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A RANDOMIZED CONTROLLED TRIAL OF A 14-DAY MINDFULNESS ECOLOGICAL MOMENTARY INTERVENTION (MEMI) FOR GENERALIZED ANXIETY DISORDER

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ABSTRACT

Background: Little is known about whether brief mindfulness ecological momentary interventions (MEMI) yield clinically beneficial effects. This gap exists despite the rapid growth of smartphone mindfulness applications. Specifically, no prior brief MEMI has targeted generalized anxiety disorder (GAD). Moreover, although theories propose that MEMI can boost executive functioning (EF), they have largely gone untested. Thus, this randomized controlled trial (RCT) aimed to address these gaps by assessing the efficacy of a 14-day smartphone MEMI (vs. self-monitoring placebo (SMP)). **Method:** Participants with GAD were randomly assigned to either condition (68 MEMI, 42 SMP). MEMI participants exercised multiple core mindfulness strategies and were instructed to practice mindfulness continually. Comparatively, SMP participants were prompted to practice self-monitoring and were not taught any mindfulness strategies. All prompts occurred five times a day for 14 consecutive days. All participants completed self-reports and neuropsychological assessments at baseline, post-treatment, and 1-month-follow-up (1MFU). Piecewise multilevel modeling analyses were conducted. **Results:** MEMI (vs. SMP) led to larger pre-post-treatment reductions in state depression and anxiety and more mindfulness gains ($|d|$ = 0.50 – 1.13). Further, MEMI (vs. SMP) produced greater pre-1-month-follow-up reductions in GAD severity and perseverative thoughts (between-group d = -0.394 – -0.393) and stronger improvements in performance-based inhibition and EF errors (d = -0.363 – -0.280). However, there were no notable treatment effects for working memory and verbal fluency. Overall, results were stronger at pre-1MFU than pre-post-treatment. **Discussion:** An unguided, technology-assisted, brief MEMI effectively targeted GAD and specific EF facets. Other theoretical and clinical implications were discussed.

Keywords: generalized anxiety disorder, mindfulness, ecological momentary intervention, executive functioning

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Introduction

Frequently, people find themselves engaging in activities on autopilot (Bargh & Chartrand, 1999) or avoiding discomfort (Kang et al., 2013). Such mindless states that prevail in our daily lives have been shown to have negative consequences. For instance, a study found that our minds wander 47% of waking hours, and mind-wandering predicted future unhappiness (Killingsworth & Gilbert, 2010). In comparison, being mindful (i.e., receptively, flexibly, and non-judgmentally focusing on the present *continually*; Baer et al., 2008; Kabat-Zinn, 2003) was related to higher daily positive affect and well-being (Brown & Ryan, 2003). Mindfulness is associated with emotion regulation processes at experiential, behavioral, and neural levels (Guendelman et al., 2017). Thus, it has important implications for the cognitive and clinical sciences.

Practicing mindfulness could improve well-being and alleviate common mental health symptoms (e.g., irritability, anxiety, depressed mood) via diverse pathways. Mindfulness theories posit that persistently exercising present-moment awareness, acceptance, and related skills reduces dwelling on the past (i.e., rumination), expecting the worst (e.g., pathological worry), and suboptimal stress reactivity (Gao et al., in press; Hilt & Swords, 2021). Specific mindfulness practices (e.g., continually attending to and engaging in current values-consistent enjoyable, and challenging activities) may confer salutary psychological effects by enhancing compassion and a sense of agency and self-efficacy (Moberg et al., 2019; Orosa-Duarte et al., 2021). Over time, mindfulness can help people experience decrements in depression and anxiety symptoms through a more adaptive and flexible way of relating to the ebb and flow of their cognitions, feelings, and physical sensations, including distress and somatic sensations (Dimidjian et al., 2014). Identifying and disengaging from unhelpful thought processes (e.g., worrying) and actions (e.g., hyperventilating) by using alternative mindfulness skills (e.g., staying present-minded, body scanning, slowed breathing) are integral to the process (Segal et al., 2010).

Furthermore, the ongoing practice of mindfulness relates closely to higher-order cognitive processes. Because being mindful makes one more cognizant and receptive of all elements in the experiential field, mindfulness-based interventions (MBIs) are theorized to enhance attention and executive functioning (EF) (e.g., *monitoring and acceptance theory*; Lindsay & Creswell, 2017; Teper et al., 2013). EF refers to the multi-domain, higher-order, cognitive control capacity to strategically initiate, plan, and maintain goal-directed actions and adapt swiftly to unanticipated events (Banich, 2009; Zink et al., 2021). EF is thus essential for people to optimally regulate various cognitive and behavioral processes. EF skills include *inhibition* (capacity to refrain from autopilot responding), *working memory (WM)* (aptitude to mentally process, track, and alter information in real-time) (Friedman & Miyake, 2004), and *verbal fluency* (ability to create categorically-cued words within a time limit) (Chan et al., 2008). MBIs teach individuals to deliberately sustain attention to a unique aspect of experience (e.g., slowed breathing, bodily sensations, task-at-hand), refocus following any distractions repeatedly, and maintain a versatile outlook. Thus, MBIs are thought to enhance attention regulation and EF and reduce cognitive errors (Lutz et al., 2015; Posner et al., 2015). Supporting these *mindfulness-cognitive enhancement models*, recent evidence across more than 111 MBI randomized controlled trials (RCTs) has shown that cultivating mindful attention, acceptance, and breathing can enhance global EF (Im et al., 2021), global cognition, and specific EF domains of inhibition and WM, but not reduce cognitive errors (Zainal & Newman, 2021b). Nonetheless, most of these studies were conducted in healthy populations. Thus, it remains unclear if MBIs improve global and specific facets of EF in clinical samples. This is an essential question as compromised EF has been reliably linked to diverse aspects of health (e.g., social relationships, well-being, common mental health symptoms, suicidal ideation) (Bredemeier & Miller, 2015; Snyder et al., 2015; Zainal & Newman, 2018; Zainal & Newman, 2021a).

One way to advance clinical science is to test the efficacy of *mindfulness ecological momentary interventions* (MEMIs) on EF and symptoms in psychiatric samples. Ambulatory MBI can repeatedly instruct patients to focus on the present moment, inhibit judgment and other unhelpful impulses or habits, and harness EF to deploy mindfulness strategies in *real-time* in various situations. To this end, patients may experience symptom changes by being more mindful and adaptable in their lives. For example, a MEMI alleviated depression symptoms in mildly depressed patients (Ly et al., 2014) and raised discomfort tolerance for patients with borderline personality disorder (Prada et al., 2017). Further, most people suffering from mental health problems own a smartphone and are receptive to mobile health (mHealth) therapies (Torous et al., 2014). For instance, for generalized anxiety disorder (GAD) sufferers who reported shame, monetary, organizational, and logistical concerns about seeking face-to-face treatment (Goetter et al., 2018), unguided EMIs may allow privacy, portability, and flexibility to manage worries and related symptoms independently. Also, as MEMIs have been proliferating in recent years (e.g., iMindfulness; Mani et al., 2015), it is ethical to examine their efficacy. Few EMIs have been studied in RCTs (Wasil et al., 2019). Additionally, MEMIs can close current treatment gaps (Alonso et al., 2018). For these reasons, studying, refining, and disseminating empirically-supported MEMIs are essential.

