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Working Memory and Mindfulness in an RCT of ABBT and AR

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WORKING MEMORY AND MINDFULNESS IN AN RCT OF ABBT AND AR

A Thesis Presented

by

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ABSTRACT

WORKING MEMORY AND MINDFULNESS IN AN RCT OF ABBT AND AR

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Working memory capacity (WMC) can be degraded by anxiety, stress, and worry, but can also be protected by mindfulness interventions (Jha et al., 2010). The current study was the first to investigate the relations between WMC, anxiety, and mindfulness within two interventions for Generalized Anxiety Disorder (GAD) that promote mindfulness: Acceptance Based Behavioral Therapy (ABBT) and Applied Relaxation (AR). In this exploratory study, we analyzed a subset of participants from a RCT of ABBT and AR who had completed the Operation Span Task (OSPAN; n = 21). First, we found that pre- to post-treatment measures of WMC (e.g., OSPAN scores) did not

significantly increase due to time or condition, nor was there a significant interaction effect, although the interaction was associated with a medium effect size: for the between-group variable of treatment condition, $F(1,19) = .40$, $p = .54$, $\eta^2 = .02$; for the repeated measure of time, $F(1,19) = .14$, $p = .71$, $\eta^2 = .007$; and for the interaction, $F(1,19) = .97$, $p = .34$, $\eta^2 = .05$. Second, we found that increases in WMC were not significantly related to reductions in anxiety; however, medium effect sizes correlating WMC to several anxiety measures (i.e., GAD CS, $r = -.38$, HAM A, $r = -.35$, and DASS Anxiety, $r = -.32$) are notable. Third, we found no significant relations and small effect sizes between changes in mindfulness and changes in WMC, *r*'s = .05 to -.19. Fourth, contrasting with findings in previous literature, a medium non-significant negative correlation, $r = -.32$, suggested that practicing therapy skills (as operationalized currently) might be related to less improvement in WMC. Important limitations include the small sample and absence of repeated measures of WMC over the course of treatment, which preclude analyses of temporal precedence of changes needed to determine directionality of relations. Research with larger sample sizes is needed to further explore the relations between WMC and mindfulness in anxiety treatments, as well as more thorough assessment of practice to determine its role in therapeutic change.

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CHAPTER 1

SPECIFIC AIMS AND HYPOTHESES

Acceptance-Based Behavioral Therapy (ABBT) and Applied Relaxation (AR) have been shown to be effective treatments for anxiety, particularly Generalized Anxiety Disorder (GAD). A randomized controlled trial of these interventions indicated that 63.3 to 80.0% of clients receiving ABBT and 60.6 to 78.8% of clients receiving AR exhibited significant clinical improvement across five calculations of change at posttreatment and follow-up (Hayes-Skelton, Roemer, & Orsillo, 2013). While these interventions differ in practice, it appears that both influence mindfulness. ABBT uses mindfulness to promote awareness of a client's internal experience (e.g., a worry cycle), as well as to alter the client's relationship with this experience through decentering (i.e., recognizing that the thoughts may not be all-encompassing truth), acceptance, and self-compassion. Rather than being held captive by distressing internal experiences, ABBT uses mindfulness to empower clients to make intentional choices about how they would like to respond, such as through valued action. While not explicitly teaching mindfulness, AR appears to also implicitly cultivate mindfulness (Hayes-Skelton, Usmani, Lee, Roemer, & Orsillo, 2012). AR teaches clients to notice muscle tension and early cues of anxiety, which appears to encourage clients to increase awareness of their internal experience as well as altering their relationship with their internal experience to be more decentered, accepting, and

self-compassionate. Both ABBT and AR, explicitly or implicitly, incorporate mindfulness as a tool to treat anxiety.

However, more research is needed to explore potential underlying mechanisms of mindfulness as a tool to treat anxiety. For example, a cognitive factor called working memory capacity (WMC) has been shown to be related to both mindfulness and anxiety (e.g., Jha et al., 2010; Sorg & Whitney, 1992). Briefly, WMC can be defined as maintaining information as initially encoded despite distraction or interference. WMC is mutable and the literature indicates that anxiety, worry, and stress degrade WMC. Yet, mindfulness has been shown to both treat anxiety and enhance or protect WMC (Jha et al., 2010). It is possible that practicing mindfulness skills in ABBT or AR may also practice or strengthen WMC because clients are needing to maintain particular thoughts amidst interference (e.g., strong emotion). Thus, more investigation is needed to elucidate the relationships between anxiety, mindfulness, and working memory capacity.

The overarching goal of this study was to understand the role of working memory in mindfulness and the therapeutic effects of Acceptance-Based Behavioral Therapy (ABBT) and Applied Relaxation (AR) as interventions for GAD. Specifically, this study addressed the following four aims:

We examined whether WMC improves following treatment in general and if the improvement differs by treatment. Supported by previous research (e.g., Jha et al., 2010), we hypothesize that **post-treatment measures of WMC will significantly increase from pre-treatment levels**; however, this improvement will not differ by condition.

Secondly, we explored whether changes in working memory were correlated with decreases in general anxiety symptoms. Specifically, we investigated **whether increases in WMC were related to reductions in anxiety**.

Thirdly, we explored whether changes in mindfulness scores were related to changes in WMC. We hypothesized that **changes in mindfulness scores would be related to changes in WMC** regardless of condition.

Lastly, we explored whether percentage of time spent engaging in mindfulness (for the ABBT condition) or noticing early cues of anxiety (for the AR condition) was associated with changes in WMC within each condition. We hypothesized that **time spent practicing these skills would be significantly related to changes in WMC**, and that this relationship would not differ by condition.

CHAPTER 2

BACKGROUND AND SIGNIFICANCE

In this review, I investigate the state of the literature on working memory, its relationship to anxiety, its relationship to mindfulness, and the relevance of working memory in anxiety treatments. First, I define working memory capacity and how it has been measured. Then I discuss the mutability of WMC, especially in relation to stress, anxiety, and worry, including a potential bi-directional relationship between WMC and anxiety. Next, I review potential anxiety interventions in which WMC may be relevant or enhanced, such as Cognitive Behavioral Therapy (CBT) and mindfulness. Finally, I review how ABBT and AR specifically, as interventions that incorporate explicit or implicit mindfulness, treat anxiety and may enhance WMC.

Working Memory Capacity

Considering the frequent meta-cognitive thinking and skills that require cognitive resources in therapy, working memory capacity may be a relevant construct to investigate. First, we discuss working memory capacity (WMC). Consider an instance of someone driving while talking on the phone via Bluetooth. The person on the other line gives the driver a phone number to memorize immediately before the driver attempts to change lanes in heavy traffic. Changing lanes serves as a significant distractor, making it

difficult for the driver to maintain the phone number in memory (e.g., through rehearsal). The necessity for the driver to organize information and resist distraction illustrates working memory. More specifically, working memory capacity (WMC) is the active maintenance of information during simultaneous distraction, interference, and/or processing for a short period of time (Conway et al., 2005; Kane & Engle, 2002). Similarly, Jha and colleagues define WMC as the "capacity to selectively maintain and manipulate goal-relevant information without getting distracted by irrelevant information over short intervals" (Jha et al., 2010, p.55).

What does *active maintenance of information* entail? Active maintenance can include domain-general executive attention and domain-specific storage and skills (Conway et al., 2005). The use of domain-general executive attention or domain-specific skills may differ based on the context, individual variables, or a combination of the two. For example, playing chess can illustrate both types of maintenance. An amateur chess player may rely mostly on domain-general executive attention to plan a few moves ahead while also attending to the status of the board. On the other hand, an expert chess player may rely more on domain-*specific* skills (e.g., learned strategies) with comparably less reliance on domain-*general* executive attention.

Domain-general executive attention is not only characterized by a non-specific domain, but also the maintenance of memory representations in the face of interference. Interference creates opportunities for error, necessitating the active maintenance of correct information. In the driving example, changing lanes serves as the interference while the driver attempts to maintain the phone number in memory. When interference is

not present, then these memory representations could be drawn from short-term or long-term memory, demonstrating how the interference component of domain-general executive attention is so critical to the construct of WMC (Kane & Engle, 2002). Another example of therapeutically relevant interference could be a situation that triggers strong emotion or anxiety. An individual may be distracted by their strong emotions and less able to maintain a plan of behaviors or responses they would want to carry out. Specific strategies, such as mindfulness discussed below, may strengthen an individual's ability to resist the impact of distraction (e.g., strong emotion) as well as enhance working memory.

Given the importance of interference and domain-general executive attention, measures of WMC should capture these constructs. The literature indicates that working memory span tasks (or complex span tasks) may best include these components by interleaving the to-be-remembered target stimuli (e.g., digits or words) with an interference or processing task (e.g., comprehending sentences or solving equations; Conway et al., 2005; Daneman & Carpenter, 1980; Redick et al., 2012; Turner & Engle, 1989). For example, counting span, operation span, and reading span are widely used complex span tasks (CSTs) with demonstrated reliability and validity (Conway et al., 2005). Automated, computerized CSTs are also increasingly being used in research. Because interference of rehearsal is an important feature of CSTs, automated CSTs can more easily control the amount of time between stimulus presentations and prevent the rehearsal that lends itself to short term memory capacity (STMC). To prepare participants for this kind of task, automated CSTs follow the same basic structure of practice

conditions: 1) storage only task, 2) processing only task, and 3) storage and processing tasks interleaved (Redick et al., 2012). For example, in the automated operation span task (OSPAN), participants practice: 1) recalling random letter strings only, 2) solving basic arithmetic problems only, and 3) recalling random letter strings interleaved with solving arithmetic (Unsworth, Heitz, Schrock, & Engle, 2005). Automated CSTs are also useful because they've shown little to no gender effects (Redick et al., 2012), despite research with other WMC measures claiming male advantages driven by advantage in *g* (Lynn & Irwing, 2008). Additionally, automated CSTs are useful in research because they have been shown to have high test-retest reliability, high internal consistency, convergent and discriminant construct validity, and criterion-related validity (Redick et al., 2012).

