing the clinical utility of this type of training as an intervention.

### **Overview of the present study**

The proposed project aimed to test the effect of a computer-based proactive interference control training program on symptoms of PTSD. This study utilized a translational approach to target cognitive processes implicated in the maintenance of PTSD based on findings from experimental psychopathology research. The proactive interference control training program consisted of a multi-session version of the program utilized in Bomyea and Amir (2010). Individuals who completed the training program were expected to demonstrate relatively greater working memory capacity performance on this type of task due to gaining proficient control over proactive interference in the task. The first aim of the study was to evaluate the effects of this training program on cognitive performance. Performance was measured using an alternate WMC task as a manipulation check to confirm the effectiveness of the program in improving proactive interference control. The second aim was to evaluate the effect of this training protocol on PTSD symptoms. Exploratory analyses examined generalizability and maintenance of effects. This study explored the transfer of training effects to cognitive performance on an alternate proactive interference control task and regulation of intrusive thoughts during a thought suppression task. The generalization of training effects to other general distress symptom measures (i.e., anxiety and depression), as well as maintenance of change in symptoms through one-month post training, were



also assessed. The study was designed both to further our knowledge of the effect of proactive interference control on PTSD symptoms and also to conduct a preliminary assessment of the clinical utility of these procedures.

The primary study hypotheses included the following. First, those in the HIC would perform better on the Ospan measure from pre-assessment to post-assessment relative to those in the LIC (i.e., the HIC training program would effectively improve cognitive performance relative to the LIC program). Second, that the HIC would yield larger decreases on the interview-based measure of PTSD re-experiencing symptoms from pre-assessment to post-assessment than would the LIC (i.e., the HIC training program would effectively reduce PTSD re-experiencing symptoms relative to the LIC program). The secondary study hypotheses pertained to generalization of the HIC training effects. We hypothesized that effects of HIC on cognitive performance would generalize to the alternate assessment of proactive interference control (i.e., CVLT-II interference index would improve over time in the HIC group relative to the LIC group). In addition, we hypothesized that individuals in the HIC condition would experience fewer intrusions during the post-suppression monitoring period than individuals in the LIC condition during the thought suppression task. The final hypothesis was that individuals in the HIC group would experience greater decreases in self-reported symptoms of general anxiety and depression from pre-assessment to post-assessment relative to the LIC group.

## **Method**

### **Participants**

Participants included forty-one women between the ages of 18 and 65 who had experienced sexual trauma. Individuals were recruited to participate through several sources, including the university subject pool at SDSU, university affiliated mental health providers, including the Military Sexual Trauma clinic within the VA San Diego Healthcare System, and by posting IRB-approved recruitment materials on multiple college campuses in San Diego, including SDSU, UCSD, USD, and the four local community colleges. Flyers were also posted in community posting areas and online using sites such as craigslist.com.

Upon initial telephone contact, prospective participants were provided with information regarding the assessment and computer-based procedures involved in the study. At this time they also completed a brief telephone screening interview to provisionally determine their appropriateness for study participation. Participants were informed that participation would include random assignment into an experimental protocol designed to test a novel procedure that may reduce symptoms of PTSD. Participants who qualified based on this preliminary screening were invited to complete an initial clinical intake to confirm diagnostic status and eligibility.

At the initial intake assessment, diagnostic status was determined by J.B. under the supervision of a licensed clinical psychologist (AJL). The Structured Clinical Interview for DSM-IV (SCID-IV; First, Spitzer, Gibbon, &

Williams, 1994), a semi-structured interview that assesses past and present diagnostic criteria, was used to collect information about Axis-I disorders and treatment history. PTSD diagnosis was determined using the Clinician-Administered PTSD Scale for DSM-IV (CAPS; Blake, Weathers, & Nagy, 1995). All interviews were videotaped, and a portion (25%) of the tapes was rated by a second independent clinician to assess inter-rater agreement for PTSD diagnoses. Interviewers agreed diagnostic status in all cases. The Life Events Checklist (Gray, Litz, Hsu, & Lombardo, 2004) was used to elicit participants' trauma history as part of the CAPS administration. Eligible participants were required to meet primary DSM-IV diagnosis of PTSD secondary to a traumatic sexual experience. In the case where a participant has experienced multiple traumatic events, she was included if sexual assault was subjectively considered the most distressing. Exclusion criteria included current trauma or PTSD-focused psychosocial treatment, active suicidality (i.e., expression of intent or plan to commit suicidal gestures, or suicide attempt within the past 6 months), evidence of substance dependence in the past 6 months, and evidence of current or past schizophrenia, bipolar disorder, or organic mental disorder. Individuals with additional diagnoses were not excluded so long as PTSD was the primary diagnosis. Current comorbid diagnoses included Major Depressive Disorder or other mood disorders (n=21, 51%), other anxiety disorders (n=18, 44%), substance abuse (n=2, 5%), and eating disorders (n=2, 5%). Participants taking medications were required to meet a six-week stability criterion; this occurred for six individuals. In addition, all participants

were required to meet English-language proficiency criteria due to the linguistic requirements of the cognitive tasks (i.e., ability to accurately comprehend all assessment instructions).

In total, 171 women inquired about the program and 116 were screened for participation. Of those, 30 did not attend their first assessment appointment and 31 were deemed ineligible during the phone screening (due to not having experienced sexual trauma, having experienced trauma too recently, having recent changes in treatment, being outside the San Diego area, or being unable to attend sessions regularly due to job or transportation difficulty). In total, 55 women were interviewed to assess eligibility (see Figure 1). Of those, 13 were excluded because they did not meet eligibility criteria (6 PTSD not primary or sub-clinical, 3 met diagnostic criteria for Bipolar disorder, 3 had recent medication or therapy changes, 1 reported that she had been diagnosed with dementia), and one participant declined to participate. Of the 41 women who were eligible and consented to participate, 37 attended the baseline assessment session and were subsequently randomized to the HIC or LIC condition, although 3 were removed for failing to follow study procedures (i.e., initiating alternative treatment). Of the remaining 34 participants, 7 did not return to begin the intervention, and 9 additional participants dropped out and were unavailable for subsequent assessments. Although most individuals who dropped out of the study were not able to be contacted, reasons provided for dropping included unexpectedly leaving the San Diego area ( $n = 1$ ), obtaining new work that conflicted with appointment

scheduling ( $n = 3$ ), being advised by a provider or family member that completing a research program might be harmful ( $n = 2$ ), and a sudden change in personal situation ( $n = 1$ ). There were no other statistically significant differences between women who completed the study and those who dropped out of treatment prematurely in terms of demographic characteristics, baseline clinical characteristics, or initial perceived treatment acceptability (all  $ps > .10$ ).

## **Measures**

**Interview-based Symptom Measures.** The Clinician-Administered PTSD Scale for DSM-IV (CAPS; Blake et al., 1995) was used to determine PTSD symptom severity and served as the primary symptom dependent measure. The CAPS is a structured interview designed to measure symptoms of PTSD (Weathers, Keane, & Davidson, 2001). Severity was determined using a total score of severity and intensity ratings for each symptom item.

Dichotomous PTSD diagnosis was determined by converting severity and intensity ratings using the “F1/I2” scoring rule (i.e., a symptom is considered present if the frequency is scored at least 1 and intensity is scored at least 2; Weathers, Ruscio, & Keane, 1999). The Structured Clinical Interview for DSM-IV (SCID-IV; First et al., 1994) was employed at to assess presence/absence of comorbid Axis-I disorders according to DSM-IV criteria and to determine inclusion/exclusion criteria.