To fine-tune ambulatory MBIs, a fruitful endeavor may be to investigate their potential to produce therapeutic benefits across *brief* durations, defined as a single session or multiple exposures to the intervention for up to two weeks (Schumer et al., 2018). Recently, an RCT by LaFreniere and Newman (2016) showed that 10 days of tracking worries, chances of anticipated fears occurring, and actual outcomes (vs. recording thoughts), four times a day, reduced trait worry in participants with GAD. Treatment gains were maintained at 30-day follow-up. It also showed notable between-group differences in the number of participants meeting GAD diagnostic criteria post-treatment but not at follow-up. Relatedly, a 7-day audio-based self-guided MBI plus WM training (vs. control) reduced worry and increased WM in high worriers (Course-Choi et al., 2017). Note that these brief treatments reflect the exception rather than the norm. Most EMI conducted so far targeted depression (Serrano-Ripoll et al., 2022) and involved long therapy sessions, therapist contact, and standard cognitive-behavioral therapy (CBT; see meta-analyses and reviews by Firth et al., 2017; Heron & Smyth, 2010; Newman et al., 2014; Newman et al., 2011; Versluis et al., 2016; Wasil et al., 2019). Thus, little is known about short-term, low-intensity, self-help mindfulness apps. Standard 1-2.5 hours weekly across 8-16 sessions MBIs require sizeable monetary and time commitment (Creswell, 2017). Thus, brief MEMI can defray such costs and help people effectively regulate acute stress in various settings (Bettis et al., 2022).

Despite the potential advantages of brief MEMI, only five RCTs have examined their impacts. First, a 10-day MEMI that instructed mindfulness exercises three times per day enhanced daily mindfulness, sleep length, and quality in a convenience sample of stressed workers (Hülsheger et al., 2015). However, as it did not include an active control group, threats to internal validity (e.g., regression to the mean, expectancy effects, naturalistic symptom course) could not be ruled out. Second, a 14-day MEMI (vs. thought wandering control) reduced nicotine craving and consumption in heavy smokers (Ruscio et al., 2016); however, between-group effects on negative affect may not have been found due to the small sample size. Another three RCTs tested the efficacy of Headspace, an app-delivered series of mindfulness techniques (e.g., breathing retraining, observing) used for 10 minutes each day across 10 days. Howells et al. (2016) found that Headspace (vs. list-making) led to changes in depression and positive affect in middle-aged, happiness-seeking adults; nonetheless, expected changes in negative affect, life satisfaction, and flourishing were not found. Flett et al. (2018) extended the prior study by testing two widely used MEMIs (Headspace and Smiling Mind vs. activity listing) in unselected undergraduates. Both MEMIs reduced depressive symptoms and enhanced college adjustment (but not anxiety, stress, and flourishing) at post-treatment and 30-day follow-up. Also, Champion et al. (2019) showed that Headspace (vs. waitlist) raised life satisfaction and resilience and decreased stress in a convenience sample of unselected workplace employees.

These prior five MEMI RCTs also have three other shortcomings. First, none recruited persons with any mental health disorder clinical symptoms. Therefore, there is a need for more studies to determine if such results can be extrapolated to diverse clinical samples. Second, the studies testing popular apps instructed mindfulness practices for only one, 10- or 20-minute time period per day. It is thus unclear if findings would be replicated or improved upon in a MEMI that prompted clinically distressed participants *multiple* times daily. Third, these apps still incur considerable costs to customers (e.g., $95.88 to $239.88 for an annual subscription to Headspace).

Therefore, a nominally costing MEMI with the same benefits as these subscription apps would be valuable.

Accordingly, this study tested the efficacy of a 14-day MEMI package compared to a self-monitoring placebo (SMP) for persons with GAD. Maintenance of gains was assessed at 1-month-follow-up (1MFU). We hypothesized that MEMI (vs. SMP) would significantly reduce GAD symptom severity and perseverative cognitions. Further, we expected maintenance of gains during a 1MFU on these primary outcome measures. In addition, we predicted that compared to SMP, MEMI would lead to greater enhancements in inhibition, WM, verbal fluency, and EF errors, with the maintenance of gains across time.

Method

Overall Design

Our preregistered randomized trial (NCT04846777 on ClinicalTrials.gov) used a 2 (Treatment: MEMI, SMP) × 3 (Time: pre-, post-treatment, 1MFU) mixed design to test the differential impacts of MEMI (vs. SMP) on outcomes. Treatment was the between-subject factor, whereas Time was the within-subject factor. One hundred-and-ten participants were recruited (68 MEMI, 42 SMP). Based on an *a priori* Monte Carlo power analysis using the *lmmpower R* package (Arend & Schafer, 2019; Magnusson, 2018), the current study had 80.64%–92.14% power to detect a significant Treatment × Time interaction with a small-to-moderate effect size of Cohen's d = 0.25.

Participants

This project attained ethics approval at a state university in the eastern part of the United States. Figure 1 shows the CONSORT (Consolidated Standards of Reporting Trials; Boutron et al., 2008) flowchart for participant enrollment and progression. Treatment-seeking participants currently not receiving treatment from a mental health professional were recruited from the psychology subject pool and the local community. The study was advertised on StudyFinder. Participants had to meet the criteria for GAD based on the Diagnostic and Statistical Manual–Fifth Edition (DSM-5; American Psychiatric Association, 2013). First, potential participants were screened using the 14-item Generalized Anxiety Disorder Questionnaire–Fourth version (GAD-Q-IV; Newman et al., 2002). Those who scored at or above the clinical cut-off were invited to undergo the Anxiety Disorder Interview Schedule-5 (ADIS-5; Brown & Barlow, 2014) to ascertain GAD and other psychiatric diagnoses. Also, participants were at least 18 years of age, owned an iPhone or Android phone, and provided informed consent. Exclusion criteria included the presence of suicidality, mania, psychosis, or substance use disorders.