In addition to complex span tasks, researchers also use simple span tasks and dynamic span tasks to measure working memory. However, some argue that simple span tasks (e.g., digit span) measure short-term memory or brief storage and rehearsal (e.g., remembering a string of numbers without interference) and thus do not adequately include components of maintaining information during interference or distraction (Conway et al., 2005; Redick et al., 2012). In WMC and anxiety literature, some researchers have also recently included dynamic span tasks, like the *N*-Back task (Moran, 2016; Shackman et al., 2006; Vytal, Cornwell, Arkin, & Grillon, 2012). In the *N*-Back task, participants are given a series of items (e.g., letters), attempting to maintain the most recent "n" items and identify when an item matches that of "n" items ago. For example, a stream of letters includes: T L H C H O **C** Q L **C** K **L** H C Q T R R K C H R. If the "n" is 3, the participant needs to identify the letters (marked in bold here) that match the letter

3 items before it. Some researchers argue that dynamic span tasks and complex span tasks are not interchangeable measures of WMC (Redick & Lindsey, 2013). In a meta-analysis, Redick and Lindsey found low correlations between the *N*-Back and both the complex span (r = .20) and simple span (r = .25). They argue that dynamic tasks and complex span tasks may measure different underlying processes. Further, Shipstead and colleagues found that performance on dynamic span tasks was related to storage, while performance on complex span tasks was related to that of attentional control (Shipstead, Lindsey, Marshall, & Engle, 2014). Thus, it appears that simple span and dynamic span tasks may not be appropriate tasks to measure working memory capacity.

Further, because the distinguishing feature of WMC is the domain-general executive attention, some researchers argue that findings should be consistent across perceptual domains (e.g., verbal or spatial). Research using complex span tasks supports the claim that they capture the domain-general executive attention component of WMC regardless of presentation modality. A latent-variable study compared the domain-general or domain-specific qualities of working memory and short-term memory tasks (Kane et al., 2004). They investigated several measures, including verbal WMC, visuospatial WMC, verbal short-term memory capacity (STMC), visuospatial STMC, verbal and spatial reasoning, and general fluid (Gf) intelligence. Confirmatory factor analyses and structural equation models demonstrated that WMC tasks indeed reflected domain-general qualities, strongly predicted Gf, and weakly predicted domain-specific reasoning. On the other hand, STMC tasks reflected domain-specific qualities, weakly predicted Gf, and strongly predicted domain-specific reasoning. Thus, a distinction between verbal or

spatial WMC tasks may not be necessary because individual differences on these tasks should be driven by domain-general executive attention.

Considering these individual differences, Conway and colleagues (2005) argue that variation in WMC illustrate both stable, normally distributed individual variation as well as mutable, state-dependent variation. As an example of its mutability and relevance to mental health, the literature suggests that stress and anxiety reduce WMC (as measured by complex span tasks). Klein and Boals, for example, explored the relationship between life stress, state anxiety, and WMC (Klein & Boals, 2001). Participants answered a survey of various life events, their positive or negative impacts, and how recently they occurred. Participants also completed the operation span task as well as measures of state anxiety and self-report intrusive and avoidant thinking. They found that participants with more life event stress occurring recently exhibited lower WMC. They also found that negative life events were related to more intrusive thoughts. The authors argue that cognitive representations of negative life events compete for cognitive resources, which diminish WMC. Examining a similar relationship in another domain, Schmader and Johns investigated the relationship between stress due to gender stereotype threat and WMC (Schmader & Johns, 2003). In this study, gender was defined as men and women, with no acknowledgment or assessment of nonbinary gender identity. To prime stereotype threat, a male researcher described a working memory test as a reliable measure of “quantitative capacity,” which may highlight “underlying gender differences in quantitative capacity” to participants. A manipulation check asking participants to rate their concern that their math ability would be judged based on their gender also indicated

that both men and women expressed concern. They found that women exhibited lower OSPAN scores than men in the stereotype condition, which led the authors to argue that the negative stereotype, in which women perform worse on math, interfered with their WMC. Finally, the authors found that the working memory deficit mediated the effect of stereotype threat on women's math performance. Thus, it appears there is a relationship between stress and WMC in which stress may reduce WMC.

Working Memory Capacity & Anxiety

Similar to the relationship with stress, the literature indicates a relationship between WMC and anxiety. Briefly, researchers differ in how this relation between WMC and anxiety should be studied, such as the emphasis on domain specificity (e.g., phonological vs. spatial) versus emphasis on domain generality as well as the direction of causality (Moran, 2016). However, there appears to be agreement in two ways. First, "anxiety" is broken down into worry and arousal (e.g., Andrews & Borkovec, 1988; Heller & Nitschke, 1998; Hope & Izard, 1996). "Worry" is characterized by verbal rumination about future negative events, and is a primary symptom of generalized anxiety disorder (GAD). "Arousal" is characterized by physiological symptoms (e.g., dizziness, sweating, increased pulse) and hypervigilance, and is a primary symptom of panic (Watson et al., 1995). The second area of agreement is that the relation between anxiety (both worry and arousal) and working memory capacity may involve interference or competition with task-relevant resources, similar to the relationship with stress as discussed above (Moran, 2016). For example, some claim that anxiety causes deficits of

cognition by competing with attention, phonological resources, or storage of memory representations (e.g., Eysenck & Calvo, 1992; Eysenck, Derakshan, Santos, & Calvo, 2007; Robinson, Krimsky, & Grillon, 2013; Shackman et al., 2006). Others claim that pre-existing cognitive deficits predispose individuals to anxiety, suggesting a possible bi-directional relationship between WMC and anxiety (e.g., Mathews & MacLeod, 2005; Ouimet, Gawronski, & Dozois, 2009). Even further, some claim that particular domains of anxiety influence particular domains of WMC – specifically that arousal obstructs spatial processes and worry obstructs phonological processes (Shackman et al., 2006).

A meta-analysis of 177 samples (N = 22,061 individuals) integrated some of these competing theories (Moran, 2016). In general, they found a moderate but robust negative association between self-report measures of anxiety (both worry and arousal) and measures of working memory capacity ($g = -.334$, $p < 10^{-29}$). They included varied types of anxiety presentations and working memory tasks. Further, they found this association to be true across complex span (e.g., OSPAN; $g = -.342$, $k = 30$, $N = 3{,}196$, $p = .000001$), simple span (e.g., digit span; $g = -.318$, $k = 127$, $N = 17{,}547$, $p < 10^{-17}$), and dynamic span tasks (e.g., *N*-Back; $g = -.437$, $k = 20$, $N = 1{,}318$, $p <.001$), with largely comparable effect sizes, despite literature stating that simple span and dynamic span tasks likely capture different underlying constructs than those of complex span tasks. The authors also note that the results indicate that both domains of anxiety (i.e., worry and arousal) were associated with deficits in both domains of working memory measures (i.e., verbal and visuospatial). However, effects were more pronounced in measures of domain-general executive attention than domain-specific measures.

Despite the findings across different types of working memory tasks, the relative dearth of studies using complex span tasks is an important weakness of the state of literature on anxiety and WMC. Simple span measures are most frequently used in research on anxiety, perhaps because they are already included in most psychological evaluations (e.g., the Wechsler Intelligence Scale). As mentioned earlier, simple span tasks do not capture interference or domain-general executive attention, but rather, assess domain-specific short-term storage. Also as mentioned earlier, research indicates that dynamic tasks do not measure the same underlying construct as complex span tasks. Thus, anxiety research using simple span and dynamic span tasks must be interpreted carefully.

As supported by Moran's meta-analysis, anxiety research that does use complex span measures of WMC generally supports a relationship between the two. Studies inducing anxiety have found that it reduces WMC. For example, Sorg and Whitney conducted a study in which individuals of high or low trait anxiety were exposed to 10 minutes of competitive video games, simulating a stressful environment, and then completed both simple and complex span tasks (Sorg & Whitney, 1992). They found no differences on the simple span task; however, higher trait-anxiety individuals in the stress condition performed worse on the complex span tasks than those of low trait-anxiety. Additionally, high trait-anxiety individuals performed better than those of low trait-anxiety in the non-stress condition. Therefore, the authors argue that WMC deficits arise when individuals predisposed to anxiety experience stress. Further, Shi, Gao, and Zhou, explored a similar relationship with test anxiety (Shi, Gao, & Zhou, 2014). Their sample

included 53 Chinese undergraduates with high test anxiety and 58 with low test anxiety. They administered a measure of state anxiety and a modified complex Reading Span task intended to induce test anxiety, in which participants were required to remember letters serially presented, interleaved with directions to identify pseudo-words in sentence stimuli. In this case, the sentence stimuli were either neutral facts or related to test anxiety (e.g., I feel my heart beating very fast during important tests). The authors termed performance on test anxiety stimuli, emotional WMC. They found that individuals with high test anxiety performed worse on emotional WMC than neutral WMC, indicating that anxiety interfered with performance and reduced WMC. Thus, research supports the mutability of WMC, in which anxiety reduces it.

In addition to the negative effects of anxiety on WMC, researchers have found that pre-existing high WMC may bolster or protect against the effects of anxiety, indicating a bidirectional relationship. For example, Johnson and Gronlund found this bidirectional relationship (2009). They conducted a study in which fifty undergraduate students completed the OSPAN, trait measures of anxiety, and a dual-task (combined short-term memory task and a tone-discrimination task) designed to induce performance anxiety. Notably, the authors did not actually measure state anxiety induced by this task. They found an interaction of trait anxiety and WMC, such that worse performance on the dual-task in those low in WMC indicated vulnerability to disruption or interference by anxiety, whereas those high in WMC performed better on the dual-task and were protected from the effect of anxiety. The authors note implications of the role of WMC in individuals predisposed to anxiety when completing anxiety-inducing tasks, such as

standardized testing. Thus, the bidirectional relationship is evident in that anxiety reduced WMC, but pre-condition high WMC attenuated the effects of anxiety. Similar to the buffering effect found by Johnson and Gronlund, another group investigated whether high WMC could attenuate the negative impact of trait anxiety on attentional control (Wright, Dobson, & Sears, 2014). High trait anxiety individuals performed worse than low trait anxiety individuals on attentional control (i.e., antisaccade task); however, when individuals were both high in trait anxiety and WMC, they performed better on a task of attentional control. Even further, high WMC and high trait anxiety individuals performed similarly to those with high WMC and low trait anxiety. Thus, the authors argue that higher WMC buffered against the effects of high trait anxiety on performance of this attentional control task. Interestingly, they found this interaction with the complex reading span task, but not the operation span task. The authors argue that OSPAN scores may have been affected by participants' anxiety toward this task. Taken together, these findings suggest that high WMC may preserve subsequent performance, suggesting that a treatment that enhances WMC may in turn minimize the disruption of anxiety, leading to an iterative process of improvement.