**Self-Report Measures.** Participants completed a demographics form, which included questions regarding participant age, ethnicity, marital status,

and years of education. The PTSD Checklist-Civilian version (PCL-C; Weather, Litz, Huska, & Keane, 1994) was administered to assess PTSD symptoms. The PCL-C is a 17-item measure assessing PTSD symptom severity (Berlant & van Kammen, 2002). Items correspond to distress associated with PTSD symptoms outlined in the DSM-IV and are rated on a scale from 1 (not at all bothersome) to 5 (extremely bothersome). Scores are determined by summing symptom severity items, with a range from 17 to 85. For the purposes of the present study, participants were asked to rate symptoms occurring over the past week. Validation studies indicate that the PCL-C has sound psychometric properties (Orsillo, 2001). The State Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) was administered to assess general anxiety. The STAI is a 40-item self-report measure of anxiety with items scored on a one to four scale; 20 items reflect current state anxiety and 20 items reflect more general feelings of trait anxiety. The STAI-S was also administered after the cognitive assessments completed during the pre- and post-assessment to assess participant distress related to completing these tasks. Total scores for state and trait anxiety reflect the sum of items on respective scales. This measure possesses adequate psychometric characteristics (Spielberger et al., 1983). In addition, the Beck Depression Inventory II (BDI-II; Beck, Steer, & Brown, 1996) was administered to assess symptoms of depression. The BDI-II is a 21-item scale assessing symptoms over the previous two weeks. All items are multiple choice and scored on a scale of zero to three; total scores are based on the

sum of items ranging from zero to 63. The BDI-II is a reliable and well-validated measure of depressive symptoms (Beck et al. 1996). Based on evidence suggesting that the extent of trauma exposure in childhood is positively associated with adult cognitive functioning (e.g., Majer, Nater, Lin, Capuron, & Reeves, 2010), participants completed the Childhood Trauma Questionnaire – Screening Form (CTQ-SF; Bernstein et al., 2003) to determine presence and severity of childhood maltreatment. All 28 items are rated on a 5-point scale with response options ranked from “never true” to “very often true”. Items are divided into five subscales assessing specific types of childhood trauma: emotional abuse, emotional neglect, physical abuse, physical neglect, and sexual abuse. Subscale scores are calculated by summing items within each trauma type. This measure has demonstrated adequate psychometric properties (Bernstein et al., 2003). The Sheehan Disability Scale (SDS; Leon, Olfson, Portera, Farber, & Sheehan, 1997) was included as a measure of global impairment related to PTSD and other comorbid symptoms. This assessment is a three-item instrument for determining level of occupational and social impairment.

At the pre-assessment and post-assessment sessions, participants completed a brief treatment credibility measure (TCM; adapted from Borkovec & Nau, 1972). This 3-item measure assesses how logical the treatment seems, how confident the individual feels that the treatment will be effective, and how confident the individual would be recommending the treatment to a friend. Each item is rated on a 0 to 8 scale. As an additional measure of

acceptability, the number of sessions the participant attended was calculated after the individual completed participation.

The PCL-C and BDI-II were re-administered once per week after the baseline assessment for clinical monitoring purposes. These measures were also included in the follow up session that occurred one month after the post-assessment.

**Cognitive Assessments.** Participants completed assessments tapping inhibitory control processes at pre and post assessment in the following order: Ospan task, California Verbal Learning Test-II, thought suppression task.

***Working Memory Capacity Assessment.*** Proactive interference control was assessed before and after the training program using a computerized WMC task (Ospan; Unsworth et al., 2005) to determine whether or not cognitive gains from the training task are observed on a similar task with novel stimuli. In this task, each trial begins with a fixation cross in the center of the screen for 500ms. Then, a completed math problem (e.g.,  $1+3 = 6$ ) appears on the screen. Half of the equations presented are correct and half incorrect. The participant is asked to determine whether the math solution is correct by selecting a box on the screen using the mouse (left box for “yes,” right box for “no”). Once the participant completes the math problem, a letter (e.g., L) is presented on the screen for 500ms. Then the next trial begins with another equation and letter, until the end of the set. At the end of each set participants are presented with a recognition screen listing twelve letters. Using the mouse, participants are asked to select the letters that were



presented in the correct serial order. Once the recognition for the set is completed, the next set of trials begins in the same manner. The participant receives feedback about their math accuracy and memory at the conclusion of each set. Consistent with prior studies using this task, participants were tested on working memory span sizes from two to seven (Conway et al., 2005). Performance is assessed by totaling the number of items correctly identified in the correct order. Sets and trials were presented in a different random order for each participant. Figure 2 depicts this task.

***Proactive Interference Control Generalization Assessment.*** The California Verbal Learning Test, Second Edition (CVLT-II; Delis, Kramer, Kalpan, & Ober, 2000) was administered to assess generalizability of the training task to other assessments of proactive interference. The CVLT-II is a neuropsychological assessment commonly used to evaluate verbal learning and memory. The assessment has adequate psychometric properties (Woods et al., 2006). In this task, participants are first read a 16-word list (List A) containing four items from each of four semantic categories (animals, transportation, vegetables and furniture) and asked to verbally recall as many items as possible. This is repeated five times. Then, the participant is read a second 16-word list (List B) and asked to recall as many items as possible. List B consists of eight items from two of the categories included in List A (“shared categories”) and 8 items from two new categories (“unshared categories”). Thus, across both List A and B two of the word categories are the same and two are different. Although a number of memory indices can be

derived from this task, the outcome of interest for the present study was the proactive interference index (Kaplan & Delis, 1991; Verwoerd et al., 2011). To calculate this index, first the weighted average of shared category items on trial 1 is calculated ( $\# \text{ recalled on trial 1} \times \# \text{ recalled from "shared" items on trials 1-5} / \text{total } \# \text{ recalled on trials 1-5}$ ). Next, the number of shared items recalled from the second list is subtracted from this value. The decrease in recall ability for the shared category words from List A to List B reflects proactive interference. For this interference index score, higher values indicate that the individual was more susceptible to proactive interference across the lists.

***Thought Suppression Task.*** To obtain an in-laboratory assessment of thought regulation ability, participants completed a thought suppression task (Wegner et al., 1987). This task was selected first based on evidence that suppression ability is associated with WMC performance (Brewin & Beaton, 2002; Brewin & Smart, 2005). Second, data from the pilot study indicates that idiographic thought suppression is influenced by proactive interference control training (Bomyea & Amir, 2010). Third, prior research indicates that thought suppression ability related to traumatic memories differentiates individuals with and without PTSD. Although individuals with PTSD are able to suppress trauma-related thoughts when instructed to do so, compared to trauma exposed PTSD negative samples they experience a greater frequency of post-suppression “rebound” thoughts about their trauma (Shipherd & Beck, 1999, 2005).

For this task, the study experimenter first gave participants a definition of intrusive thoughts (Salkovskis & Campbell, 1994):

*Intrusions are thoughts that enter your mind repeatedly. That is, they do not only occur once or twice, but come back a number of times on separate occasions, and tend to interrupt what you are already thinking. They are unpleasant, unwanted, and can be upsetting. Intrusive thoughts are very common in the general population.*

Next, participants completed the fifteen minute thought suppression task. During this task, participants indicated the number of intrusive thoughts they experienced using a hand-held event marker. For the first five minute period, the experimenter instructed participants to think about anything they wished while simultaneously recording each time they experienced an intrusive thought about their trauma(s) (Najmi, Riemann, & Wegner, 2009):

*The next task involves a thought monitoring task. For the next five minutes, you can think of anything that comes to mind. During this time, your task is to record any occurrences of intrusive thoughts about the traumatic event you listed on your questionnaire [referring to PCL] – that is, involuntary memories such as images, sounds, thoughts, or feelings. So, for the next five minutes, please record occurrences of intrusive thoughts about the traumatic event you described. Every time such a thought occurs, record it by pressing this clicker once. It doesn't matter whether the thought occurs or not; just record the thought if it occurs. It is important that you continue this way for the full five minutes.*

For the second five minute period, the experimenter instructed participants to suppress thoughts about their traumatic event:

*During these five minutes, your task is to try not to think about the traumatic event you described. Try as hard as you can to not think of this traumatic event. Although this is your primary task, every time you notice that it pops to mind anyway please press*

*the clicker. It is important that you continue in the same way for the full five minutes.*

For the final five minute period, the experimenter instructed participants that they may think of anything, and to monitor occurrences of intrusive thoughts the traumatic event:

*For the next five minutes, you can think of anything that comes to mind. There are no additional instructions. During this time, your task is to record occurrences of thoughts about the traumatic event you described. Every time this type of thought occurs, record it by pressing this once. So, for the next five minutes, please record occurrences of intrusive thoughts about the traumatic event you described. It doesn't matter whether the thought occurs or not; just record the thought if it occurs. It is important that you continue this way for the full five minutes.*

Total number of intrusive thoughts during the suppression period indexed the participant's ability to deliberately reduce the frequency of trauma-related thoughts. Total number of thoughts during the post-suppression period indexed the "rebound effect" whereby attempts to suppress trauma-related thoughts paradoxically increase the frequency of these thoughts.