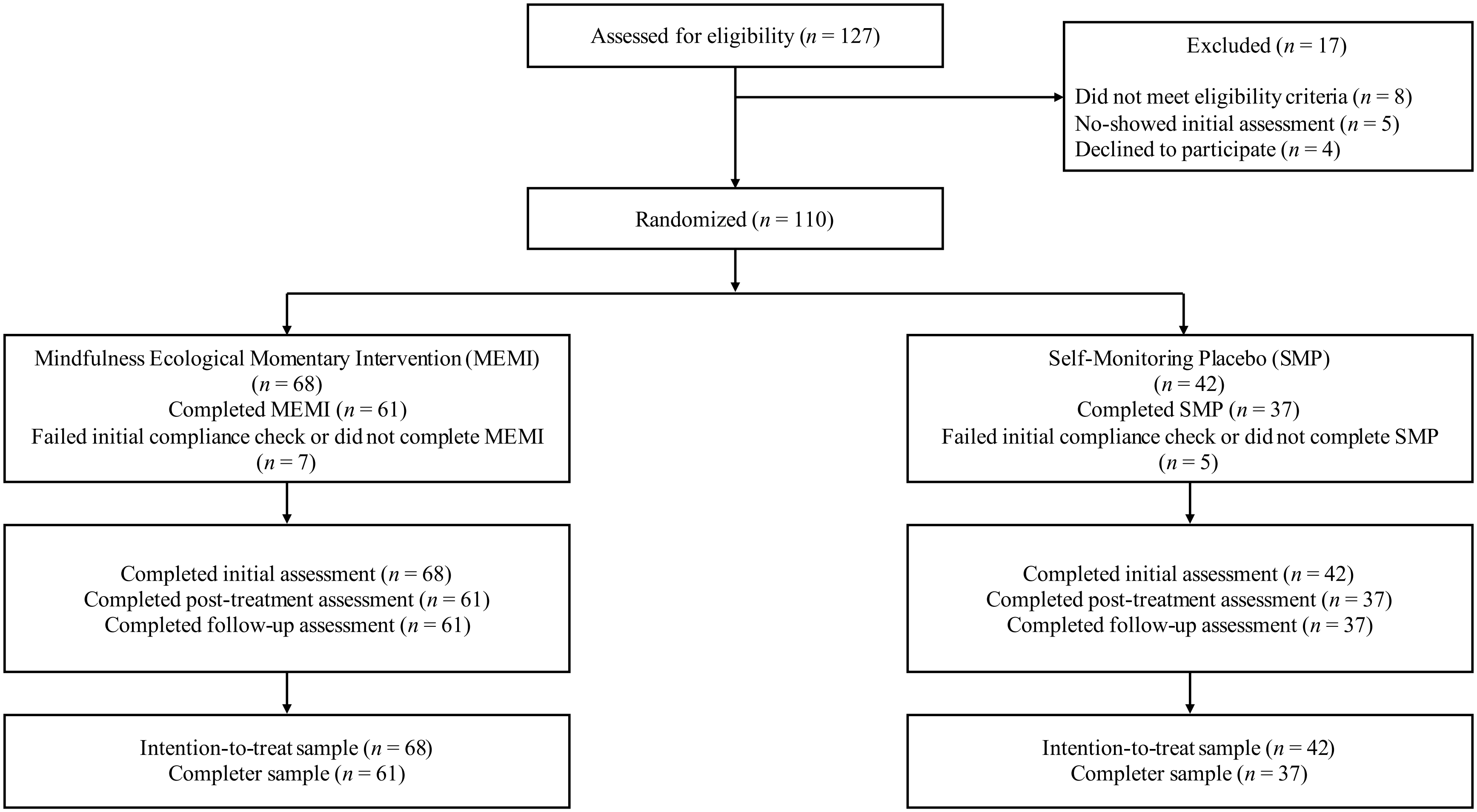

Figure 1: CONSORT Flowchart of Participant Recruitment and Progress

Note. CONSORT = Consolidated Standards of Reporting Trials; MEMI = mindfulness ecological momentary intervention; SMP = self-monitoring placebo.

Participants averaged 20.80 years of age (*SD* = 5.41, range = 18–52). Further, 86.67% (*n* = 94) were women, 13.63% (*n* = 15) men, and one person refused to disclose their gender identity. Also, 64.55% (*n* = 71) identified as White, whereas the remaining as Asian or Asian American (13.63%; *n* = 15), Hispanic (7.27%; *n* = 8), African American (5.45%; *n* = 6), Native American/Pacific Islander (1.82%; *n* = 2), another race (5.45%; *n* = 6), or refused to disclose (0.91%; *n* = 1). In addition, 22.73% (*n* = 25) described their political beliefs as conservative, 59.09% (*n* = 65) as liberal, and 18.18% (*n* = 20) as moderate. Whereas 84% of participants attained a high school education, the remaining 16% achieved a college or postgraduate degree. Of the 110 participants randomized to either MEMI (*n* = 68) or SMP (*n* = 42), 98 completed the 6-week study protocol by finishing at least 80% of the EMI prompts and laboratory study visit assessments. Further, participants were reimbursed up to $30 or 6 subject pool credits to fulfill course requirements pro-rated based on their degree of participation and assessment completion.

Pre-Treatment Clinical Interview and Screening Measure

Psychiatric diagnoses

The ADIS-5 (Brown & Barlow, 2014) was a semi-structured interview based on the DSM-5 (American Psychiatric Association, 2013). It demonstrated high convergence with the Structured Clinical Interview for DSM (SCID; Spitzer et al., 1994) for GAD, major depressive disorder, and other disorders (Shankman et al., 2018), with an excellent inter-rater agreement (κ = .88 to 1.00) (Wade et al., 2022) and strong two-week retest reliability (Rutter & Brown, 2015). The ADIS-5 also showed good convergent and discriminant validity (Gordon & Heimberg, 2011). All ADIS-5 interviews were conducted in person or over Zoom[1] by rigorously trained assessors and video-recorded in the current study. Forty percent (*n* = 45) of these video recordings were reviewed and re-assessed by another blind rater. Inter-rater agreement was excellent for GAD diagnosis (Cohen's

[1] The study protocol has been executed over Zoom since the start of the COVID-19 pandemic.

κ = 1.00) and satisfactory-to-good for other comorbid diagnoses and determination of rule-outs (average κs = 0.75–0.98).

GAD

GAD was screened with the 14-item GAD-Q-IV (Newman et al., 2002) that comprised dichotomous (i.e., 'Yes' or 'No' questions) and continuous response formats (e.g., 9-point Likert scale for items measuring interference and distress excessive worry caused). Also, the GAD-Q-IV measured DSM–Fourth Edition GAD criteria, equivalent to the DSM-5 criteria (American Psychiatric Association, 2013). It showed good sensitivity and specificity with a clinical interview across multiple samples (Moore et al., 2014; Newman et al., 2002). Convergent and discriminant validity were evidenced by large relations with trait anxiety and worry and small associations with unique constructs (e.g., depression; Newman et al., 2002). It also showed good two-week retest reliability (Newman et al., 2002) and strong internal consistency. In the present study, Cronbach's αs = .80, .89, and .91 for GAD-Q-IV (total possible score = 0–14) at baseline, post-treatment, and 1MFU, respectively.

Pre-, Post-Treatment, and 1-Month-Follow-Up Self-Report Measures

GAD Severity

GAD severity was assessed with a 16-item GAD dimensional measure (GAD-Q-Dimensional) that paralleled the GAD-Q-IV but consistently included 9-point Likert scale response formats (e.g., ranging from 0 = *not at all* to 8 = *worry all the time* or 0 = *never* to 8 = *almost every day*). The first eight items of the GAD-Q-Dimensional captured trait worry as respondents rated their degree, frequency, controllability, and intensity of worry. The next eight items asked similar questions concerning the past six months. Possible scores ranged from 0 to 128. With a cut-off score of 60.5, it showed satisfactory-to-good sensitivity (.88), specificity (.82), with a GAD-Q-IV-derived GAD DSM diagnosis (area under receiver operating curve (or percentage of correct classification) = .93, 95% confidence interval (CI) = .91–.96). Convergent and discriminant validity were evidenced by moderate-to-large relations with the GAD-Q-IV (r = .87) and small relations with trait rumination (*r* = .44) and spider phobia (*r* = .11). A confirmatory factor analysis showed that it had excellent model fit (χ^2(*df* = 104) = 96.85, *p* = .678, Confirmatory Fit Index = 1.000, Tucker-Lewis Index = 1.000, Root Mean Square Error of Approximation = .000, 95% CI [.000, 014], and Standardized Root Mean Square Residual = .029). These psychometric properties were ascertained with a dataset of 883 subject pool screen participants with high score variability. In the present study, Cronbach's αs = .90, .92, and .93.