Researchers have also explored the relationship between WMC and worry. Bredemeier and Berenbaum explored the relationship between WMC and worry in GAD (Bredemeier & Berenbaum, 2013). A sample of 198 college students completed self-report measures of worry, a diagnostic interview for GAD, two N-Back tasks, and the OSPAN task. They found that 2-back scores (i.e., participants had to maintain 2 items of an N-Back task) had a negative relationship with worry and GAD symptoms. However,

OSPAN scores, which modestly correlated with 2-back scores ($r = .18$), were not significantly related. Of note, only 6 participants qualified for GAD diagnosis, and the self-report measures of worry appear to be within a normative level. It is possible that the association between worry and the *N*-Back, but lack of association with the OSPAN, is due to low clinical severity in the sample. In another study on worry, Sari, Koster, and Derkashan investigated whether active worrying could impair WMC (Sari, Koster, & Derakshan, 2017). A sample of 64 undergraduate students completed self-report measures of anxiety and worry, a pre-condition and post-condition change detection task (not a complex span task), and were assigned to complete a worry or non-worry control condition. The authors found that level of self-reported worry mediated the relationship between condition and changes in WMC, in which the indirect effect of worry on WMC changes was significant but the direct effect of condition on WMC was not significant. They found a similar relationship between state anxiety and WMC. However, again, research using different measures of WMC must be interpreted carefully. Thus, it appears that worry and anxiety may reduce WMC.

The literature also lacks substantial research on the role of WMC in anxiety treatments. In fact, no studies were found that explored the effect of CBT interventions on WMC. Although a different construct than working memory, Mohlman suggests that the elderly may have lower response rates to psychotherapy treatments for anxiety and depression: they argue that as executive functioning (EF) diminishes with age, the elderly may have fewer resources to reason or regulate emotion (Mohlman, 2005). In the only study found investigating the effect of CBT on executive function, Mohlman and Gorman

followed up with a pilot study of cognitive behavioral therapy (CBT) for GAD in elderly patients with high and low EF (Mohlman & Gorman, 2005). They included a range of standard neuropsychological tasks, but did not administer any complex span tasks of WMC. Interestingly, they found that many participants that were identified with low EF at pre-treatment improved on these EF tests at post-treatment. The authors divided the low EF groups into those whose EF improved and those whose low EF remained stable. They found that the stable low EF group did not respond to CBT; however, the improved EF and high EF group did respond to treatment. This study is particularly interesting for the current study because it suggests that CBT-based interventions for anxiety, such as ABBT and AR, may improve WMC. Yet, the relevance of this work must be considered carefully because working memory capacity (as measured by complex span tasks) was not directly assessed. However, some researchers argue that EF and WMC may capture similar constructs. McCabe and colleagues found strong correlations (r = .97) between EF tasks and complex span tasks (Mccabe, Mcdaniel, & Hambrick, 2010). The authors argue that the attentional control captured by executive functioning (neuropsychological) tasks may be similar to that of WMC tasks. Thus, the study by Mohlman and Gorman suggests that CBT may improve executive function, including WMC, and further investigation is needed regarding the role of WMC as an underlying mechanism in treating anxiety.

Working Memory Capacity & Mindfulness

One mechanism through which WMC could relate to anxiety and its treatment is through mindfulness. The definitions of mindfulness and working memory shed light on this possible relationship. Working memory measures someone's ability to manipulate and maintain information in the face of distraction or interference (Conway et al., 2005; Kane et al., 2004). Mindfulness is a metacognitive skill of cognition about our cognition, in which an individual may practice sustained attention and awareness, experience distraction of various kinds, and return one's attention after each distraction. Both constructs indicate practice of attention, resisting distraction, and returning attention. Bishop and colleagues propose a definition of mindfulness which includes two components: 1) self-regulation of attention and awareness to the present moment and 2) orienting to these experiences with curiosity, openness, and acceptance rather than overidentification or reactivity (Bishop et al., 2004). They describe mindfulness as a skill that must be practiced rather than achieved. They further discuss how mindfulness can be conceptualized clinically as a different way for people to respond to their emotional distress. For example, someone with GAD experiences cycles of worries (and the associated difficult emotions) that may distract him/her or interfere with noticing that these worries are just thoughts and may not be true. Practicing mindfulness in this instance would help this person decenter from his/her worries and interrupt the worry cycle. Further, practicing mindfulness may also be practicing working memory because the person is attempting to maintain correct information amidst distraction and

interference, which in this case is a worry cycle and intense emotion. During distractions, both internal and external, mindfulness may be related to WMC and perhaps enhance it.

One important line of research investigates the correlation between mindfulness, working memory capacity, and other variables. As is true in other lines of research in WMC, few studies were found that operationalized WMC using complex span tasks. In one example, Dubert and colleagues explored the relationships between working memory capacity, dispositional mindfulness, and emotional regulation in nursing students (Dubert, Schumacher, Locker, Gutierrez, & Barnes, 2016). Correlations between dispositional mindfulness (i.e., Mindful Attention Awareness Scale; MAAS) and both the reappraisal subscale of the Emotion Regulation Questionnaire (ERQ; $r = .19$, $p = .045$) and OSPAN scores ($r = .30$, $p = .004$), indicate a medium-sized association between mindfulness and WMC. Structural equation modeling indicated a direct effect of mindfulness on both emotion regulation ($\gamma11 = 0.29$, $p = .034$) and working memory capacity ($\gamma21 = 4.98$, $p = .004$). However, because they found that WMC did not mediate the effect of mindfulness on emotion regulation ($b = -0.03$, $p = .236$), the authors argue that WMC may not be the mechanism by which mindfulness affects reappraisal (i.e., emotion regulation). Interestingly, these findings contradict a previous study that found a low effect size, non-significant association between dispositional mindfulness as measured by the MAAS, WMC as measured by the OSPAN, and positive or negative affect in a sample of medical students (Black, Semple, Pokhrel, & Grenard, 2011). This discrepancy indicates that more research needs to be done to elucidate these relationships. Further, one limitation to note of this cross-sectional study by Dubert and colleagues is that they do not assess

mindfulness, emotion regulation, or WMC over time. Still, this line of research indicates that mindfulness may be associated with WMC.

Another line of research most relevant to the current study explores the effect of mindfulness interventions on complex span tasks. Generally, the literature supports that mindfulness interventions either improve or bolster complex span scores, and that practicing these skills may be important for these benefits. For example, Jha and colleagues investigated an 8-week (24 contact hours) mindfulness training (MT; tailored to the military), WMC (as measured through the OSPAN), and positive and negative affect in three groups – a civilian control group, a military control group during the pre-deployment interval, and a mindfulness training (MT) military group during the pre-deployment interval (Jha et al., 2010). They found that WMC remained stable in the civilian group, but degraded in the military control group (during this high-stress time). Interestingly, they found that individuals in the MT group who spent more time practicing MT homework exhibited higher WMC at Time 2, and individuals who spent less time practicing mindfulness exhibited lower WMC at Time 2, demonstrating a bolstering effect of mindfulness. Moreover, while WMC decreased over time for both the military control group and the mindfulness group (for those that did not practice), WMC increased for those that did practice. They also found that the benefit of mindfulness practice on negative affect was mediated by WMC, but not for positive affect. The authors conclude that mindfulness training bolsters (or protects) WMC from stress-related degradation, and WMC plays a role in emotion regulation. In a study with a similar amount of intervention contact hours, Roeser and colleagues randomized a sample

of 113 school teachers to an 8-week (36 contact hours and homework assignments) mindfulness training (MT) or wait-list control and collected data at baseline, post-program, and 3-month follow-up (Roeser et al., 2013). At both post-program and 3-month follow-up, they found that teachers randomized to the mindfulness training compared to those in the control condition demonstrated significantly greater mindfulness (as measured by the Five Factor Mindfulness Questionnaire; FFMQ), greater WMC (as measured by the OSPAN), greater occupational self-compassion, and lower occupational stress and burnout. Notably, WMC in the control group did not indicate any significant decreases over time, as previous literature suggests (e.g., Jha et al., 2010); however, the lack of difference may be due to external stressors remaining similar across the time-points.