### **Training Program**

Participants were randomized to complete one of two modified Reading Span WMC tasks designed to vary in the amount of proactive interference control required (Reading Span tasks; Daneman & Carpenter, 1980, adapted by Lustig, et al., 2001; used by Bomyea & Amir, 2010), HIC or LIC. In this task, each trial begins with a fixation cross in the center of the screen for 500ms. Then, a sentence (e.g., "Jane walks her car in the park") appears on the

screen. The participant is asked to determine whether or not the sentence makes sense by selecting a box on the screen using the mouse (left box for “yes,” right box for “no”). Half of the sentences presented were correct and half incorrect. Once the participant completes the sentence problem, an item is presented on the screen for 500ms. Then the next trial begins with another sentence and item, until the end of the set. At the end of each set participants are presented with a recognition screen listing twelve items. Using the mouse, participants are asked to select the items that were presented in the correct serial order. Once the recognition for the set is completed, the next set of trials begins in the same manner. The participant receives feedback about their sentence accuracy and memory at the conclusion of each set. Participants completed three blocks of training in each session. Within each block, participants trained on span sizes of 2 to 6, with three repetitions of each span size presented in random order. Thus, during the three blocks the participant completed 45 trials total. Words and sentences used in the training task derived from four sets (one for each week) with the order of sets counterbalanced across participants.

**HIC condition.** The HIC condition contained high proactive interference across trials. To this end, item memoranda for all trials in the HIC were words (Bunting, 2006). Words used in the training task were selected from the MRC Psycholinguistic Database and included semantically unrelated words within the following parameters: length between four to eight words, frequency ratings between 30 to 100, and familiarity ratings between 400 and 700. In

order to perform well on the task participants were required to inhibit interference from memories of prior trials during each trial of the task.

**LIC condition.** The LIC condition contained relatively less proactive interference across trials. Item memoranda for trials in the LIC alternated between words and numbers (digits one through 12) every three trials (Bunting, 2006). Thus, although participants were required to remember the same total number of items as in the HIC (i.e., storage requirements were equivalent), there was relatively less proactive interference inherent in the task because trials with number memoranda interfere minimally on trials with word memoranda and vice versa.

## **Procedure**

**Baseline assessment session.** Upon arrival participants were informed about the study procedures, including a standardized description of the study rationale, and were provided written informed consent. Participants began the intake process by completing the clinical interview and self-report assessments to ascertain current and past anxiety, depression, and trauma history. Eligible participants returned for a second assessment session to complete the baseline Ospan assessment, the CVLT-II assessment, and the thought suppression task. J.B. reviewed the STAI-S completed by participants after these tasks to assess potential distress related to thinking about trauma. No participants indicated acute distress as a result of these assessments. Individuals who completed all baseline assessments were randomly assigned to the HIC condition or the LIC condition based on a computer-generated

random number system. Conditions were generated at random by an independent third party so that participants and research personnel remained blind to subjects' conditions.

**Training sessions.** Participants returned to complete a total of eight experimental sessions, with the goal of completing these sessions within four weeks. Selection of eight biweekly sessions was based on prior research using cognitive bias modification techniques in anxious populations (e.g., Amir et al., 2008). During each session, the participant completed three blocks of the HIC or LIC task, depending upon condition assignment. This computer portion of each session lasted approximately 30 minutes total. Every other session the participant completed a brief self-report packet consisting of the PCL-C and BDI for clinical monitoring of symptom exacerbation.

**Post-assessment session.** One week after completion of the last training session, participants returned to complete the post- assessment. At this point, participants completed the same assessments as were used during the baseline session, including a clinical interview, self report packet, and cognitive assessments.

**Follow up session.** One month after completion of the post-assessment session, participants returned to complete a follow up assessment. During this session, participants completed the CAPS interview and an abbreviated self-report packet including the PCL-C and BDI.

### **Study design and analysis plan**

Data was analyzed as a 2 (Group: HIC, LIC) X 2 (Time: Pre-assessment, Post-assessment) design with repeated measurement on the second factor. Primary outcome measures included: 1) performance on the cognitive assessment of proactive interference control (Ospan) and 2) PTSD re-experiencing symptoms (Clinician Administered PTSD Scale symptom severity scores for re-experiencing items). Clinical significance of symptom change was also evaluated. Secondary analyses were conducted to examine the generalization of the manipulation to 1) another assessment of proactive interference control (California Verbal Learning Test-II interference index), 2) the ability to actively regulate trauma-related cognitions (Thought Suppression Task) 3) general distress (STAI-T and BDI-II symptom scores), and 4) maintenance of treatment gains (CAPS symptom severity scores for re-experiencing symptoms from post to 1-month follow up). Each analysis was conducted two ways. First, intent-to-treat (ITT) analyses with missing data imputed using the expectation maximization (EM) method were conducted on all participants randomized (Musil, Warner, Yobas, & Jones, 2002). Second, these analyses were repeated including only women who had completed the study. Throughout the results section, only data from participants who completed the cognitive training portion of the study, and thus received the critical exposure to study procedures, are presented graphically. In the interest of determining any potential effects of the HIC and LIC conditions on cognitive performance or symptom outcomes, Cohen's d effect sizes were calculated for change from pre- to post-assessment in each group on primary measures.



## **Results**

### **Demographic, clinical, and cognitive characteristics at baseline.**

Table 1 presents descriptive data as well as statistical analyses for the demographic and clinical characteristics of the sample at baseline. Separate one-way analyses of variance (ANOVAs) indicated that participants in the two groups did not differ on age or measures of clinical features, including CAPS total severity, duration of PTSD symptoms, number of trauma types experienced, or PCL-C, STAI-T, BDI-II, SDS, or CTQ-SF subscale scores (all  $ps > .14$ ) with the exception of the physical and emotional abuse subscales (individuals in the HIC scored higher than those in the LIC;  $p < .05$  and  $.03$ , respectively). Chi-square analyses did not reveal differences in participant ethnic background, education, income, or marital status (all  $ps > .20$ ). Separate one-way ANOVAs were also conducted on the cognitive measures. These analyses confirmed that participants in the HIC and LIC groups did not significantly differ in baseline cognitive performance on the Ospan, CVLT interference index, or thought intrusions (all  $ps > .50$ ).

### **Treatment credibility, acceptability, and adherence.**

On a scale of 0 (not at all) to 8 (very), participants on average rated the treatment as moderately logical ( $M = 5.33$ ,  $SD = 1.62$ ), indicated that they were moderately confident that the treatment would work ( $M = 4.72$ ,  $SD = 1.71$ ), and reported that they were moderately confident in recommending the program to others ( $M = 5.27$ ,  $SD = 1.70$ ) at baseline. No significant group differences were found on confidence, logic, or recommendation items of the

treatment credibility questionnaire at the pre- or post-assessment ( $ps > .06$ ). Number of completed sessions was also assessed to determine if the HIC and LIC groups demonstrate differential drop-out rates. Results suggested that there were no group differences in drop rate between the HIC and LIC groups ( $p > .50$ ).

### **Intent-to-Treat Analyses**

**Change in WMC.** The effectiveness of the manipulation was assessed by comparing pre and post -training WMC performance between the groups. Ospan scores (i.e., total number of correctly identified items) were submitted to a 2 (Group: HIC, LIC) x 2 (Time: Pre-assessment, Post-assessment) ANOVA with repeated measurement on the second factor. Results revealed no significant main effect of time,  $F(1, 35) = 3.77, p = .06, \eta_p^2 = .10$ , main effect of group,  $F(1, 35) = 1.60, p = .21, \eta_p^2 = .04$ , or interaction of time and group,  $F(1, 35) = .82, p = .37, \eta_p^2 = .02$ . The observed pattern of means suggested that Ospan scores improved within HIC condition (pre:  $M = 63.36, SD = 13.58$ ; post:  $M = 68.64, SD = 7.45$ ),  $d = .58$ , while Ospan scores within the LIC condition did not (pre:  $M = 60.33, SD = 14.47$ ; post:  $M = 62.26, SD = 13.93$ ),  $d = .16$ ;  $d_{diff} = .30$ .

**Change in PTSD Symptoms.** CAPS re-experiencing scale scores were submitted to a 2 (HIC, LIC) x 2 (Time: Pre-assessment, Post-assessment) ANOVA with repeated measurement on the second factor. Results revealed a main effect of time,  $F(1, 35) = 59.27, p < .001, \eta_p^2 = .63$ . The main effect of group,  $F(1, 35) = 1.94, p = .17, \eta_p^2 = .05$ , and interaction of

time and group was not significant,  $F(1, 35) = .34, p = .56, \eta_p^2 = .01$ . The observed pattern of means suggested that CAPS re-experiencing scores improved within HIC condition (pre:  $M = 16.15, SD = 5.38$ ; post:  $M = 7.62, SD = 5.15$ ),  $d = 1.85$ , while CAPs re-experiencing scores within the LIC condition did not (pre:  $M = 18.0, SD = 7.36$ ; post:  $M = 10.67, SD = 6.69$ ),  $d = .96$ ;  $d_{diff} = .19$ .