Perseverative cognitions

The 45-item PCQ assessed perseverative cognitive traits linked to worry, rumination, and obsessive thoughts. Respondents endorsed items on a 6-point Likert scale (0 = *strongly disagree* to 5 = *strongly agree*). Further, the PCQ-45 comprised six factors: *dwelling on the past* (DP; 14 items: e.g., "I cannot help but rehash past events in my mind"); *expecting the worst* (EW; 4 items: e.g., "I usually expect the worst in ambiguous situations"); *lack of controllability* (LC; 5 items: e.g., "I am surprised by how little control I have over certain thoughts"); *thoughts discrepant with ideal self* (DT; 11 items: e.g., "I feel appalled by some of my thoughts"); *preparing for the future* (PF; 7 items: e.g., "I repeatedly think about a current problem in order to avoid it"); *searching for causes and meanings* (SC; 4 items: e.g., "I repeatedly think about my feelings to discover if they have some deeper meaning"). The PCQ had strong two-week retest reliability and discriminant and convergent validity (Szkodny & Newman, 2019). A total score for the PCQ was computed by summing the mean scores from each subscale (total possible score = 0–30). In the current study, the internal consistency was good for the PCQ-Total at all time-points (αs = .96, .97, .97).

Pre-, Post-Treatment, and 1-Month-Follow-Up Behavioral EF Measures

Working memory

Four Wechsler Adult Intelligence Scale–Fourth Edition (WAIS-IV; Wechsler, 2008) subtests were used: digit span (DS) forward, DS backward, DS sequencing, and letter-number sequencing (LNS) (Egeland, 2015). Participants repeated increasingly longer number strings verbatim (DS Forward), backwards (DS Backward), or in ascending order (DS Sequencing). LNS required recalling and rearranging lengthier alphanumeric strings in ascending numerical and alphabetical order. A composite WM score was created by summing the performance scores of the WAIS-IV DS forward, backward, sequencing, and LNS. This composite WM score had good convergent validity with other WM test scores, discriminant validity with scores of other tests tapping into different constructs (Egeland, 2015; Kane et al., 2004), and good retest reliability (Wechsler, 2008). Moreover, it had strong internal consistency (αs = .74, .73, and .77 herein).

Inhibition

The four-condition color-word interference test from the Delis-Kaplan Executive Functioning System (Delis et al., 2001) measured inhibition. Participants were instructed to read the specific color patches (condition 1: color naming) and black-inked color words (condition 2: word reading) as well as inhibit the tendency to read the word color and to name instead the ink color (condition 3: inhibition). Also, they were asked to alternate between reading the word-color and ink-color of color-words printed in red, blue, or green ink (condition 4: inhibition/switching). Response times (RTs) were recorded. A composite inhibition score was created by averaging the RTs of conditions 3 and 4. In addition, the inhibition composite score had good internal consistency herein (αs = .78, .84, and .87). Further the color-word interference test had strong retest reliability (r = .62–.76), good convergent with scores on other inhibition measures, and discriminant validity with scores on measures of other constructs (Homack et al., 2005; Martínez-Loredo et al., 2017).

Verbal fluency

The Controlled Oral Word Association Test (COWAT) (Borkowski et al., 1967; Delis et al., 2001) is a three-subtest verbal fluency measure of word production within a 1-minute time limit. Participants were assessed with a phonemic cue requiring strenuous effort (Letter Fluency) and via highly learned concepts (Category Fluency). Also, respondents had to fluidly switch between distinct, overlearned concepts (Category Switching). A composite verbal fluency score was created by summing the total score on the 3 COWAT subtests. The COWAT demonstrated high retest reliability (r = .79–.80) (Homack et al., 2005) as well as strong convergent and discriminant validity (Oliveira et al., 2016). In the present study, the COWAT score had good internal consistency (αs = .76, .79, and .74).

EF Error

A composite EF errors score was computed by summing self-corrected and uncorrected errors during the administration of the color-word interference test and the verbal fluency set loss and repetition errors. The composite EF score had excellent internal consistency in the present study (αs = .87, .74, .90).

EMI Self-Report Measures Across 14-Days from Pre-Post Treatment

Ecological momentary assessments of state symptoms and mindfulness were administered before and after exposure to the MEMI or SMP instructions during each prompt.

State depression, anxiety, and mindfulness

Participants rated on two 9-point Likert scales (1 = *Not at All* to 9 = *Extremely*) their degree of state depression (“To what degree do you feel depressed right now?”), anxiety (“To what degree do you feel keyed up or on edge right now?”), and mindfulness (“To what extent are you experiencing the present moment fully?”) before and after practicing the skills based on their assigned treatment condition.

Treatment Credibility and Expectancy Questionnaire (CEQ; Devilly & Borkovec, 2000)

The 6-item CEQ measured the degree to which participants believed the treatment was credible (e.g., “At this point, how logical does the therapy offered to you seem?”; 1 = *not at all logical* to 9 = *very logical*) and would substantially change symptoms (e.g., “By the end of the therapy period, how much improvement in your symptoms do you think will occur?”; 0%–100%). The CEQ showed strong retest reliability (Devilly & Borkovec, 2000) and high internal consistency (αs = 0.86 and 0.88 for credibility and expectancy herein, respectively).

Procedure

During Visit 1, participants first underwent the ADIS-5 clinical interview. Eligible participants then completed initial self-report and performance-based neuropsychological measures in a counterbalanced fashion to rule out order effects. Next, they were randomized to either MEMI or SMP with the Microsoft Excel randomization function (Padhye et al., 2009). All interviewers were blinded to treatment conditions before randomization. All participants installed the PACO app programmed with the MEMI on their smartphones, and the experimenter demonstrated how to use it. Participants were informed that they would be prompted five times a day (about 9am, noon, 3pm, 6pm, and 9pm) for the next 14 days. The prompts were adjustable based on participants' schedules. Responses on state depression, anxiety, and mindfulness pre- and post-MEMI or SMP induction had to be keyed in within two hours of prompting to be valid. The prompts would instruct them to engage in mindfulness or self-monitoring strategies depending on their condition. After 14 days, all participants returned to the laboratory post-treatment (Visit 2) and at 1MFU (Visit 3) to complete the self-report scales and neuropsychological tests. Also, during Visit 1, the experimenter introduced the treatment rationale and provided brief psychoeducation by playing a pre-recorded video detailed below.