Further, other literature supports these WMC benefits in less time-intensive mindfulness interventions. Mrazek and colleagues conducted a study in a sample of 48 undergraduate students randomized to a 2-week (6 contact hours and homework assignments) mindfulness class or nutrition class (Mrazek, Franklin, Phillips, Baird, & Schooler, 2013). The mindfulness class required students to incorporate skills and practice 10 minutes of daily meditation outside of class. The authors found that scores in both the OSPAN task and GRE reading comprehension questions significantly improved after the mindfulness class, but not in the nutrition class. In another study, Banks and colleagues compared WMC in a 1-week home MT condition to a relaxation training condition (Banks, Welhaf, & Srour, 2015). Participants completed the OSPAN before and after the first session of their respective trainings (i.e., MT or relaxation), as well as

before and after the second session of these trainings. The second session, however, included a writing stressor task in which participants spent 10 minutes writing about a current personal negative event, which was followed by the last OSPAN administration. MT focused on promoting acceptance and awareness of thoughts and emotions, and the relaxation training focused on progressive muscle relaxation and body scan. The authors found that after the writing stressor, WMC remained the same in the MT group but degraded in the relaxation group. Importantly, the authors report no differences in number of practice sessions completed between the conditions ($M = 4.62$ sessions, $SD = 1.42$, $p > .05$). Thus, the authors argue that the MT protected WMC from stress-related degradation. These findings are consistent with those of Jha and colleagues, who found that military cohorts that completed MT practice were protected from stress-related degradation (Jha et al., 2010). Finally, Quach and colleagues conducted a study in 198 adolescents randomized to MT, hatha yoga, or a waitlist control group (Quach, Jastrowski Mano, & Alexander, 2016). Both interventions lasted 4 weeks for a total of 6 contact hours. Participants were also encouraged to log and practice the respective skills daily for 15-30 minutes. They found that there were no differences of stress or anxiety between the groups, but WMC scores in the MT condition significantly improved, while scores in the hatha yoga and waitlist condition remained the same. The authors argue that abridged MT trainings in adolescents may improve WMC. In a follow-up paper of the same study, Quach and colleagues explored the role of practice (Quach, Gibler, & Jastrowski Mano, 2017). They found that the hatha yoga group reported significantly more practice (7.22 out of 21 days, $SD = 5.06$; for approximately 140.05 min, $SD =$

155.95) than that of the MT group (5.66 out of 21 days, *SD* = 4.24; for approximately 77.16 min, *SD* = 114.93; *p* = .003). However, they found that for both conditions, high or low practice had no significant effect on WMC, which contrasts with findings by Jha and colleagues who found that practicing mindfulness improved WMC (Jha et al., 2010). Moreover, these studies indicate that mindfulness interventions may be effective in protecting or improving WMC.

Acceptance Based Behavioral Therapy and Applied Relaxation

While research indicates that stand-alone mindfulness training may influence working memory capacity and some mental health factors, it may also be true that evidence-based empirically validated psychotherapy treatments that directly incorporate or indirectly target mindfulness, such as Acceptance-Based Behavioral Therapy (ABBT) and Applied Relaxation (AR), may have similar relationships to WMC. Specifically, ABBT and AR for GAD is of particular interest because GAD's defining feature is worry: there may be a relationship between ABBT and AR's promotion of mindfulness (a metacognitive skill), worry, and WMC.

ABBT is a treatment adapted from CBT that uses mindfulness as a tool to help clients alter the relationship with their internal experiences and improve quality of life through valued living (Hayes-Skelton, Roemer, & Orsillo, 2013). Specifically, ABBT aims to promote awareness of the present moment that is open, compassionate, and decentered, as opposed to narrow, threat-focused, judgmental, or fusing thoughts and feelings as all-encompassing truth that cannot change (Roemer & Orsillo, 2014). Clients

are taught to use mindfulness to notice when thoughts and feelings occur and relate to them with self-compassion and acceptance that they are understandable human experiences. Further, while the natural response to distress about one's internal experience may be avoidance, ABBT promotes mindful awareness of this experiential avoidance, which empowers clients to make intentional choices of how they would like to respond to distress. As they practice identifying thoughts and behaviors, clients learn that even strong emotions do not have to determine their behavior or response: they can choose their behavior despite these emotions. Finally, ABBT helps clients identify their values (e.g., in the areas of relationships, school, work, self-care, community engagement, etc.) and how their actions can be consistent with their values (i.e., valued action). Moreover, ABBT teaches self-monitoring, formal and informal mindfulness exercises, values clarification, and valued action. Because knowledge itself is not enough to alter these learned ways of relating to internal experience, ABBT devotes significant time to practicing mindfulness skills. Mindfulness practice begins with basic skills, such as noticing the breath while sitting, progresses to noticing tastes and sounds, then to thoughts and emotions, and then more to applied contexts (e.g., noticing thoughts and emotions during painful circumstances and remembering that one can choose valued action rather than avoidance; Hayes-Skelton, Roemer, & Orsillo, 2013). While sustained attention during mindfulness practice may be difficult, clients are encouraged to be compassionate towards their mind-wandering and gently return their attention each time. Thus, mindfulness is an important tool in this treatment and it is possible that working memory capacity may be enhanced through practicing this skill, such as through

returning their attention after being distracted or choosing acceptance or valued action despite strong emotions.

Applied Relaxation (AR) for GAD is a treatment that does not explicitly include mindfulness, but appears to implicitly cultivate it (Hayes-Skelton et al., 2012). AR teaches individuals to respond to anxiety differently by noticing early cues of anxiety and applying relaxation to decrease muscle tension, which disrupts the cycle of anxiety and prevents it from strengthening (Hayes-Skelton, Roemer, Orsillo, & Borkovec, 2013). Specifically, AR teaches diaphragmatic breathing and progressive muscle relaxation (PMR), which begins with 16 muscles groups and gradually decreases to fewer groups. AR also teaches awareness of early signs of anxiety and self-monitoring skills to distinguish cognitive, affective, physiological, and behavioral cues. After practicing these relaxation skills, therapists teach cue-controlled relaxation, in which clients associate the word "relaxing" with a state of relaxation. The goal is to develop a very short (e.g., 30 second) "portable" skill that can be applied in natural settings (Hayes-Skelton, Roemer, Orsillo, et al., 2013). In this portable skill, clients take a deep breath, think the word, "relaxing," and scan their body for areas needing release of tension. However, while this intervention does not explicitly mention mindfulness, it appears that mindfulness may still be an underlying mechanism in its impact on anxiety. A paper reviewing case examples illustrates how some clients use PMR and early cue detection to adjust their relationship with their internal experiences in a mindful, decentered, and self-compassionate way (Hayes-Skelton et al., 2012). These cases were drawn from a larger sample of the randomized controlled trial comparing ABBT and AR (Hayes-Skelton,

Roemer, & Orsillo, 2013) analyzed for the present study. Further, while this change of attitude towards internal experiences is explicitly taught in ABBT, it appears to be implicitly cultivated for some clients in AR. For example, self-monitoring of early cues of anxiety and recording one's observations promoted an open awareness of anxiety responses that is less fused or judgmental and more objective and decentered. In one of the case studies, a client reported that when she sensed anxiety, rather than having a rigid behavioral response, the treatment led her to notice her sensations and stay in the present moment. Further, scores of Mindfulness (as measured by the FFMQ) for all three cases reviewed started close to or below the mean at baseline and increased at least 2 standard deviations above the mean by the post-treatment visit. Therefore, it appears that AR implicitly increased mindfulness in some clients. Further, it's possible that components of AR that implicitly cultivate mindfulness, such as noticing early cues of anxiety, may also improve working memory capacity.

The Current Study

Given the findings that WMC can be degraded by anxiety, stress, and worry, but can also be protected or enhanced by mindfulness interventions, the current study explored the relationship between anxiety, WMC, and mindfulness within two interventions for GAD that promote mindfulness: ABBT and AR. We analyzed a subset of participants from a randomized controlled trial of ABBT and AR who had completed the OSPAN. We predicted that: 1) WMC would be significantly improved following these interventions, 2) increased WMC would be related to reduced anxiety symptoms, 3)

changes in mindfulness would be related to changes in WMC, and 4) time spent practicing therapy skills (i.e., mindfulness for ABBT or noticing early cues of anxiety for AR) would be related to changes in WMC. The small sample and absence of repeated measures of WMC over the course of treatment preclude analyses of temporal precedence of changes needed to determine directionality of these relations. Therefore, this study was exploratory to determine whether correlations emerge that support the hypothesized relations.

CHAPTER 3

METHOD

Sample

The sample included 21 participants, a subset from a larger sample of 81 randomized participants in the randomized controlled trial by Hayes-Skelton and colleagues (Hayes-Skelton, Roemer, & Orsillo, 2013). This subset of 21 participants are those that completed the working memory task (i.e., Automated Operation Span), which was later added to the original protocol (see Figure 1 for participant flow). Of those participants who enrolled in the larger study after the task was added, 16 participants were excluded from this sample: three of these participants completed the task, but there was a technical problem and the data were lost; four participants declined the option of completing the task; five participants completed the pre-treatment WMC task, but not at post-treatment; and four participants completed the WMC tasks but exhibited greater than 15% math errors on the task (see section on the OSPAN for further description). Participants for the larger study were recruited from a pool of treatment-seeking individuals at the Center for Anxiety and Related Disorders at Boston University and referrals from the U Mass Boston Counseling Center between 2007 and 2010. Eligibility was assessed by an independent assessor (IA) who administered the diagnostic assessment. Eligibility criteria included: a) receiving a primary diagnosis of GAD on the

Anxiety Disorders Interview Schedule for DSM–IV (ADIS-IV; DiNardo, Barlow, & Brown, 1994) with a clinician severity rating of at least 4 (moderate); b) onset of GAD before a first episode of major depressive disorder; c) stable on medications for 3 months and maintaining current levels of psychotropic medication while also abstaining from other (non-pharmacological) treatments for anxiety or mood during the study; d) fluent in English; and e) were 18 years of age or older. Clinical exclusion criteria included bipolar disorder, a psychotic disorder, autism-spectrum disorder, or substance dependence.

Regarding demographic characteristics of the sample (n = 21), please see Table 1 for a breakdown by treatment condition. The mean age was 31.67 years of age (SD = 11.11), ranging from 19 to 65 years. Regarding gender identity, 28.6% identified as men (n = 6) and 71.4% identified as women (n = 15). Regarding sexual orientation, 4.8% identified as bisexual (n = 1), 4.8% identified as gay/lesbian (n = 1), and 90.5% (n = 19) identified as heterosexual. Regarding race/ethnicity, 9.5% (n = 2) identified as Asian, 4.8% (n = 1) identified as Black, 4.8% (n = 1) identified as White Hispanic/Latino, and 81.0% (n = 17) identified as White. Regarding previous experience in psychotherapy, 81.0% (n = 17) had previous individual or group therapy. Lastly, 9.5% (n = 2) of participants noted that they were currently taking psychotropic medication during the study. Please see Table 2 for means of pre-treatment outcome measures for this sample.