**Clinical significance analysis.** To determine clinical significance of observed changes, the percentage of individuals in the HIC and LIC groups who no longer met diagnostic criteria for PTSD at post assessment was compared. Chi-squared analyses did not indicate a significant between-group difference in the number of individuals who no longer met diagnostic criteria on the CAPS (61% in LIC vs. 68% in HIC;  $X^2(1) = .22, p = .64$ ;  $\Phi = .08, p = .64$ ). Recovery status was also examined, with response defined as an individual with at least a 20% reduction from pre-assessment CAPS severity score (Ladoucer et al., 2000). Cases where participant symptoms worsened was determined from the presence of a reliable increase of 20% or more in symptoms. Individuals with no change or change within 20% of pre-assessment scores were considered non-responders. Chi-square analysis conducted on recovery status for participants in the two groups (i.e., number of responders, non-responders, and deteriorated cases in the two groups) indicated an equivalent percentage of responders in the groups (83% in LIC vs. 84% in HIC;  $X^2(2) = .01, p = .94$ ;  $\Phi = -.01, p = .94$ ). Finally, functional impairment in the two groups based on the SDS (a summed score of social,

occupational, and domestic domains) was examined. This rating was submitted to a 2 (HIC, LIC) x 2 (Time: Pre-assessment, Post-assessment) ANOVA with repeated measurement on the second factor. Results revealed a main effect of time,  $F(1, 34) = 12.98, p < .01, \eta_p^2 = .28$ . The main effect of group  $F(1, 34) = .03, p = .87, \eta_p^2 < .01$ , and interaction of time and group was not significant,  $F(1, 34) = .61, p = .44, \eta_p^2 < .02$ .

**Cognitive Generalization: CVLT interference index.** To examine the effect of the experimental manipulation on cognitive tasks tapping inhibitory control, CVLT-II interference index scores were submitted to a 2 (Group: HIC, LIC) x 2 (Time: Pre-assessment, Post-assessment) ANOVA with repeated measurement on the second factor. Results revealed no significant main effect of time,  $F(1, 35) = 2.76, p = .11, \eta_p^2 = .07$ , group,  $F(1, 35) = .83, p = .37, \eta_p^2 = .02$ , or interaction of group by time,  $F(1, 35) = .09, p = .76, \eta_p^2 < .01$ .

**Cognitive generalization: thought suppression task.** The thought suppression task was analyzed as a behavioral index of the training program's generalization to participant's ability to intentionally regulate intrusive cognitions. To analyze the assessment of thought intrusions over each time point (thought monitoring 1, suppression, thought monitoring 2) a MANOVA approach for repeated measures was used. The within-subjects component of the hypothesized Group (LIC, HIC) x Time (Thought Monitor 1, Suppression, Thought Monitor 2) interaction of interest consisted of two contrast variables. The first model, whereby the number of intrusions is reduced from baseline thought monitoring to suppression then increases from suppression to post

thought monitoring (i.e., -1, -2, 3), was non-significant,  $F(1, 31) = .50, p = .48$ .

The second compared the baseline thought monitoring to the suppression phase (i.e., 1, -1, 0) was also non-significant  $F(1, 31) = .10, p = .75$ .

**Generalization to other distress symptoms.** General distress measures (STAI-T, BDI-II) were entered simultaneously in multivariate analyses of variance (MANOVA; a 2 (Group: HIC, LIC) x Time (Pre-assessment, post-assessment) with anxiety (STAI-T) and depression (BDI-II) scores as the two dependent variables. Results revealed a main effect of time,  $F(2,34) = 20.72, p < .001, \eta_p^2 = .55$ . The main effect of group,  $F(2,34) = .36, p = .70, \eta_p^2 = .02$ , and interaction of time and group was not significant,  $F(2,34) = .12, p = .89, \eta_p^2 < .01$ .

**Follow-up analysis.** CAPS re-experiencing scale scores at post-assessment and follow-up were submitted to a 2 (HIC, LIC) x 2 (Time: Post-assessment, follow-up) ANOVA with repeated measurement on the second factor. Results revealed no significant main effect of time,  $F(1, 35) = 3.84, p = .06, \eta_p^2 = .10$ , main effect of group,  $F(1, 32) = 1.10, p = .30, \eta_p^2 = .03$ , or interaction of time and group,  $F(1, 35) = 2.22, p = .15, \eta_p^2 = .06$ .

### **Completer analysis**

**Change in WMC.** The effectiveness of the manipulation was assessed by comparing pre and post -training WMC performance between the groups. Ospan scores were submitted to a 2 (Group: HIC, LIC) x 2 (Time: Pre-assessment, Post-assessment) ANOVA with repeated measurement on the second factor. Results revealed that no significant main effect of time,  $F(1, 16)$

= 2.92,  $p = .11$ ,  $\eta_p^2 = .15$ , group,  $F(1, 16) = 1.61$ ,  $p = .422$ ,  $\eta_p^2 = .09$ , or interaction of time and group,  $F(1, 16) = 2.20$ ,  $p = .16$ ,  $\eta_p^2 = .12$ , was present. The observed pattern of means suggested that Ospan scores improved within HIC condition (pre:  $M = 64.82$ ,  $SD = 13.03$ ; post:  $M = 70.90$ ,  $SD = 9.31$ ),  $d = 1.16$ , while Ospan scores within the LIC condition did not (pre:  $M = 58.57$ ,  $SD = 17.82$ ; post:  $M = 59.00$ ,  $SD = 22.44$ ),  $d = .05$ ;  $d_{diff} = .52$ .

**Change in PTSD Symptoms.** CAPS re-experiencing scale scores were submitted to a 2 (HIC, LIC) x 2 (Time: Pre-assessment, Post-assessment) ANOVA with repeated measurement on the second factor. Results revealed a main effect of time,  $F(1, 16) = 18.86$ ,  $p < .001$ ,  $\eta_p^2 = .54$ . There was additionally a marginally significant time by group interaction  $F(1, 16) = 3.66$ ,  $p = .07$ ,  $\eta_p^2 = .19$ . Exploratory follow up paired samples t-tests suggested that re-experiencing symptoms improved within HIC condition,  $t(10) = 6.23$ ,  $p < .001$ ,  $d = 1.96$ , but not the LIC condition  $t(6) = 1.23$ ,  $p = .26$ ,  $d = .47$ ;  $d_{diff} = .66$ . Figure 3 represents the means and standard errors of the CAPS re-experiencing severity scores pre and post-training as well as follow-up for each group.

**Clinical significance analysis.** To determine clinical significance of observed changes, the percentage of individuals in the HIC and LIC groups who no longer met diagnostic criteria for PTSD at post assessment was compared. Chi-squared analyses indicated no significant between-group difference in the number of individuals who no longer meet diagnostic criteria on the CAPS (73% in HIC vs. 57% in LIC;  $X^2(1) = .48$ ,  $p = .49$ ;  $\Phi = .16$ ,  $p =$

.49). Recovery status chi-square analysis also indicated no significant difference in percentage of responders (82% in HIC vs. 71% in LIC;  $X^2(1) = .27, p = .61$ ;  $\Phi = -.12, p = .61$ ). No participants experienced clinically significant deterioration. Finally, functional impairment in the two groups based on the SDS was submitted to a 2 (HIC, LIC) x 2 (Time: Pre-assessment, Post-assessment) ANOVA with repeated measurement on the second factor. Results revealed a main effect of time, with improvements from pre- to post-assessment,  $F(1, 16) = 5.82, p = .03, \eta_p^2 = .27$ . The main effect of group  $F(1, 16) = .39, p = .54, \eta_p^2 = .02$ , and interaction of time and group were not significant,  $F(1, 16) = .03, p = .86, \eta_p^2 = .002$ . Table 2 presents descriptive information for CAPS total severity and SDS scores.

**Cognitive Generalization: CVLT interference index.** To examine the effect of the experimental manipulation on cognitive tasks tapping inhibitory control, CVLT-II interference index scores were submitted to a 2 (Group: HIC, LIC) x 2 (Time: Pre-assessment, Post-assessment) ANOVA with repeated measurement on the second factor. Results revealed no significant main effect of time,  $F(1, 16) = 2.00, p = .18, \eta_p^2 = .11$ , group,  $F(1, 16) = .71, p = .41, \eta_p^2 = .04$ , or interaction of group by time,  $F(1, 16) = 1.46, p = .25, \eta_p^2 = .08$ . Figure 4 represents the means and standard errors of the CVLT-II interference index scores pre and post-training for each group.