Multi-Component Mindfulness EMI (MEMI)

For MEMI participants, a video showed the first author reading a script verbatim (see Appendix A). It conveyed principles of evidence-based MBI protocols, such as mindfulness-based stress reduction (MBSR; Kabat-Zinn, 1990). MEMI participants were introduced to a definition of mindfulness and asked to concentrate entirely on their current situation and activities. This portion was meant to equip habitual worriers with the skills of *open monitoring* and *attending to small moments*. The video therapist momentarily paused for about three seconds before reading the next paragraph of the script that relayed the skill of *slowed, rhythmic, diaphragmatic breathing*. As the video therapist delivered this part of the treatment, she demonstrated how to perform diaphragmatic breathing. Next, the video therapist taught MEMI participants *non-judgmental acceptance*. Again, she paused for about 3 seconds before conveying the next portion. This component reflected calmness-inducing breathing retraining and mindful observing, non-reactivity, and non-judgmental acceptance skills delivered in mindfulness-based cognitive therapy (MBCT; Segal et al., 2002). Next, the video therapist informed each MEMI participant of the importance and benefits of practicing mindfulness habitually, following another 3-second pause. Finally, the experimenter implementing the study protocol answered any queries. All experimenters continued to administer the 6-item CEQ only after each participant had indicated that they understood the rationale and mindfulness techniques. The experimenter then provided a copy of the script in Appendix A in the online supplementary materials (OSM) and encouraged each participant to review it regularly.

Appendix B displays screenshots of MEMI prompts. During each EMI prompt, MEMI participants were first instructed to engage in *slowed, steady, rhythmic breathing*, "Pay attention to your breathing. Breathe in a slow, steady, and rhythmic manner. Stay focused on the sensations of the air coming into your lungs and then letting it out. Click 'Continue'". Then, they were instructed to practice *open monitoring* and *acceptance*, "As you're breathing, observe your experience as it is. Let go of judgments that do not serve you. Focus your attention in the here-and-now. Click 'Continue'." Last, they were instructed to *attend to small moments*: "Attend to the small moments right now (e.g., reading a chapter, having a cool glass of water) as that is where enjoyment, peace, and serenity in life happen. Click 'Okay' to continue."

Self-Monitoring Placebo (SMP)

The rationale for the SMP condition was adapted from the treatment rationale used in a recent brief EMI (LaFreniere & Newman, 2016). It was developed to parallel the treatment while eliminating its theorized active therapeutic elements – open monitoring, acceptance, attending to small moments, breathing retraining, and continual mindfulness practice. Therefore, it did not mention anything about mindfulness. Instead, the SMP started by defining self-monitoring. It did not instruct participants to be more attuned and aware of their current experience (i.e., it focused on monitoring their thoughts and emotions). Also, participants were not asked to focus entirely on their present moment activities, which would inevitably alter their mood states. As SMP participants were instructed to notice their cognitions and emotions, there was no instruction on accepting their thoughts and feelings as they arose. It also did not provide any breathing retraining instructions as it was not intended to create any form of relaxing or pleasant sensations or mindful states that came with slowed, rhythmic, abdominal breathing. SMP participants were not asked to practice self-monitoring between the prompts and after treatment ended. The SMP approach thus contrasted the principle that mindfulness was meant to be practiced moment-to-moment and cultivated throughout life. To this end, the SMP was intended to control for credibility and expectancy effects and regression to the mean and prevent inflated effect sizes as would occur with a no-treatment or waitlist control group (Cunningham et al., 2013).

The psychoeducation and treatment rationale video for SMP showed the therapist reading verbatim the script in Appendix C that instructed participants to self-monitor by being highly attentive to their cognitions and emotions and observing any distress related to them. Next, similar to MEMI, all experimenters administered the 6-item CEQ after each SMP participant showed they understood the rationale and self-monitoring technique. Following this, the experimenter provided a copy of the script in Appendix C but did not instruct them to review it regularly. Appendix D shows screenshots of the EMI prompts for the SMP condition. During each EMI prompt, SMP participants were asked to observe their thoughts, “Notice your thoughts and how distressing they may be. Click ‘Okay’ to continue.”

Data Analyses

Table 1 presents the descriptive statistics of all the study variables at various time points. We detected no univariate outliers, and most study variables had acceptable skewness (within ± 3) and kurtosis (within ± 8) values. Piecewise multilevel modeling analyses were conducted with the *R* package *nlme* (Pinheiro et al., 2020). We assumed random intercepts and slopes for all models. Whereas Level 1 models within-person changes over time, Level 2 models between-person factors. We tested the effect of all EMI prompts, examining if treatment led to greater change across the treatment period in pre-post-prompt and the impact of treatment across pre-to-1-month-follow-up (pre-1MFU) while accounting for clustering of momentary assessment variables within persons. Distinct analyses were performed for each outcome. Further, robust estimators were used to handle non-normality and multivariate outliers without introducing biases to parameter estimates by transforming the data (Koller, 2016). In addition, we determined that sociodemographic variables (age, gender, ethnicity) and study enrollment time (before or during the COVID-19 pandemic) did not significantly predict primary and secondary outcomes (p values ranged from .072 to .917). Therefore, we did not adjust for these variables as covariates in our series of multilevel models.

Table 1: Descriptive Statistics of Study Variables

	M	(SD)	Min	Max	Skewness	Kurtosis
Pre-treatment: SMP						
GADQ-Dims	44.500	(9.981)	16.000	62.000	-0.700	0.635
PCQ-Total	18.021	(4.267)	5.197	26.816	-0.389	0.573
Inhibition	47.447	(7.822)	32.500	80.035	1.706	5.496
WM	47.405	(8.076)	32.000	67.000	0.378	-0.332
VFS	115.143	(22.994)	80.000	174.000	0.534	-0.512
EF errors	5.690	(4.831)	0.000	20.000	1.176	0.526
Pre-treatment: MEMI						
GADQ-Dims	42.118	(9.391)	13.000	60.000	-0.426	0.248
PCQ-Total	17.068	(4.358)	2.143	26.519	-0.663	0.895
Inhibition	46.548	(10.172)	20.095	82.500	0.814	1.890
WM	49.250	(6.562)	37.000	65.000	0.392	0.027
VFS	112.868	(18.591)	71.000	159.000	0.312	0.249
EF errors	5.632	(5.670)	0.000	37.000	2.792	11.638
Post-treatment: SMP						
GADQ-Dims	43.952	(11.508)	22.000	72.000	0.647	0.496
PCQ-Total	16.764	(5.284)	3.656	26.840	-0.234	-0.254
Inhibition	43.050	(6.327)	22.885	59.525	-0.060	2.015
WM	50.524	(7.363)	35.000	70.000	0.419	0.568
VFS	119.190	(20.694)	78.000	170.000	0.292	-0.022
EF errors	5.643	(3.427)	0.000	14.000	0.521	-0.280
Post-treatment: MEMI						
GADQ-Dims	38.562	(11.348)	11.200	62.000	0.033	-0.768
PCQ-Total	14.836	(4.375)	6.000	26.232	0.319	-0.339
Inhibition	40.829	(8.276)	17.300	65.000	0.684	1.873
WM	51.426	(6.447)	39.000	72.000	0.470	0.171
VFS	118.176	(18.979)	81.000	167.000	0.176	-0.189
EF errors	5.059	(4.092)	0.000	15.000	0.529	-0.836

Note. EF = executive functioning; GADQ-IV = generalized anxiety disorder questionnaire – fourth edition; GAD-Q-Dims = GADQ-IV-dimensional score; MEMI = mindfulness ecological momentary intervention; PCQ = perseverative cognitions questionnaire; SMP = self-monitoring placebo; VFS = verbal fluency score; WM = working memory.