Table 1

Demographic Characteristics of the Sample

Characteristic	AR (*n* = 9)	ABBT (*n* = 12)	Total (*n* = 21)
Age *M* (*SD*)	28.67 (9.43)	33.92 (12.12)	31.67 (11.11)
Gender Identity			
Men	22.2% (*n* = 2)	33.3% (*n* = 4)	28.6% (*n* = 6)
Transgender	0% (*n* = 0)	0% (*n* = 0)	0% (*n* = 0)
Women	77.8% (*n* = 7)	66.7% (*n* = 8)	71.4% (*n* = 15)
Sexual Orientation			
Bisexual	11.1% (*n* = 1)	0% (*n* = 0)	4.8% (*n* = 1)
Gay/Lesbian	0% (*n* = 0)	8.3% (*n* = 1)	4.8% (*n* = 1)
Heterosexual	88.9% (*n* = 8)	91.7% (*n* = 11)	90.5% (*n* = 19)
Race/ethnicity			
Asian	11.1% (*n* = 1)	8.3% (*n* = 1)	9.5% (*n* = 2)
Black	0% (*n* = 0)	8.3% (*n* = 1)	4.8% (*n* = 1)
Hispanic/Latino	0% (*n* = 0)	8.3% (*n* = 1; White)	4.8% (*n* = 1; White)
Middle Eastern	0% (*n* = 0)	0% (*n* = 0)	0% (*n* = 0)
Multiracial	0% (*n* = 0)	0% (*n* = 0)	0% (*n* = 0)
Native American	0% (*n* = 0)	0% (*n* = 0)	0% (*n* = 0)
White	88.9% (*n* = 8)	75.0% (*n* = 9)	81.0% (*n* = 17)
Previous psychotherapy			
Yes	77.8% (*n* = 7)	83.3% (*n* = 10)	81.0% (*n* = 17)
No	22.2% (*n* = 2)	16.7% (*n* = 2)	19.0% (*n* = 4)
Taking psychotropic medication			
Yes	22.2% (*n* = 2)	0% (*n* = 0)	9.5% (*n* = 2)
No	77.8% (*n* = 7)	100% (*n* = 12)	90.5% (*n* = 19)
Additional Diagnoses			
Yes	88.9% (*n* = 8)	58.3% (*n* = 7)	71.4% (*n* = 15)
No	11.1% (*n* = 1)	41.7% (*n* = 5)	28.6% (*n* = 6)
Social Anxiety			57.1% (*n* =12)
Major depression			14.3% (*n* = 3)
Panic disorder w/ag			19.0% (*n* = 4)
Specific phobia			19.0% (*n* = 4)
Eating disorder NOS			4.8% (*n* = 1)
OCD			9.5% (*n* = 2)
PTSD			4.8% (*n* = 1)
Other[a]			23.8% (*n* = 5)

Note. AR = Applied Relaxation; ABBT = Acceptance-based Behavioral Therapy

Measures and Tasks

Primary Outcome Measures

Anxiety Disorders Interview Schedule for DSM–IV (ADIS-IV; DiNardo et al., 1994). The ADIS-IV is a semi-structured clinical interview to determine current and lifetime diagnostic status based on the fourth version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; Association American Psychiatric, 1994). Independent assessors administered the lifetime version (ADIS-IV-L) at pretreatment. These assessors were trained postdoctoral fellows or graduate students blind to treatment condition. For each diagnosis, a clinician severity rating (CSR; ranging from 0 to 8, with 4 or greater as clinically significant) was given. The ADIS-IV has demonstrated adequate reliability for GAD (κ = .67; Brown, Di Nardo, Lehman, & Campbell, 2001). Consensus meetings with a doctoral-level psychologist (Dr. Tim Brown) and therapists confirmed diagnoses. Further, a second rater scored 30% of the interviews, with an interclass correlation (ICC) of .73 on the CSR for GAD. The current sample scored in the clinical range for pretreatment GAD severity, M = 5.47, SD = 0.57.

Depression Anxiety Stress Scale–21-item version (DASS-21; Lovibond & Lovibond, 1995). The Depression, Anxiety, Stress Scale (DASS) is a 21-item self-report measure that assesses three types of symptoms over the past week: depression, anxiety, and stress. We analyzed the stress and anxiety subscales, in which research has shown the stress subscale to be elevated in GAD samples and the anxiety subscale to be elevated in panic disorder samples (Brown, Chorpita, Korotitscw, & Barlow, 1997).The stress

subscale includes items relating to general anxiety (e.g., “I found myself getting agitated;” “I found it difficult to relax; “I tended to over-react to situations”). The anxiety subscale includes items relating to physical sensations of anxiety (e.g., “I was aware of dryness in my mouth;” “I experienced breathing difficulty (e.g., excessively rapid breathing, breathlessness in the absence of physical exertion);” “I experienced trembling (e.g., in the hands).” Participants respond to items on a scale from 0 (Did not apply to me at all) to 3 (Applied to me very much, or most of the time). In both community and clinical samples, the DASS-21 has been found to demonstrate sufficient reliability, construct validity, internal consistency, and temporal stability (Henry & Crawford, 2005). In this study, we found internal consistencies for the Stress Subscale to be good at pre-intervention ($\alpha = .83$) and post-intervention ($\alpha = .90$). Internal consistencies for the Anxiety subscale were also acceptable, at pre-intervention ($\alpha = .74$) and post-intervention ($\alpha = .70$). Scores can fall within the following ranges: normal, mild, moderate, severe, and extremely severe. For the stress subscale, the current sample scored in the moderate range, *M* = 23.33, *SD* = 7.55, at pre-intervention. For the anxiety subscale, the current sample scored in the mild range, *M* = 8.33, *SD* = 6.89, at pre-intervention.

Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990). The PSWQ is a widely used 16-item self-report measure of trait worry (e.g., “I am always worrying about something”) with demonstrated validity and reliability (Molina & Borkovec, 1994). Scores range from 16 to 80, with higher scores indicating higher levels of worry. Scores on the PSWQ have also been shown to discriminate GAD from other

anxiety disorders (Brown, Antony, & Barlow, 1992). In this sample, internal consistency was found to be acceptable at pre-intervention (α = .73) and post-intervention (α = .88).

Structured Interview Guide for the Hamilton Anxiety Rating Scale (HAM-A; Shear et al., 2001). The Structured Interview Guide for the Hamilton Anxiety Rating Scale is a structured to administer the 14-item Hamilton Anxiety Rating Scale (HAM-A) of anxiety symptoms over the past month (Hamilton, 1959). However, in this study, participants were assessed for the past week. Some items evaluated in this measure include anxious mood, general somatic symptoms, cardiovascular symptoms, behavior at the interview. Each item is rated from 0.0 (none to mild boundary) to 4.0 (severe to very severe boundary), with units of .5 (e.g., 0.0, 0.5, 1.0, 1.5, etc.). Trained postdoctoral and doctoral students administered this measure, with 15% rated twice for interrater reliability. Intraclass Correlations (ICC) of .89 demonstrate strong interrater reliability. In this sample, internal consistency was found to be good at pre-intervention (α = .80) and post-intervention (α = .85). The total score can range from 0 to 30, and the current sample at pretreatment scored in the mild to moderate severity range, M = 18.94, SD = 6.57.

Additional Measures

Five Factor Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). The FFMQ is a 39-item self-report measure of mindfulness, including five subscales: observing sensations, describing thoughts and feelings, acting with awareness, nonjudgement of experience, and nonreactivity to experience. Participants respond to statements that were “generally true for [them]” on a

scale from 1 (never or very rarely true) to 5 (very often or always true). Higher scores indicated more mindfulness. In this sample, internal consistency was found to be good to excellent for all five subscales at pre-intervention (α from .81 to .93) and post-intervention (α from .86 to .95).

Weekly Assessment. A clinician-administered 9-item assessment was developed to measure the percentage of time that clients practiced intervention skills outside of session. Clinicians asked participants about their general “impression” of the week regarding “things we are focusing on in therapy.” In the ABBT version of the assessment, we are interested in the item, “What percentage of the time were you mindful over the past week? By mindful we mean aware of your current experience, focused on where you are at that moment and what you are doing, as opposed to what you did earlier or will do later?” In the AR version, we are interested in the item, “What percentage of the time did you notice your anxious cues over the past week?” We chose this item in AR because it most resembles mindfulness skills. Participants responded to both items by providing a percentage between 0 and 100 in increments of 10. In the current study, we measured practice of these skills by averaging the practice time reported between sessions 3 and 16.

Automated Operation Span Task

Participants completed the Automated Operation Span Task to measure working memory capacity (OSPAN; Unsworth, Heitz, Schrock, & Engle, 2005). Unsworth and colleagues demonstrated the OSPAN to have good internal consistency (α = .78) as well as test-retest reliability (α = .83; 2005). They also found the OSPAN to correlate with

other measures of working memory capacity, such as the OSPAN (non-automated; $r = .45$, $p < .01$; Turner & Engle, 1989) and Raven's progressive matrices ($r = .38$, $p < .01$). These correlations are similar to those among other measures of WMC, such as .43 found by Engle and colleges in another study (Engle, Tuholski, Laughlin, & Conway, 1999).

Participants completed this mouse-driven computer task as indicated by Unsworth and colleagues (Unsworth et al., 2005). The task presents letters on a screen, one at a time for 800ms, in a random series of three to seven letters. Between each presented letter, participants must complete a basic math equation (e.g., (1*2) + 1 = ?). After presented with each equation, participants are given a possible solution and must indicate "True" or "False." The following screen provides feedback on accuracy, which participants are instructed to keep above 85%. The program also implements a time limit to prevent participants from rehearsing the letters during the math problems. This time limit was determined from the participant's mean duration to complete each equation during the practice session plus 2.5 standard deviations. If participants run through the time limit, the program automatically moves on and counts the trial as an error. Finally, after solving each math problem, participants must identify the previously presented letters in the correct order from a 4 x 3 matrix of letter choices (F, H, J, K, L, N, P, Q, R, S, T, and Y). This recall phase is untimed and is followed by computer generated feedback on the number of letters correctly recalled. Participants complete three sets of each size of 3 to 7 letters series (e.g., 3 sets 3 letters, 3 sets of 4 letters, etc.). Thus, participants view a total of 75 letters and solve 75 math problems. Set sizes were presented in random order and the entire task takes approximately 20 to 25 minutes.