**Cognitive generalization: thought suppression task.** The first modeled effect, whereby the number of intrusions is reduced from baseline thought monitoring to suppression, then increases from suppression to post

thought monitoring (i.e., -1, -2, 3), was non-significant  $F(1, 12) = .31$   $p = .59$ . The second comparing the baseline thought monitoring to the suppression phase (i.e., 1, -1, 0) was also non-significant,  $F(1, 12) = .03$ ,  $p = .87$ . Figure 5 presents the means and standard deviations of the thought intrusions at each time point within the HIC and LIC groups.

**Generalization to other distress symptoms:** Symptoms of anxiety and depression were entered simultaneously in 2 (Group: HIC, LIC) x Time (Pre-assessment, post-assessment) MANOVA with anxiety (STAI-T) and depression (BDI-II) scores as the two dependent variables. Results revealed a main effect of time,  $F(2,15) = 9.03$ ,  $p < .001$ ,  $\eta_p^2 = .55$ . The main effect of group,  $F(2,15) = 1.18$ ,  $p = .137$ ,  $\eta_p^2 = .12$ , and interaction of time and group were not significant,  $F(2,15) = .05$ ,  $p = .95$ ,  $\eta_p^2 = .01$  (see Table 2 for descriptive statistics).

**Follow-up analysis.** CAPS re-experiencing scale scores at post-assessment and follow-up were submitted to a 2 (HIC, LIC) x 2 (Time: Post-assessment, follow-up) ANOVA with repeated measurement on the second factor. Results revealed no significant main effect of time,  $F(1, 12) = .004$   $p = .95$ ,  $\eta_p^2 < .001$ , main effect of group,  $F(1, 12) = 1.29$ ,  $p = .28$ ,  $\eta_p^2 = .10$ , or interaction of time and group,  $F(1, 12) = 1.96$ ,  $p = .19$ ,  $\eta_p^2 = .14$ .

**Exploratory mediation analysis.** An exploratory mediation analysis was conducted in order to examine the potential effect of changes in cognitive functioning on changes in re-experiencing symptoms. To determine the presence of mediation, analysis was conducted to determine whether or not



the potentially mediating variable (i.e., change in Ospan) partially or fully accounted for the relationship between the independent variable (i.e., condition, HIC or LIC) and the outcome of interest (i.e., change in CAPS re-experiencing symptoms). Originally described by Baron and Kenny (1986), mediation traditionally involves demonstration that the relationship between a given independent variable and the outcome of interest is reduced when the mediator and independent variable are modeled simultaneously (see also Mackinnon, Fairchild, & Fritz, 2007 for an updated description of mediated effects). We also indexed the significance of potential mediated effects using the Prodcin program (MacKinnon et al., 2007), which provides confidence intervals for the indirect effect, and calculated the percent mediation for each model using the procedures described by Kenny and colleagues (2003). Figure 6 presents the results of this mediation analysis. Tests of the indirect effect using the Prodcin program did not indicate the presence of a significant mediated effect, as the confidence intervals for the indirect effect crossed zero ( $ab = -.74$ ; 95% CI  $[-2.95, 1.48]$ ). Change in Ospan accounted for 2% of the effect of condition on PTSD re-experiencing symptom reduction.

## **Discussion**

The present study sought to experimentally manipulate a cognitive process, specifically proactive interference control, using a WMC task in an effort to modify re-experiencing symptoms in a sample of women with PTSD. It was hypothesized that participants completing the HIC program, which required repetitive practice controlling proactive interference, would demonstrate better improvement on a WMC task from pre- to post-training relative to the LIC program, which provided less proactive interference control practice. It was also hypothesized that participants in the HIC condition would demonstrate greater reductions in CAPS re-experiencing symptoms from pre- to post-training relative to participants in the LIC condition. Generalization of any potential training effects to alternative inhibitory control measures and self-reported anxiety and depression symptoms was also assessed.

### **Change in WMC: Assessing the effect of training on Ospan performance**

Results from the both the intent-to-treat (ITT) and completer samples indicated that participants did not differ in WMC performance over time. ITT data did not support the hypothesized differential improvement in WMC scores across the HIC and LIC conditions. Within completers, results similarly indicated that participants in both groups demonstrated no differential change in WMC performance from pre- to post-assessment. However, examining groups separately indicated that the effect size observed in individuals in the HIC group was large, while the effect size for those in the LIC group was small. These differences in effect size may indicate that participants did not

simply improve as a result of practicing and becoming more familiar with task demands and/or by becoming more proficient at the necessary functions required for the task. For those who completed the full protocol, the greater intensity of the HIC condition appears to have had a greater effect on the targeted capacity. However, the lack of a time by group interaction precludes firm conclusions regarding the differential change across the HIC and LIC conditions.

Findings from the WMC assessment are only partially consistent with the cognitive training literature, suggesting that training on complex span tasks such as the reading span task transfers to other similar tasks (Harrison, Shipstead, Hicks, Hembrick, Redick, & Engle, in press), and broader findings in the literature indicating that training components of executive functioning is possible with psychiatric populations (Vinogradov, Fisher, & de Villers-Sidani, 2012). Results from the earlier study (Bomyea & Amir, 2010) using this form of WMC training demonstrated more robust evidence that the HIC improved WMC more effectively than the LIC. One possible explanation for this discrepancy pertains to the multiple sessions participants completed in the current study. Because participants in the LIC condition completed the LIC task repeatedly over the course of the study, they had greater opportunity to master the WMC task relative to those in the single-session version in Bomyea and Amir (2010). That is, the lack of a condition by time interaction may have been due to better performance in the LIC group due to increased opportunity for practice of the trained task, which contained some degree of proactive

interference control. However, examination of the means suggests that individuals in the LIC group minimally improved in their performance across studies. Thus, the lack of an observed interaction may be due to the study being underpowered to detect this effect. It is notable that these clinical participants achieved this level of cognitive functioning after seven additional training sessions compared to participants in Bomyea & Amir (2010). This suggests that effectively training the necessary proactive interference control may be more difficult in this population relative to healthy undergraduates, consistent with suggestions that individuals with psychopathology may be more resistant to training due to deficits in the cognitive systems that this type of training targets (Vinogradov et al., 2013).

### **Change in CAPs re-experiencing: Assessing the effect of training on PTSD symptoms and clinical change**

In the ITT sample and among completers, both the HIC and LIC groups demonstrated a decrease in re-experiencing symptoms over time on the CAPS interview. There was preliminary evidence of differential change by group from pre- to post-assessment in re-experiencing symptoms among completers, with participants in the HIC condition showing a trend toward greater improvement relative to those in the LIC condition. The improvements in the HIC condition across time were statistically significant with a large effect size, while those in the LIC condition were non-significant with a small effect size. Interestingly, across both the HIC and LIC groups most participants experienced a substantial reduction in overall PTSD symptoms and functional

impairment. The majority of participants no longer met diagnostic criteria for PTSD at the end of the intervention. Given that PTSD is typically a chronic unremitting disorder in the absence of treatment, this large proportion of participants with clinical change suggests both LIC and HIC may have conferred benefits. However, firm conclusions about the nature of these changes cannot be made in the absence of a waitlist control group. While no statistically significant differential improvement was seen over time between the HIC and LIC conditions, participants in the HIC group reported modestly greater improvements in overall severity and self-rated functional impairment. As with findings of WMC improvements across both groups, these findings may reflect a combination of lack of statistical power and effects of the LIC being a less intense version of the HIC.

The trends observed during the active phase of the study remained generally stable from post to follow up period, with some degree of convergence in the groups over this time period. These data suggest it is possible that any effect of the HIC condition is not enduring. However, a number of methodological issues make conclusions about the follow up data very preliminary. First, a large number of participants were lost to follow up, resulting in a small final sample that was not necessarily representative of all participants who received the intervention. It is also important to note that participants were given recommendations for treatment after the study if they continued to meet clinical criteria for PTSD. Many participants pursued treatment after the acute phase of the study, which may be reflected in these

data. Future study with a controlled, long-term follow up period is needed to make more definitive conclusions about any potential continued effect of this type of training program.