Table 1: Descriptive Statistics of Study Variables

	M	(SD)	Min	Max	Skewness	Kurtosis
1-Month Follow-Up: SMP						
GADQ-Dims	43.714	(13.731)	14.000	72.000	-0.120	-0.012
PCQ-Total	17.129	(4.858)	6.508	26.312	-0.024	-0.641
Inhibition	41.063	(4.718)	30.415	54.845	0.148	0.740
WM	50.810	(6.783)	37.000	71.000	0.612	0.669
VFS	123.500	(17.95)	93.000	168.000	0.650	-0.025
EF errors	5.905	(4.700)	0.000	13.000	0.178	-1.778
1-Month Follow-Up: MEMI						
GADQ-Dims	34.985	(10.353)	12.000	61.000	0.157	-0.096
PCQ-Total	13.514	(4.833)	4.900	25.773	0.475	-0.348
Inhibition	37.966	(6.755)	25.310	75.155	2.556	11.985
WM	52.588	(5.728)	34.000	67.000	-0.286	1.028
VFS	121.529	(14.941)	88.000	164.000	-0.010	0.312
EF errors	2.868	(3.785)	0.000	14.000	1.312	0.802

Note. EF = executive functioning; GADQ-IV = generalized anxiety disorder questionnaire – fourth edition; GAD-Q-Dims = GADQ-IV-dimensional score; MEMI = mindfulness ecological momentary intervention; PCQ = perseverative cognitions questionnaire; SMP = self-monitoring placebo; VFS = verbal fluency score; WM = working memory.

In total, 3.55% of the data were missing. Consistent with an intent-to-treat approach, missing data were managed using multiple imputation (Graham, 2009) by aggregating data across 100 imputed datasets, each with 10 iterations. Lower baseline WM and non-White (compared to White) substantially predicted attrition. Also, MEMI, but not SMP, participants significantly more likely to drop out were females (vs. males or unknown gender) and those with higher baseline GAD-Q-Dimensional severity and lower verbal fluency, WM, and EF errors (refer to Appendix E in the OSM). Thus, we included these significant predictors of attrition as auxiliary variables to improve the precision of the multiple imputation model (Enders et al., 2020). Between-group effect sizes ($d = 2t/\sqrt{(df)}$) (Dunst et al., 2004) and within-group effect sizes were calculated ($d = t*\sqrt{(2/N)}$) (Dunlap et al., 1996) to ease interpretation. Between-group d values of 0.2, 0.5, and 0.8 denoted small, moderate, and large effect sizes, respectively, whereas within-group d values of 0.5, 0.8, and 1.1 were treated similarly (Morris & DeShon, 2002). Readers can refer to the analytic data scripts on OSF (https://osf.io/akmcr/).

Results

Compliance

Overall participant compliance rate was 89.29%, such that the median number of prompts completed was 63 (range = 0–70).

Credibility and Expectancy

On average, neither treatment credibility (MEMI: 6.00 (1.39); SMP: 5.72 (1.58), $p = .336$, $d = 0.19$) nor expectancy (MEMI: 43.46 (17.33); SMP: 44.29 (18.13), $p = .310$, $d = 0.20$) significantly differed across conditions. Thus, the interventions were similarly credible to participants.

Descriptive Statistics and Pre-Treatment Group Differences

There were no significant baseline differences in primary outcomes – GAD-Q-Dimensional ($b = -2.38$, $p = .210$, $d = -0.24$) and PCQ-Total ($b = -0.95$, $p = .264$, $d = -0.22$). Likewise, no significant baseline differences emerged for secondary outcomes – inhibition ($b = -0.71$, $p = .542$, $d = -0.12$), WM ($b = 0.72$, $p = .488$, $d = 0.13$), verbal fluency ($b = -2.28$, $p = .571$, $d = -0.11$), and EF errors ($b = -0.058$, $p = .956$, $d = -0.011$).

Primary Outcome Measures

Table 2 and Table 3 summarize the multilevel models for primary and secondary outcome measures. Figures S1 to S4 present the visual plots of change in scores on PCQ-Total, inhibition, WM, and verbal fluency, respectively.

Table 2: Within-Treatment Group Simple Slopes Analysis of Hierarchical Linear Modeling with Random Intercepts

		Pre-post		Pre-1MFU		Post-1MFU	
Measure	Condition	β	*d*	β	*d*	β	*d*
GADQ-Dims	MEMI	-3.556*	-0.383	-3.567***	-0.936	-3.577*	-0.347
	SMP	-0.548	-0.056	-0.393	-0.090	-0.238	-0.023
PCQ-Total	MEMI	-2.232**	-0.570	-1.777***	-0.964	-1.322	-0.286
	SMP	-1.258	-0.295	-0.446	-0.322	0.365	0.081
Inhibition	MEMI	-4.407***	-1.053	-3.958***	-1.377	-3.509***	-0.753
	SMP	-1.879	-0.393	-2.276**	-0.760	-2.672**	-0.592
WM	MEMI	2.177***	0.579	1.669***	0.796	1.162	0.319
	SMP	3.119***	0.808	1.702**	0.633	0.286	0.062
VFS	MEMI	5.309**	0.544	4.331***	0.920	3.353*	0.357
	SMP	4.048	0.362	4.179**	0.713	4.310*	0.521
EF errors	MEMI	-0.574	-0.161	-1.382***	-0.653	-2.191***	-0.772
	SMP	-0.0476	-0.014	0.107	0.060	0.262	0.125

Note. $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.
β = regression weight; *d* = Cohen's *d* effect size; 1MFU = 1-month follow-up; EF = executive functioning; GADQ-IV = generalized anxiety disorder questionnaire – fourth edition; GAD-Q-Dims = GADQ-IV-dimensional score; MEMI = mindfulness ecological momentary intervention; PCQ = perseverative cognitions questionnaire; SMP = self-monitoring placebo; VFS = verbal fluency score; WM = working memory.