Before the experimental task begins, participants completed three practice sessions. The first practice session required participants only to remember a series of letters, presented on the screen one at a time, and identify the letters from the 4x3 matrix. The second practice session required participants to solve 15 basic math problems. Finally, the third practice combined the previous two, simulating the experimental session: participants are presented the series of letters, solve the math problem, and finally must identify the previously presented letters on the 4x3 matrix.

Regarding scoring, a number of scores are collected by the OSPAN, including absolute storage scores, partial storage scores, processing errors, speed errors, and accuracy errors. Absolute scores are the sum of trials in which all items in the trial were recalled in correct serial order, and partial scores are the sum of items recalled in correct serial order regardless of whether the entire trial was correctly recalled. The current study reports partial scores because research indicates that partial scores have the most robust psychometric properties and correlate well with reading comprehension and matrix reasoning (Redick et al., 2012). Consistent with procedure from Unsworth and colleagues (2005), the current study also removed data from participants that failed to maintain 85% accuracy on the math operations. Maintaining accuracy on math operations is important to ensure that it is truly functioning as an interference, and participants are not using the math portions of the task to rehearse the letter strings. Without interference, this task would be measuring short-term memory rather than working memory.

Table 2

Pre-Treatment Outcome Measures

Measure M (SD)	AR (*n* = 9)	ABBT (*n* = 12)	Total (*n* = 21)
WMC	63.56 (11.47)	59.00 (6.92)	60.95 (9.18)
GAD CS	5.56 (.73)	5.25 (.45)	5.38 (.59)[a]
HAM A	22.00 (8.07)	18.43 (5.71)	19.96 (6.87)[c]
DASS Stress	25.89 (4.81)	22.25 (6.12)	23.81 (5.77)[b]
DASS Anxiety	8.67 (6.63)	9.00 (6.74)	8.86 (6.53)[c]
PSWQ	67.44 (6.33)	66.04 (6.17)	66.64 (6.12)[d]
FFMQ Obs	24.22 (6.74)	23.58 (5.50)	23.86 (5.91)
FFMQ Desc	27.33 (6.96)	25.91 (8.72)	26.52 (7.86)
FFMQ Aware	20.19 (3.79)	21.33 (5.79)	20.84 (4.95)
FFMQ Nonjudg	24.92 (4.35)	21.17 (5.98)	22.78 (5.56)
FFMQ Nonreact	18.33 (4.90)	16.91 (3.70)	17.52 (4.20)
Practice	59.83 (11.20)	50.56 (16.39)	54.53 (14.83)

Note. a = clinically significant, b = moderate severity, c = mild to moderate serverity d = high worry; AR = Applied Relaxation; ABBT = Acceptance-based Behavioral Therapy; WMC = Working memory capacity, measured by Ospan Partial scores; GAD CS = Generalized Anxiety Disorder Clinical Severity Score on the Anxiety Disorders Interview Schedule for DSM–IV; HAM A = Hamilton Anxiety Rating Scale; DASS Stress = Stress subscale on the Depression Anxiety Stress Scale–21-item version; DASS Anxiety = Anxiety subscale on the Depression Anxiety Stress Scale–21-item version; PSWQ = Penn State Worry Questionnaire; FFMQ = Five Factor Mindfulness Questionnaire; Obs = Observing; Desc = Describing; Aware = Acting with awareness; Nonjudg = nonjudging of inner experience; Nonreact = nonreactivity to inner experience; Practice = average percentage of time participants practiced skills over the past week

Procedure

All study procedures were approved by a data safety and monitoring board and the internal review boards for Boston University, University of Massachusetts Boston, and Suffolk University. Participants provided informed consent for the overall treatment study and an additional informed consent for the OSPAN, as this task was added to the

protocol after the study had started. Participants could continue in the overall treatment study even if they did not consent to the working memory study. Regarding compensation, participants received therapy free of charge and were paid $50 each for posttreatment and follow-up assessment. Participants were also paid $10 for each completion of the OSPAN task.

After completing the initial phone screen and ADIS-IV diagnostic interview to determine eligibility, participants signed informed consent and completed pretreatment assessments. First, participants were given informed consent for the treatment study and, if they consented, an interviewer audio-recorded and completed the SIGH-A. Next, participants were given informed consent for the working memory portion of the study. If they signed consent, participants completed the OSPAN. Participants completed the OSPAN task alone while study staff waited in another room. After this, participants were taken to a waiting room to complete a packet of self-report questionnaires, which included the DASS-21, FFMQ, PSWQ, and other measures not discussed in this paper. Finally, regardless of completing the OSPAN task, participants were randomized to treatment condition (either ABBT or AR) and were told that their assigned therapists would contact them to schedule the engagement session – another pretreatment visit. In the engagement session, participants met with their assigned therapist to discuss the client's understanding of his/her worry and anxiety, contextual factors that may affect symptoms and therapy (e.g., urgent family or financial issues), the client's cultural identity, prior experiences with psychotropic medication or psychotherapy, possible obstacles to treatment, and to instill hope.

Treatment consisted of 16 sessions for both conditions. ABBT was administered as described in Hayes-Skelton et al. (2013), Orsillo and Roemer (2011), and Roemer and Orsillo (2009). AR treatment was derived from that of Bernstein, Borkovec, and Hazlett-Stevens (2000) and Öst (2007); however, it was expanded to 16 sessions to match the number of sessions of ABBT. The manual for the expanded version of AR was reviewed by T.D. Borkovec. For both conditions, the first four sessions were 90-minute weekly sessions. Sessions 5 to 13 were 60-minute weekly sessions. Sessions 14 to 16 were 60-minute biweekly sessions. At every session, clinicians administered the Weekly Assessment to measure the percentage of time participants practice intervention skills outside of being in therapy. At Session 16, participants were given a packet of self-report questionnaires, which included the DASS-21, PSWQ, and FFMQ, to bring to the post-treatment assessment visit. Notably, the study demonstrated sufficient adherence and competency of therapists (see details in Hayes-Skelton et al., 2013). Finally, at the post-treatment assessment visit, an interviewer audio-recorded and completed the ADIS and SIGH-A. Then, participants completed the OSPAN and another packet of questionnaires.

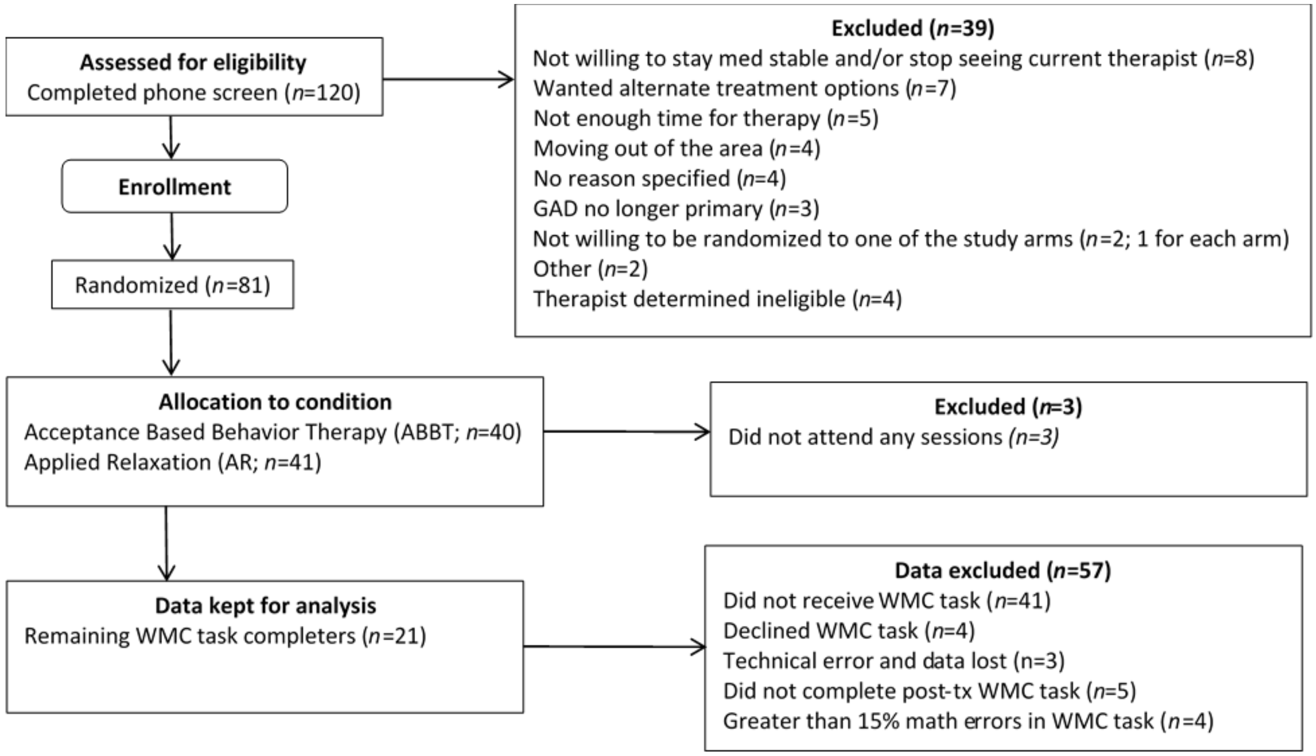

Figure 1. Participant flow through the study. GAD = generalized anxiety. WMC = working memory capacity

CHAPTER 4

RESULTS

Sample Normality and Equivalence

First, tests of normality and outliers run on all primary study variables indicated that the residualized gain scores for HAM-A, DASS Anxiety, FFMQ Aware were positively skewed. Square root transformations of these variables (i.e., HAM-A, DASS Anx, and FFMQ) resolved the skewness. All study analyses were run with both the untransformed and transformed variables. However, the pattern of results remained the same with transformed variables, thus untransformed variables were kept to facilitate interpretation of results (i.e., HAM-A and DASS Anxiety in Hypothesis 2 and the FFMQ Aware in Hypothesis 3). Additionally, analyses of group (i.e., condition) equivalence based on demographic variables and/or central study variables at pre-intervention were also run. ANOVA and Chi-Square analyses were nonsignificant, with small to medium effect sizes.