The present study is the first to examine the effect of a computerized cognitive training program on symptoms of anxiety or PTSD. However, these findings are broadly consistent with literature suggesting that symptoms can be reduced by computerized cognitive training programs that are designed to target purported cognitive mechanisms of anxiety (e.g., MacLeod, 2012; MacLeod & Mathews, 2012). The present study posited, based on theoretical models (e.g., Anderson & Levy, 2011) and documented relationships between proactive interference control and intrusive thoughts (e.g., Bomyea, Amir, & Lang, 2012; Eren-Kocak, Kilic, & Hizli, 2009), that the proposed mechanism for this change is the differential practice of proactive interference control between the HIC and LIC groups. However, mediation analyses designed to test change in WMC as a mediator of the relationship between condition and re-experiencing symptoms did not reach statistical significance. Given the small sample, this type of analyses was likely underpowered to detect statistical significance of the indirect path in a mediation approach. Alternatively, the measure utilized to assess proactive interference control may not have optimally captured the purported cognitive process at work because of the additional cognitive capacities required for the task (e.g., memory). Other unknown mechanisms may also account for the reduction in symptoms over time. These might be non-specific factors such as the behavioral activation

required to come to the lab weekly, placebo effects from attending either the HIC or LIC sessions, or talking openly about traumatic experiences with the assessor. Regression toward the mean is another possible explanation for these changes, although it seems unlikely that this would fully account for the changes observed in participants. Response rates observed in the present study are similar to rates seen in many trials of psychotherapy interventions such as CPT or PE. For example, Resick et al. (2002) reported that approximately 40-80% of women completing CPT or PE no longer met diagnostic criteria for PTSD at post-treatment. The numbers in the present study may be slightly higher due to the relatively mild overall severity of the sample. Nonetheless, the initial success of these programs in reducing PTSD symptoms and functional impairment is promising.

### **Assessment of symptom and cognitive generalization**

In the ITT and completer samples, both HIC and LIC groups demonstrated a reduction in general distress symptoms over time with no group differences. These findings are consistent with the improvements seen in PTSD symptoms and suggest generalization of symptom improvement.

There was limited evidence of generalization of cognitive training effects. There was no statistically significant impact of time or condition on CVLT interference index performance. As this is the first study to use the CVLT PI index as a measure of change over the course of training, it is possible that the lack of generalization reflects a problem with this measure (e.g., low sensitivity to change). However, these findings are consistent with a

common finding among cognitive training paradigms that training effects often fail to generalize to alternative tasks (von Bastian & Oberauer, 2013). In particular, tasks that are further removed from the parameters of the trained task appear to be less impacted by training programs. Both the WMC and CVLT indices utilized were designed to tap proactive interference control to some extent. The methodology in each of these tasks, however, differed from the WMC training programs substantially. It may be the case that other cognitive processes heavily involved in these tasks, such as verbal or memory processes, were not impacted sufficiently by the HIC or LIC training programs to translate to meaningful changes in performance. The effect of the training on symptoms, however, suggests that there may have been some form of generalization to cognitive functioning that was not tapped by the cognitive generalization task used. Future research is needed to determine what the mechanism of action might be for the reduction in symptoms, given that the transfer to other cognitive tasks appears absent in the current data.

Analysis of the thought suppression task did not indicate the expected increase in “rebound” intrusions in either the HIC or LIC group at pre- or post-assessment during the suppression and post-suppression phases. It appears that even prior to completing study procedures, participants demonstrated a fairly proficient ability to decrease intrusive thoughts about their traumatic event when instructed to do so. This finding is at odds with prior studies of thought suppression in individuals with PTSD, which indicate a post-suppression increase in trauma-related thoughts (Beck et al., 2006; Shipherd



& Beck, 1999). Methodological differences may have partially accounted for this discrepancy. For example, Beck et al. (2006) and Shipherd and Beck (1999) required participants to write their stream of consciousness rather than using an event marker to indicate the presence of trauma-related thoughts. In this type of procedure, participants were able to see trauma reminders in their own writing, which may have prompted a greater number of subsequent intrusive thoughts relative to the silent event marker paradigm used in the present study. Although the expected interaction of phase by condition was not observed in the present data, the pattern of means suggests the HIC condition experienced a general reduction in intrusive thoughts from pre- to post-assessment across the three phases, while those in the LIC condition had minimal changes in intrusive thoughts from the pre- to post-assessment.

### **Limitations and Future Directions**

A number of limitations to the present study should be noted. First, the sample of women recruited for the study was relatively small and characterized by a high drop-out rate. Treatment drop-out rates are reported to be relatively high in many treatment outcome studies (up to 55%; Schottenbauer et al., 2008); the rate of the present study (43% of those randomized, 30% of those who began the intervention) is on the upper end of the published rates in prior research. The relatively high rate of voluntary withdrawal from the study could be due to a number of factors. First, given that avoidance is a cardinal feature of PTSD, participants may have felt that returning to the lab after completing difficult assessments (e.g., CAPS) was

too difficult or unpleasant. Second, features of the study design may have contributed. The study was not recruiting from treatment-seeking sample. Thus, motivation to continue with the program may have been relatively diminished for some individuals. In addition, the structure of compensation payments (i.e., compensating participants after the first assessment and then not again until after the post-assessment) may have played a role for participants motivated by the monetary aspect of the study. Consistent with these hypotheses, the majority of withdrawals from the study occurred after the pre-assessment and before the participants had completed any of the HIC or LIC sessions. Finally, the program may have been perceived as uninteresting by participants. Although assessment of study acceptability indicated ratings in the moderate range, anecdotal evidence examining participants' comments after study completion suggest that some individuals wished the program had been more engaging.

A number of characteristics of the sample also limit generalizability. The decision to select a sample homogenous in terms of trauma history is consistent with other treatment outcome studies for PTSD, and was done to maximize study power to detect an effect of the HIC/LIC manipulation. However, this selection process limits conclusions that can be made about the potential effects of the HIC or LIC programs in individuals with other types of trauma exposure. Similarly, the use of relatively stringent inclusion/exclusion criteria means that findings may not generalize to other samples with specific comorbid conditions or other features that were not included in this study. In

addition, although the participants all met clinical diagnoses for PTSD, on average the level of symptomology was only moderate.

Given the small sample in the present study, one logical future direction would be to recruit a larger sample of participants. Assessing the effects of the LIC and HIC in a larger sample would provide adequate power to detect potential interactive effects of condition by time. A larger sample would also allow for adequate statistical analysis of proposed mediators of symptom reduction. In addition to increasing the overall number of participants, future studies might also allow for broader inclusion and exclusion criteria and recruit participants with more severe levels of symptomology to test generalizability of HIC/LIC effects. The addition of an alternative control group, such as a waitlist, assessment-only, or an attention control group, would also bolster the conclusions that can be made about the role of proactive interference control relative to regression toward the mean, the effect of repeated testing, or other non-specific factors.

Improvements to the design and implementation of the training programs might also be addressed in subsequent studies. For example, the HIC and LIC conditions might be made more distinct to maximize any potential group differences as a result of the programs. Adding the HIC/LIC procedures to more explicit, compensatory cognitive rehabilitation programs might demonstrate more robust effects on cognition. Similarly, future studies might explore the effect of adding cognitive training as an adjunct to traditional PTSD psychotherapy. Rapidly increasing technological advances have made

psychotherapeutic interventions accessible via smartphones, tablets, and computers (see for example PE Coach and other apps produced by the T2 division of the Department of Defense; [www.t2.health.mil](http://www.t2.health.mil)). One interesting possibility for future cognitive training techniques would be to harness this technology to tap essential cognitive processes such as attention and memory using “gaming” programs that are fun and engaging to participants. Should these types of cognitive training techniques prove effective in improving cognitive performance and reducing intrusive thoughts, future studies might also explore the effectiveness of this type of program for other disorders (e.g., traumatic brain injury, depression).

### **Summary and conclusions**

Based on prior theory and empirical data suggesting a link between cognitive control and re-experiencing symptoms, the present study experimentally tested two computerized training programs designed to differentially train proactive interference control. Results of the current study suggest that participants in both the HIC and LIC conditions improved in PTSD re-experiencing and general distress symptoms over time. Preliminary evidence suggests that those in the HIC condition may have demonstrated incremental improvements over the LIC on WMC. There was less evidence for generalization of gains to alternative cognitive control tasks. Results are promising in that participants completing this brief computerized intervention demonstrated clinically significant reductions in distress. However, future research is needed to recruit and retain larger samples of participants,

improve training procedures, and determine potential mechanisms of action.

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## Tables and Figures

Table 1. Baseline characteristics of the ITT sample.