Table 3: Hierarchical Linear Modeling with Random Intercepts for Pre-Post-Treatment and Pre-1MFU Time-points, Group, and Their Interaction Predicting Primary Treatment Outcomes

	Pre-post				Pre-1MFU			
	β	(*SE*)	*t*	*d*	β	(*SE*)	*t*	*d*
GADQ-Dims								
Intercept	44.500***	(1.484)	29.980	4.043	44.500***	(1.484)	29.980	4.043
Condition	-0.548	(2.067)	-0.265	-0.036	-0.393	(0.878)	-0.447	-0.060
Time	-2.382	(1.888)	-1.262	-0.170	-2.382	(1.888)	-1.262	-0.170
Condition × Time	-3.008	(2.629)	-1.144	-0.154	-3.173***	(1.117)	-2.842	-0.383
PCQ-Total								
Intercept	18.021***	(0.667)	27.013	3.642	18.021***	(0.667)	27.013	3.642
Condition	-1.258	(0.884)	-1.423	-0.192	-0.446	(0.368)	-1.214	-0.164
Time	-0.953	(0.849)	-1.123	-0.151	-0.953	(0.849)	-1.123	-0.151
Condition × Time	-0.974	(1.124)	-0.866	-0.117	-1.331**	(0.468)	-2.845	-0.384
Inhibition								
Intercept	43.873***	(1.365)	32.145	4.334	43.873***	(1.365)	32.145	4.334
Condition	-1.879	(0.965)	-1.947	-0.262	-2.276	(0.637)	-3.571	-0.482
Time	-0.372	(1.736)	-0.214	-0.029	-0.372	(1.736)	-0.214	-0.029
Condition × Time	-2.528*	(1.228)	-2.059	-0.278	-1.682*	(0.811)	-2.076	-0.280

Note. * $p < .05$; ** $p < .01$; *** $p < .001$.
β = regression weight; *d* = Cohen's *d* effect size; 1MFU = 1-month follow-up; EF = executive functioning; GADQ-IV = generalized anxiety disorder questionnaire – fourth edition; GAD-Q-Dims = GADQ-IV-dimensional score; PCQ = perseverative cognitions questionnaire; VFS = verbal fluency score; WM = working memory.

Table 3: Hierarchical Linear Modeling with Random Intercepts for Pre-Post-Treatment, Pre-1MFU, and Post-1MFU Time-points, Group, and Their Interaction Predicting Primary Treatment Outcomes (*continued*)

	Pre-post				Pre-1MFU			
	β	(*SE*)	*t*	*d*	β	(*SE*)	*t*	*d*
WM								
Intercept	47.405***	(1.107)	42.822	5.774	47.405***	(1.107)	42.822	5.774
Condition	3.119***	(0.829)	3.763	0.507	1.702**	(0.511)	3.334	0.450
Time	1.845	(1.408)	1.311	0.177	1.845	(1.408)	1.311	0.177
Condition × Time	-0.943	(1.054)	-0.894	-0.121	-0.033	(0.649)	-0.051	-0.007
VFS								
Intercept	115.143***	(3.144)	36.625	4.938	115.143***	(3.144)	36.625	4.938
Condition	4.048	(2.251)	1.799	0.243	4.179***	(1.130)	3.699	0.499
Time	-2.275	(3.999)	-0.569	-0.077	-2.275	(3.999)	-0.569	-0.077
Condition × Time	1.261	(2.862)	0.441	0.059	0.152	(1.437)	0.106	0.014
EF Error								
Intercept	5.690***	(0.828)	6.871	0.927	5.690***	(0.828)	6.871	0.927
Condition	-0.048	(0.765)	-0.062	-0.008	0.107	(0.435)	0.246	0.033
Time	-0.058	(1.053)	-0.055	-0.007	-0.058	(1.053)	-0.055	-0.007
Condition × Time	-0.526	(0.973)	-0.541	-0.073	-1.489**	(0.554)	-2.690	-0.363

Note. * $p < .05$; ** $p < .01$; *** $p < .001$.
β = regression weight; *d* = Cohen's *d* effect size; 1MFU = 1-month follow-up; EF = executive functioning; GADQ-IV = generalized anxiety disorder questionnaire – fourth edition; GAD-Q-Dims = GADQ-IV-dimensional score; PCQ = perseverative cognitions questionnaire; VFS = verbal fluency score; WM = working memory.

GAD-Q-Dimensional

Figure 2 depicts that a significant time ⨉ treatment effect emerged at pre-1MFU (*b* = -3.17, *p* = .005, *d* = -0.38), but not pre-post-treatment (*b* = -3.01, *p* = .255, *d* = -0.15). Despite that, at pre-post-treatment, simple slopes analyses indicated a significant decrease in GAD-Q-Dimensional in MEMI (*b* = -3.56, *p* = .029, *d* = -0.38) but not SMP (*b* = -0.55, *p* = .798, *d* = -0.056). In addition, during pre-1MFU, a significant reduction in GAD-Q-Dimensional occurred in MEMI (*b* = -3.57, *p* < .001, *d* = -0.94) but not SMP (*b* = -0.39, *p* = .681, *d* = -0.090).

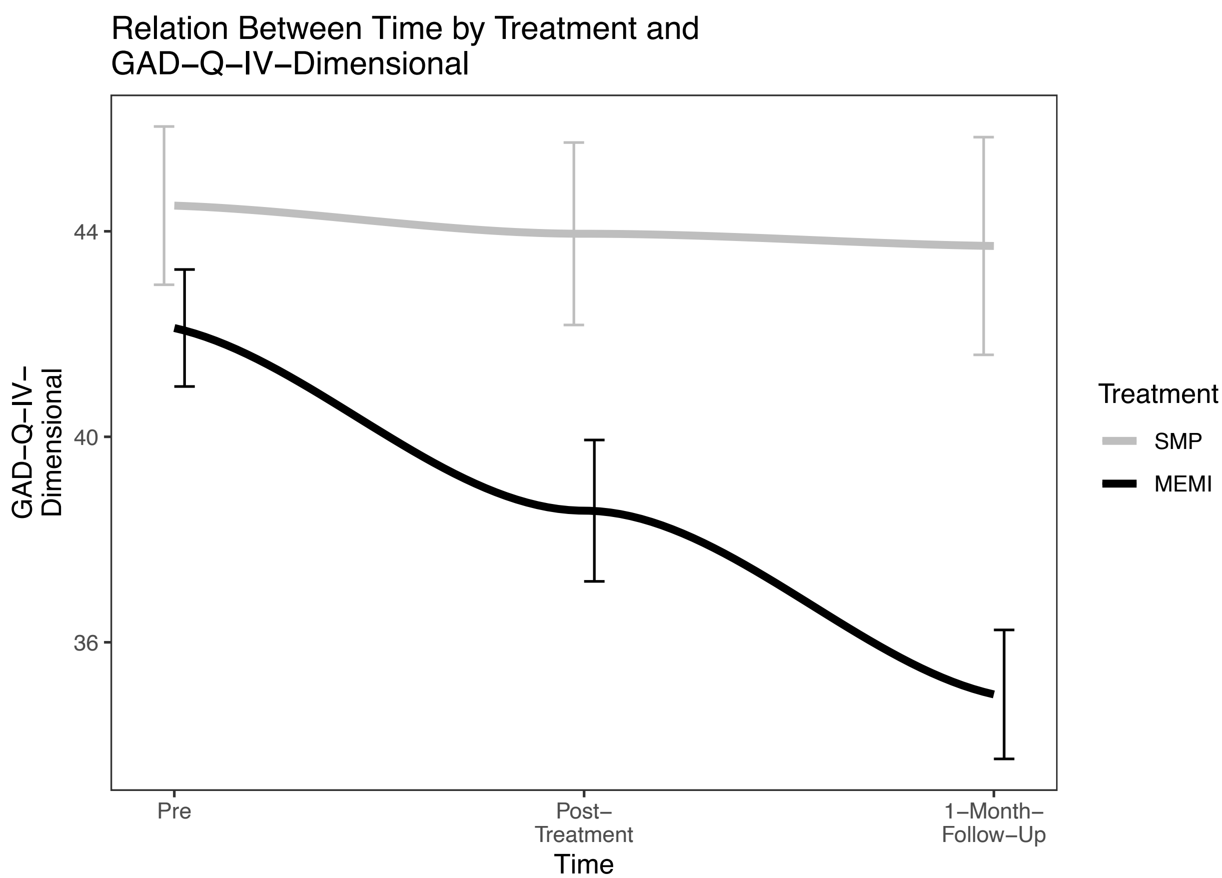

Figure 2: Time by Treatment Effect on GAD-Q-IV-Dimensional
Note. 1MFU = 1-month follow-up; GAD-Q-IV = generalized anxiety disorder questionnaire-fourth edition; MEMI = mindfulness ecological momentary intervention; SMP = self-monitoring placebo.