The remaining analyses reported and interpreted effect sizes, in addition to significance testing, due to small sample size. Similarly, due to being underpowered and the exploratory nature of the study, we did not test differences in correlations across conditions. Descriptions of nonsignificant findings or patterns of difference between correlations should therefore be interpreted very cautiously – these are simply descriptions of patterns that might warrant further study, not conclusions that can be

drawn. Further, residualized gain scores were calculated from all pre- and post-treatment measures (except the practice measure) to indicate change over time.

Hypothesis 1

We hypothesized that post-treatment measures of WMC would significantly increase from pre-treatment measures, and this increase would not differ by condition. A two-way ANOVA with treatment condition as the between-group measure and time as a repeated measure (with 2 levels, pre- and post-treatment) indicated no significant main effects or interaction effect. Effect sizes for main effects were small, while the effect size for the interaction was small to medium. For the between-group variable of treatment condition, $F(1,19) = .40$, $p = .54$, $\eta^2 = .02$; for the repeated measure of time, $F(1,19) = .14$, $p = .71$, $\eta^2 = .007$; and for the interaction, $F(1,19) = .97$, $p = .34$, $\eta^2 = .05$. While the interaction was not significant, it was of a near medium effect size; thus, we calculated paired sample t-tests of the pre-treatment and post-treatment WMC scores within each condition to see if those differences were significant (see Figure 2 for graph of means). In the AR condition, WMC scores did not differ between pre-treatment ($M = 63.56$, $SD = 11.47$) and post-treatment ($M = 62.22$, $SD = 8.76$; see Table 3); $t(8) = .37$, $p = .72$, $d = .12$. Similarly, in the ABBT condition, WMC scores did not significantly differ between the pre-treatment ($M = 59.00$, SD = 6.92) and post-treatment ($M = 62.00$, SD = 11.92); $t(11) = 01.11$, $p = .29$, $d = .32$.

Figure 2

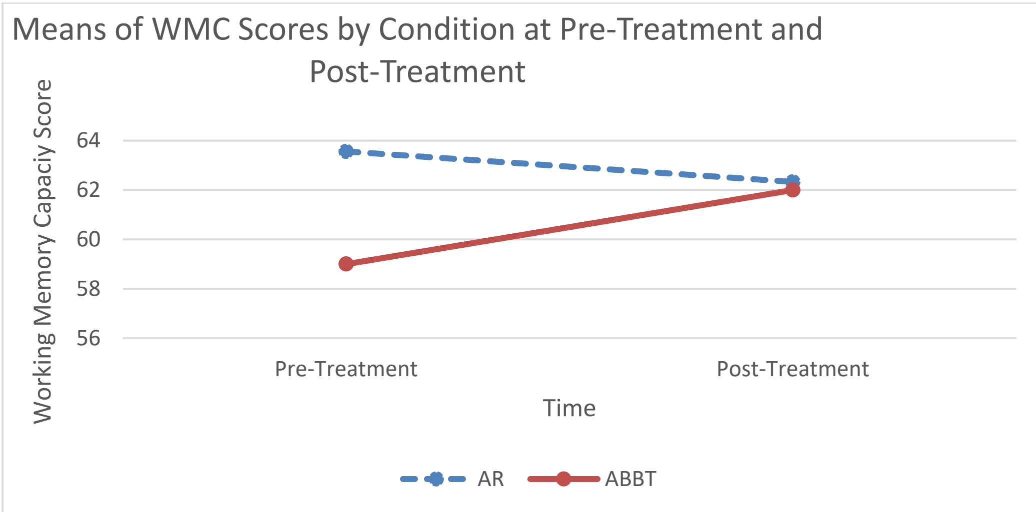

Table 3

Means and Standard Deviations of WMC Scores at Pre-Treatment and Post-Treatment

	AR (SD) *n* = 9	ABBT (SD) *n* = 12
Pre-Treatment	63.56 (11.47)	59.00 (6.92)
Post-Treatment	62.22 (8.76)	62.00 (11.92)

Note. SD = Standard deviation; WMC = Working memory capacity, measured by Ospan Partial scores; AR = Applied Relaxation; ABBT = Acceptance-based Behavioral Therapy.

Hypothesis 2

We hypothesized that increases in WMC would be related to reductions in anxiety. Correlations of WMC residualized gain scores and the residualized gain scores of the five anxiety measures (i.e., GAD CS, HAM-A, DASS Stress, DASS Anxiety, and PSWQ) indicated no significant relations with effect sizes ranging from r = -.05 to r = -.38. Notably, GAD CS, HAM A, and DASS Anxiety demonstrated effect sizes larger than r = ±.3, i.e., medium sized effects. These negative correlations indicate that decreases in measures of anxiety over the course of treatment were nonsignificantly associated with increases in WMC. Additionally, we found that the patterns appear to differ (by observation, not by analysis, due to small sample size) when the sample is split by condition (see Table 4). For example, the correlations of the residualized gain scores of WMC and GAD CS were r = -.21 in the AR condition and r = -.59 in the ABBT condition. The large effect of r = -.59 is also a significant relation, p <.05, indicating that improvement in WMC is significantly related to GAD outcomes in ABBT, but not in AR. A similar pattern was found in the correlations of the residualized gain scores of WMC and HAM A, where r = -.10 in the AR condition and r = -.47 in the ABBT condition. Neither of these correlations were significant. In sum, it appears that several measures of anxiety produced medium to large correlations with WMC scores in the ABBT condition, but DASS Anxiety was the only anxiety measure to produce a medium effect size in the AR condition (see Table 4). Medium or large correlations when the sample was split by condition include the following: DASS Anxiety in the AR condition, r = -.37, GAD CS in ABBT, r = -.59, HAM A in ABBT, r = -.47, DASS Stress in ABBT, r = -.37, and

DASS Anxiety in ABBT, r = -.36. As noted above, this differential pattern is merely descriptive, given the small sample size, which precludes detecting significant differences in correlations, which would be necessary to determine whether these are statistically reliable differences.

Table 4

Correlations of Residualized Gain Scores for WMC and Anxiety Measures in Full Sample and Split by Treatment Condition

	Full sample	AR (n = 9)	ABBT (n = 12)
GAD CS	-.38	-.21	-.59* p<.05
HAM A	-.35	-.10	-.47
DASS Stress	-.26	-.25	-.37
DASS Anxiety	-.32	-.37	-.36
PSWQ	-.05	.13	-.24

Note. WMC = Working memory capacity, measured by Ospan Partial scores; AR = Applied Relaxation; ABBT = Acceptance-based Behavioral Therapy; GAD CS = Generalized Anxiety Disorder Clinical Severity Score on the Anxiety Disorders Interview Schedule for DSM–IV; HAM A = Hamilton Anxiety Rating Scale; DASS Stress = Stress subscale on the Depression Anxiety Stress Scale–21-item version; DASS Anxiety = Anxiety subscale on the Depression Anxiety Stress Scale–21-item version; PSWQ = Penn State Worry Questionnaire

Hypothesis 3

We hypothesized that changes in mindfulness scores would be related to changes in WMC, regardless of condition. Correlations among the residualized gain scores of the FFMQ warranted keeping the subscales, rather than using a total score, r's < .54, except for r = .75 between FFMQ Nonjudgement and FFMQ Nonreactivity. Correlations of the

residualized gain scores of the FFMQ Subscales and WMC found no significant relations, with small effect sizes, r's = .05 to -.19. However, correlations after splitting the sample by condition indicated somewhat different patterns, although only one correlation reached the level of medium effect size (see Table 5). For example, the correlations of the residualized gain scores of WMC and FFMQ Desc were r = -.35 in the AR condition, suggesting that for those in the AR condition, the ability to describe internal experiences may be related to less gain in WMC; however, this correlation in the ABBT condition was r = .07. Additionally, the correlations of the residualized gain scores of WMC and FFMQ Nonreact were r = -.20 in the AR condition and r = .25 in the ABBT condition. Again, because sample size precludes directly testing the differences in these correlations, these patterns should guide future research, rather than lead to meaningful conclusions in this preliminary study.

Table 5

Correlations of Residualized Gain Scores for WMC and Mindfulness Subscales in Full Sample and Split by Treatment Condition

	Full Sample	AR	ABBT
FFMQ Obs	.05	-.08	.10
FFMQ Desc	-.10	-.35	.07
FFMQ Aware	-.09	-.13	-.04
FFMQ Nonjudg	-.19	-.21	-.17
FFMQ Nonreact	.05	-.20	.25

Note. WMC = Working memory capacity, measured by Ospan Partial scores; AR = Applied Relaxation; ABBT = Acceptance-based Behavioral Therapy; FFMQ = Five Factor Mindfulness Questionnaire; Obs = Observing; Desc = Describing; Aware = Acting with awareness; Nonjudg = nonjudging of inner experience; Nonreact = nonreactivity to inner experience

Hypothesis 4

Finally, we hypothesized that time spent practicing therapy skills (i.e., mindfulness for ABBT or noticing early cues of anxiety for AR) would be related to changes in WMC, regardless of condition. Correlations between average practice time and residualized gain scores of WMC indicate a non-significant medium effect, $r = -.32$, in which more practice of therapy skills was associated with less improvement in WMC. After splitting the sample by condition, the correlations showed similar patterns: the correlations of average practice time and the residualized gain scores of WMC were $r = -.39$ in the AR condition and $r = -.28$ in the ABBT condition.