Variable	HIC (n = 19)	LIC (n = 18)
Mean Age (SD)	30.8 (11.1)	26.6 (11.0)
Education	n	n
< 12 years	0	1
12 years	3	4
13 -15 years	9	6
16 years	5	5
> 16 years	2	2
Race		
Caucasian	10	6
Latina	4	5
Black	2	1
Asian	3	5
Other/Biracial	0	1
Marital Status		
Single	14	7
Married	2	5
Divorced	1	2
Cohabiting	1	1
Other/declined to respond	1	3
Income (thousands per year)		
> \$50	4	2
\$20-50	7	6
< \$15	7	10
Unknown	1	0
Mean CAPS total severity score (SD)	61.6 (13.0)	67.39 (15.3)
Mean number of traumas (SD)	5.5 (2.4)	4.5 (1.9)
Mean months duration of PTSD (SD)	151.8 (171.3)	103.4 (118.1)
Mean STAI- Trait (SD)	58.10 (10.2)	58.37 (13.3)
Mean BDI (SD)	28.47 (11.4)	29.94 (11.4)
Mean SDS (SD)	19.33 (7.8)	18.06 (6.2)
Mean CTQ- Physical abuse (SD)	11.06 (5.0)	8.00(3.8)
Mean CTQ- Physical neglect (SD)	12.11(2.8)	11.89 (3.0)
Mean CTQ- Emotional abuse (SD)	16.64 (6.4)	12.22 (5.0)
Mean CTQ- Emotional neglect (SD)	15.06 (4.2)	14.72 (6.0)
Mean CTQ- Sexual abuse (SD)	15.47 (8.3)	13.72 (8.2)

Table 2. Descriptive statistics for clinical data in completer sample.

Variable	HIC (n = 11)	LIC (n = 7)
Mean CAPS total severity score at pre (SD)	60.5 (14.0)	66.4 (20.9)
Mean CAPS total severity score at post (SD)	35.5 (16.3)	39.9 (19.0)
Mean STAI- Trait at pre (SD)	56.4 (10.2)	61.4 (11.0)
Mean STAI- Trait at post (SD)	47.8 (11.9)	54.6 (11.4)
Mean BDI at pre (SD)	26.1 (11.2)	32.6 (5.3)
Mean BDI at post (SD)	14.3 (13.1)	22.1 (11.9)
Mean SDS at pre (SD)	18.9 (8.9)	20.7 (5.25)
Mean SDS at post(SD)	13.6 (9.9)	16.1 (17.0)

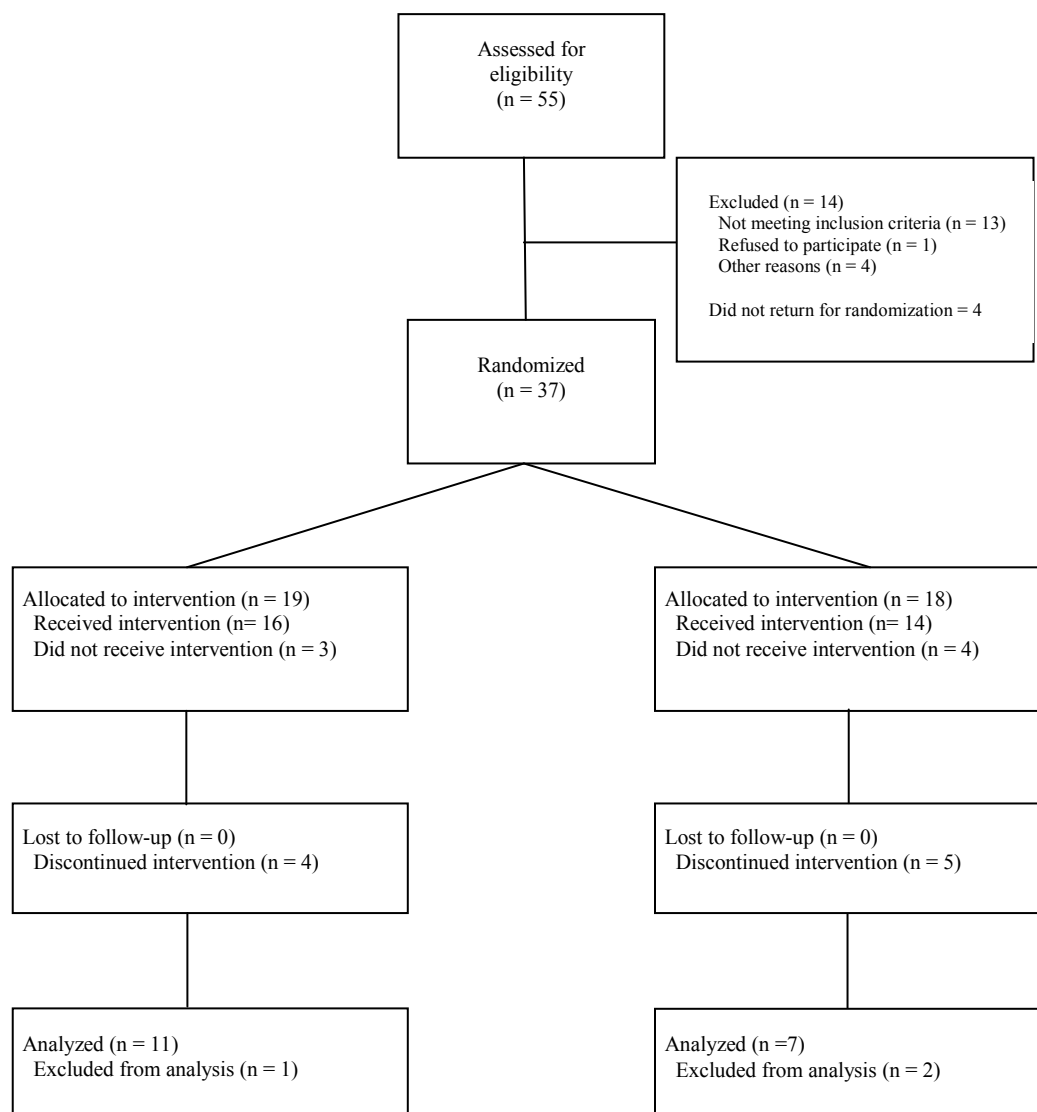


Figure 1. Flow chart of the progression of participants through the study

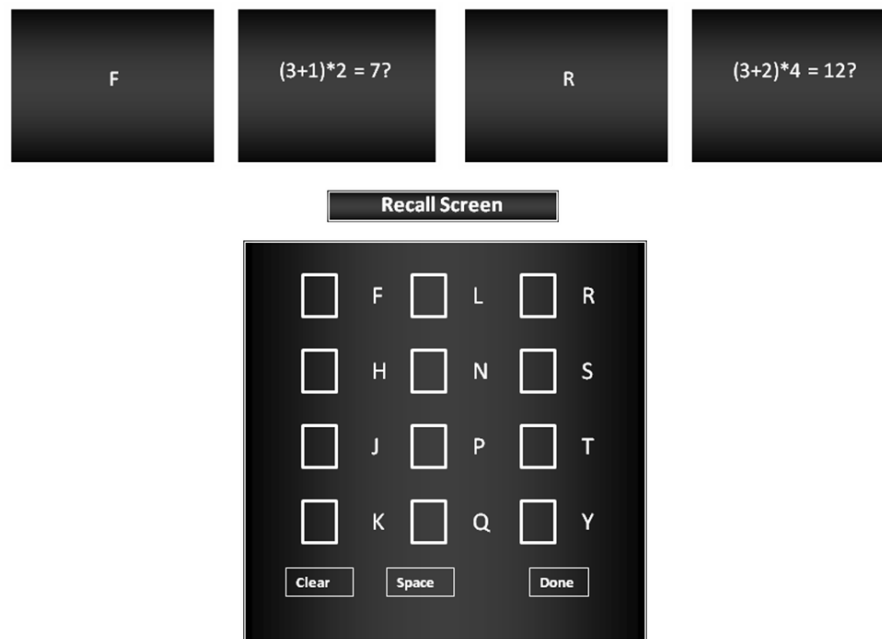


Figure 2. Depiction of Ospan task

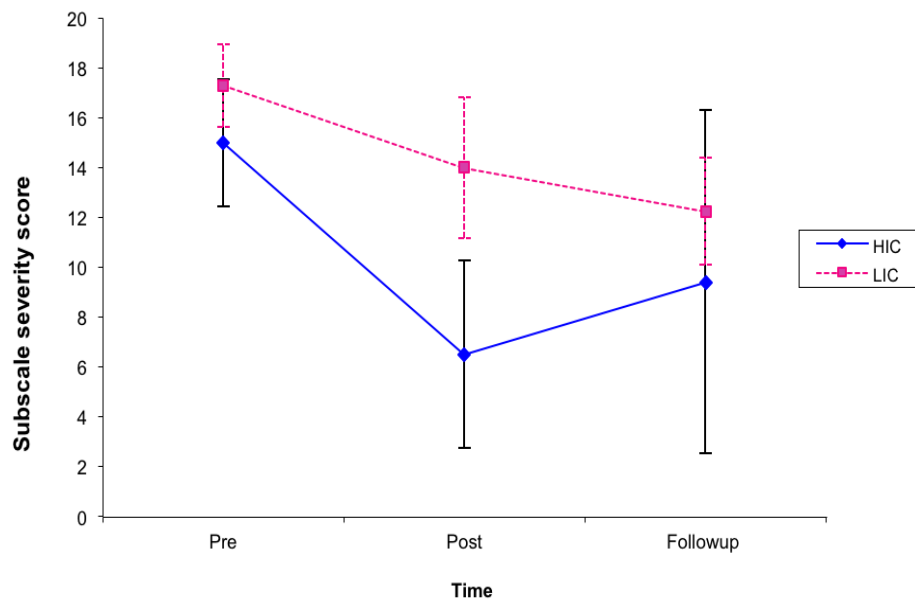


Figure 3. Mean severity score on the re-experiencing subscale of the Clinician Administered PTSD Scale for the HIC (n = 11) and LIC (n = 7) groups (bars represent standard errors).

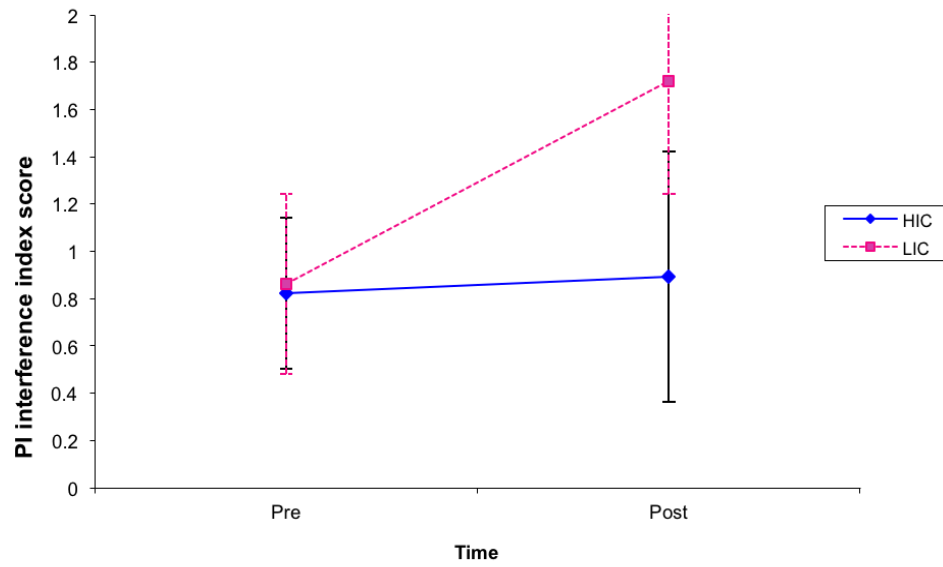


Figure 4. Mean proactive interference index scores from the CVLT-II for the HIC (n = 11) and LIC (n = 7) groups (bars represent standard errors).

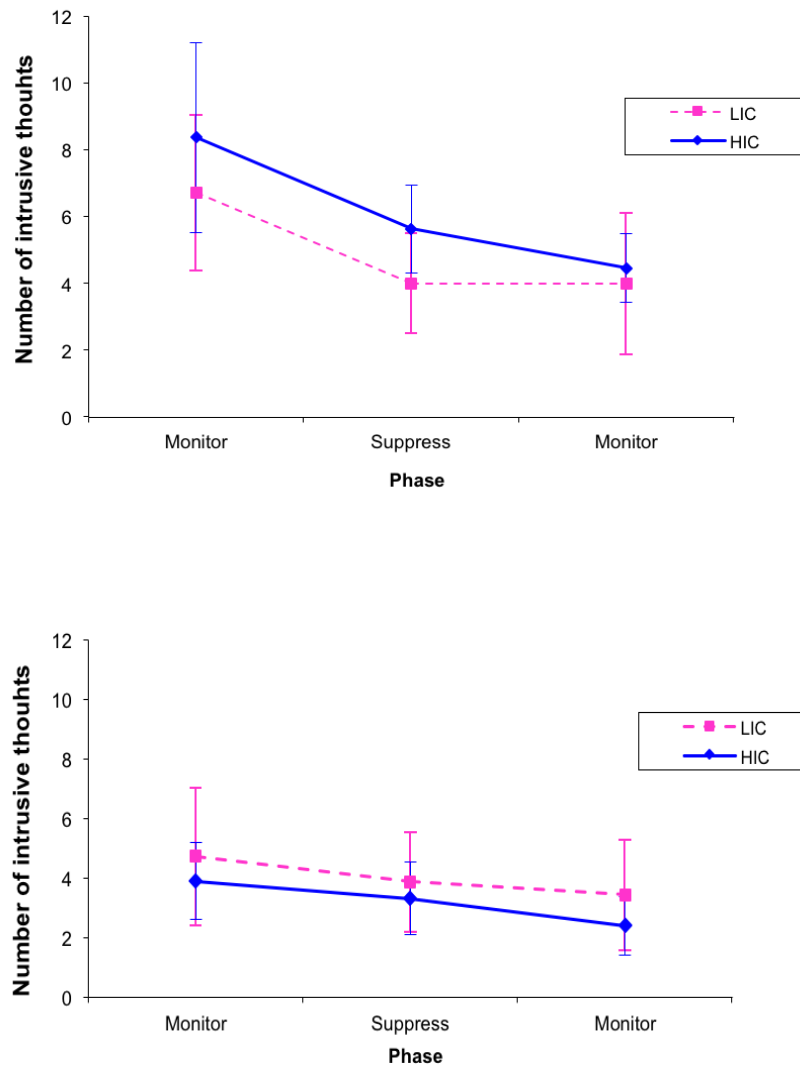


Figure 5. Mean number of intrusive thoughts at pre (top) and post-assessment (bottom) in the HIC ( $n = 11$ ) and LIC ( $n = 7$ ) groups (bars represent standard deviations).



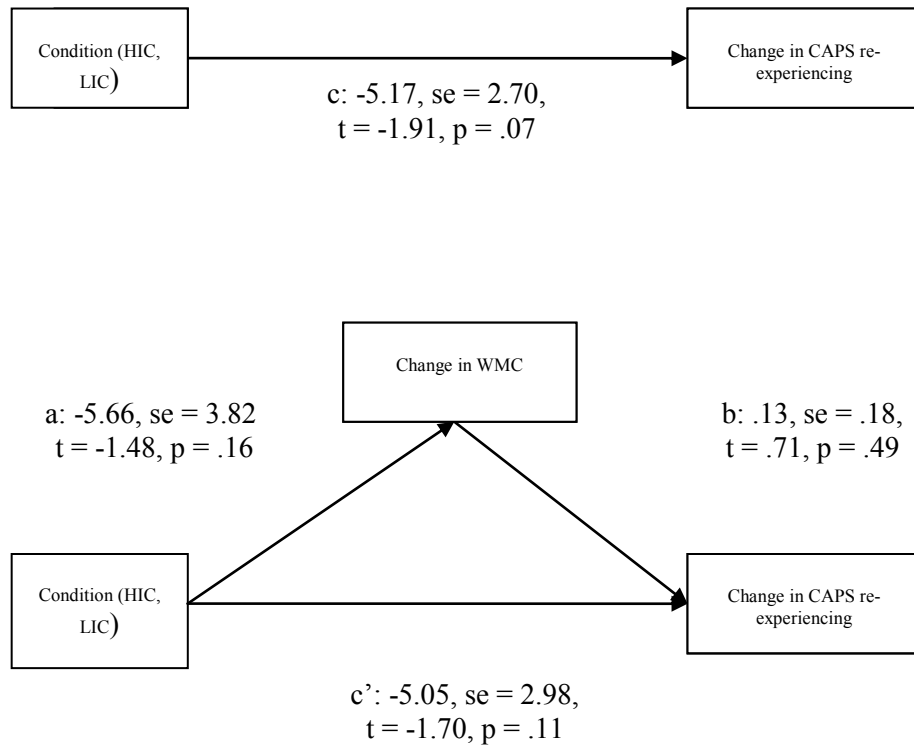


Figure 6. Results of mediation analysis.