CHAPTER 5

DISCUSSION

Overall, our hypotheses were not supported. Firstly, when interpreting these results, we must reiterate that this study was exploratory in nature, considering the small sample size and absence of repeated measures of WMC over the course of treatment, and cannot indicate temporal precedence or directionality. Further, small sample size and non-significant findings highlight the risk for Type II error in this particular study and the challenges in interpreting these findings. Thus, research in larger samples may clarify some of these questions and challenges.

In relation to hypothesis one, we found that pre- to post-treatment measures of WMC did not significantly increase, and these relations exhibited small effect sizes. Additionally, the interaction was non-significant with a small to medium effect. We hypothesized that, because both of these interventions cultivate mindfulness directly or indirectly, they would not differ in their effects on WMC, and thus would have non-significant main effects of condition and a non-significant interaction. Thus, the non-significant main effect of treatment condition and interaction are consistent with what we expected; however, our hypothesis that these interventions would improve WMC was not supported, given the absence of an effect of time. Review of previous literature on mindfulness interventions indicated that mindfulness enhances or protects WMC from

stress-related degradation (Banks, Welhaf, & Srour, 2015; Jha et al., 2010; Roeser et al., 2013); however, the current study was the first to explore whether changes in mindfulness within a treatment for anxiety in a clinically significant population for anxiety might be associated with changes in WMC. Perhaps the impact of mindfulness on WMC within the context of an anxiety treatment is different. Further, previous literature has not explored the impact of interventions that cultivate mindfulness in addition to other skills (e.g., valued living in ABBT or relaxation in AR). It is also possible that our assumption that the effect of these interventions on WMC would be similar was, in fact, incorrect, and that this difference could not be detected by hypothesis testing. Considering the small to medium effect size of the interaction, perhaps a higher-powered study may produce significant findings. However, as discussed, interpreting non-significant findings is challenging.

Regarding hypothesis two, we found that increases in WMC were not significantly related to reductions in anxiety; however, medium effect sizes in relation to several anxiety measures (i.e., GAD CS, HAM A, and DASS Anxiety) in the overall sample are notable. Further, when splitting the sample by condition, it appears that scores in the ABBT condition may be driving these effect sizes. Specifically, we found medium to large effect sizes in the ABBT condition for associations between WMC and the GAD CS, HAM A, DASS Stress, and DASS Anxiety scales. On the other hand, in the AR condition, we found a medium effect size for only one measure, the DASS Anxiety. While acknowledging these effects and differences across condition are non-significant, this pattern is worth considering. They may indicate that improvements in WMC are

related to positive GAD outcomes in ABBT, but not in AR. Further, it appears that broad symptom reduction was related (significantly for GAD CS, and non-significantly for HAM A, Dass Stress, and Dass Anxiety) to improvements in WMC in ABBT only; however, only anxious arousal (as measured by the DASS Anxiety) was related (non-significantly) to WMC in AR. This finding in AR makes sense when considering a primary goal of AR is to reduce anxious arousal. Additionally, it is unclear why correlations between gain scores in WMC and the PSWQ (measuring worry) were particularly low. Previous literature investigating worry and WMC (as measured by the OSPAN) is scarce and mixed, but suggests that worry and WMC may have a negative relationship (Bredemeier & Berenbaum, 2013; Hallion, Ruscio, & Jha, 2014; Sari, Koster, & Derakshan, 2017). Still, we must acknowledge that the findings of the current study were largely non-significant, and research in larger samples is needed to clarify the mechanisms of ABBT and AR that may improve WMC and reduce anxiety and worry, as well as the time-course of these changes.

We had predicted that changes in mindfulness (via these interventions) may play a role in the relationship between WMC improvement and anxiety reductions; however, in hypothesis three, we found no significant relations and small effect sizes in the overall sample between changes in mindfulness and changes in WMC. Further, when we split the sample by condition, we found some puzzling (non-significant) correlations. Specifically, we found a medium effect size between changes in WMC and the FFMQ Describing subscale for the AR condition, suggesting that participants in the AR condition who increased in their ability to describe their internal experiences also exhibited less gain in

WMC. Items from the FFMQ Describing Subscale include: “I’m good at finding words to describe my feelings;” “I can easily put my beliefs, opinions, and expectations into words;” “Even when I’m terribly upset, I can find a way to put it into words.” Thus, participants in the AR condition who improved on items like these also exhibited less gain in WMC. Imagining the potential role of WMC in mindfulness, one would expect that as our skills to describe our internal experiences amidst the distraction or interference of negative emotions (e.g., anxiety), we would be practicing and perhaps improving our WMC. However, the findings of the current study do not support this pattern of relationship. This finding contrasts with previous research suggesting that mindfulness was related to improved WMC (Banks et al., 2015; Jha et al., 2010; Mrazek, Franklin, Phillips, Baird, & Schooler, 2013; Roeser et al., 2013). In another puzzling finding, we found a small-medium (non-significant) negative correlation between WMC and FFMQ Nonreactivity subscale in the AR condition, but a small-medium (non-significant) positive correlation in the ABBT condition. Some FFMQ Nonreactivity subscale items include: “I perceive my feelings and emotions without having to react to them;” “I watch my feelings without getting lost in them;” “When I have distressing thoughts or images, I ‘step back’ and am aware of the thought or image without getting taken over by it.” The difference in direction, although non-significant, is perplexing and requires more research.

In hypothesis four, the medium non-significant negative correlation suggested that practicing therapy skills (as measured by the particular items in the current study) might be related to less improvement in WMC. Further, results showed a similar pattern when

the sample was split by condition. These findings, although non-significant, contrast with the findings of Jha and colleagues, who found that participants who spent more time practicing mindfulness exercises exhibited bolstered WMC during a high stress time-period (Jha et al., 2010). On the other hand, Quach and colleagues found no significant differences of WMC between those with high or low practice times (Quach, Gibler, & Jastrowski Mano, 2017). Considering the inconsistency with findings by Jha and colleagues, we speculated that findings in the current study may point to a measurement validity problem with our practice variable. Perhaps the particular items used (e.g., in the ABBT condition, “What percentage of the time were you mindful over the past week? By mindful we mean aware of your current experience, focused on where you are at that moment and what you are doing, as opposed to what you did earlier or will do later?” and in the AR condition, “What percentage of the time did you notice your anxious cues over the past week?”) were not capturing practicing the aspects of mindfulness that we believed to be related to WMC. Thus, we also correlated the WMC residualized gain scores with other practice items that may capture practice of relevant therapy skills. For ABBT, we substituted “What percentage of the time did you spend practicing the mindfulness exercises you have been learning in sessions?” For AR, we substituted, “What percentage of the time did you spend practicing the relaxation strategies you have been learning in session?” Unfortunately, we still found similar patterns, in which more time practicing therapy skills was related to less gain in WMC. Another potential explanation of the non-significant relations between practice time and WMC is that participants who reported more average practice time may have been “doing worse” and

experiencing some additional cognitive load that impacted their WMC, thus diluting the potential effect of participants who may have benefitted from practice. Similarly, the time participants spent being mindful of their internal experiences or noticing cues of anxiety may have actually produced a cognitive load that impacted WMC scores. Unfortunately, the study design doesn't allow us to test this hypothesis.

The current study was the first to investigate the relations between WMC, anxiety, and mindfulness in interventions for GAD (i.e., ABBT and AR). We found that the data did not support the hypothesis that these interventions improve WMC. Further, we found that both mindfulness scores and practice of therapy skills (i.e., being mindful or noticing cues of anxiety) were not significantly related to improved WMC. However, in the expected direction, we found non-significant relations with medium to large effect sizes, supporting a potential relationship between anxiety reduction and WMC improvement. The current study is the first to suggest this relation in the context of interventions in clinically significant anxiety.

Study limitations may explain some of the findings overall, as well as point to future directions of research. An important consideration is that the current study's small sample size included high variability (illustrated by the standard deviations, see Table 3) that may have made it harder to detect the effects of the intervention on WMC. Another limitation that may have made effects difficult to detect is the possibility that participants may have produced artificially low WMC scores at post-treatment due to decreased motivation to participate at the end of a long research study, and potentially diluting the effects of the intervention on WMC. Notably, we are not able to test the hypothesis of

“artificially low” WMC scores. Similarly, we had to remove data from participants that exhibited greater than 15% error in the arithmetic portions of the WMC task. These errors may illustrate variability of participant attention, motivation in completing the task, or even higher anxiety. It’s also possible that participants who produced more errors could have benefited from the impact of the interventions on WMC improvement. Finally, it’s possible that the measurement of WMC used in the current study did not capture the WMC or the domain-general executive attention that we believed to be involved in these interventions or practice of mindfulness skills. Moreover, study limitations and unexpected findings in the current study point to the need for future research.

As previously discussed, the literature exhibits very little research studying anxiety and WMC using complex span tasks in general, and none looking at anxiety treatments in clinical populations and their impact on WMC using complex span tasks. Previous research exploring anxiety and WMC as measured using complex span tasks included an anxiety induction task in non-clinical populations (e.g., Shi, Gao, & Zhou, 2014; Sorg & Whitney, 1992). In the current study, medium to large effect sizes of relations between anxiety reduction and improvements in WMC suggest that future research in clinical populations, such as those with GAD, is needed to confirm relations between clinical anxiety reduction and WMC improvements. Further, more research is needed in CBT and mindfulness-based interventions for treating clinically significant anxiety to elucidate the role of WMC. Perhaps dismantling studies could explore which mechanisms of these interventions may impact WMC or even the relevance of WMC. Perhaps other constructs or measures of executive function may be more relevant than

working memory as measured by a complex span task. Finally, future studies may consider designs (e.g., repeated measures) that could illustrate the time-course of change in anxiety, mindfulness, and working memory capacity, which may demonstrate the relations between these constructs or point to the need to explore other relevant constructs.

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