PCQ-Total

Figure 3 shows a significant time ⨉ treatment effect emerged during pre-1MFU (*b* = -1.33, *p* = .005, *d* = -0.38) but not pre-post-treatment (*b* = -0.97, *p* = .388, *d* = -0.12). Nonetheless, during pre-post-treatment, significant reduction in PCQ-Total was observed for MEMI (*b* = -2.23, *p* =

.001, *d* = -0.57) but not SMP (*b* = -1.26, *p* = .184, *d* = -0.29). Likewise, during pre-1MFU, PCQ-Total significantly decreased in MEMI (*b* = -1.78, *p* < .001, *d* = -0.96) but not SMP (*b* = -0.45, *p* = .148, *d* = -0.32).

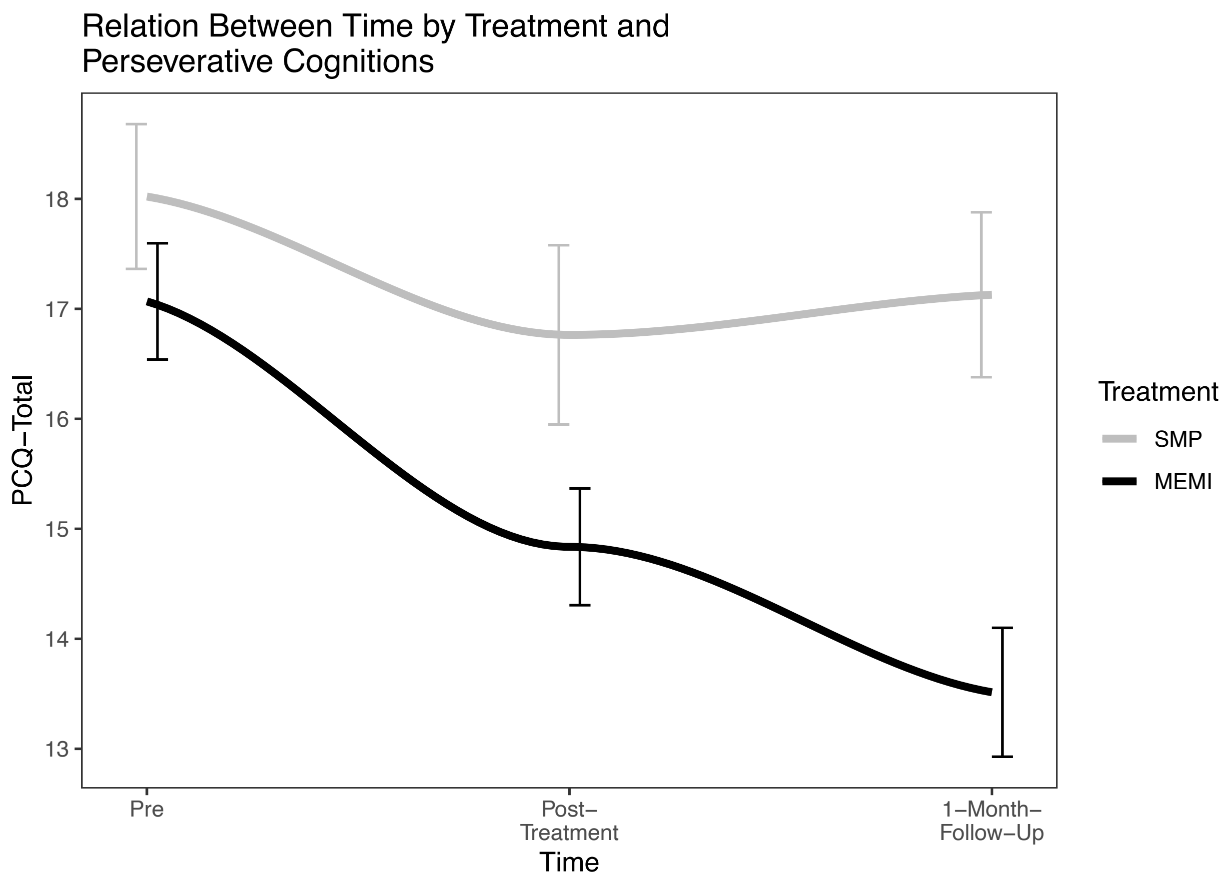

Figure 3: Time by Treatment Effect on PCQ-Total
Note. 1MFU = 1-month follow-up; MEMI = mindfulness ecological momentary intervention; PCQ-Total = perseverative cognitions questionnaire – total score; SMP = self-monitoring placebo.

State Measures of Anxiety, Depression, and Mindfulness

Across the 14-day pre-post-treatment, significant induction × treatment effects were found for state anxiety (*b* = -0.92, *p* < .001, *d* = -0.50), state depression (*b* = -1.35, *p* < .001, *d* = -0.76), and state mindfulness (*b* = 1.96, *p* < .001, *d* = 1.13). From pre-post-treatment, the inductions showed larger reduction in state anxiety for MEMI (vs. SMP) (MEMI: *b* = -1.20, *p* < .001, *d* = -1.17; SMP: *b* = -0.33, *p* = .028, *d* = -0.49). Further, across pre-post-treatment, whereas pre-post-induction state depression significantly reduced in MEMI (*b* = -0.90, *p* < .001, *d* = -0.84), it unexpectedly increased in SMP (*b* = 0.33, *p* = .002, *d* = 0.68). Similarly, across pre-post-treatment, whereas pre-post-induction state mindfulness significantly increased in MEMI ($b = 0.86$, $p < .001$, $d = 1.52$), it unexpectedly reduced in SMP ($b = -1.15$, $p < .001$, $d = -0.97$).

Secondary Outcome Measures

Inhibition

Figure 4 shows that significant time × treatment effects on inhibition score were observed at pre-post-treatment ($b = -2.53$, $p = .042$, $d = -0.28$) and pre-1MFU ($b = -1.68$, $p = .040$, $d = -0.28$). At pre-post-treatment, significant reduction in inhibition latency was produced by MEMI ($b = -4.41$, $p < .001$, $d = -1.05$), but not SMP ($b = -1.88$, $p = .079$, $d = -0.39$). At pre-1MFU, the significant decrease in inhibition latency was considerably larger in MEMI ($b = -3.96$, $p < .001$, $d = -1.38$) than SMP ($b = -2.28$, $p = .001$, $d = -0.76$).

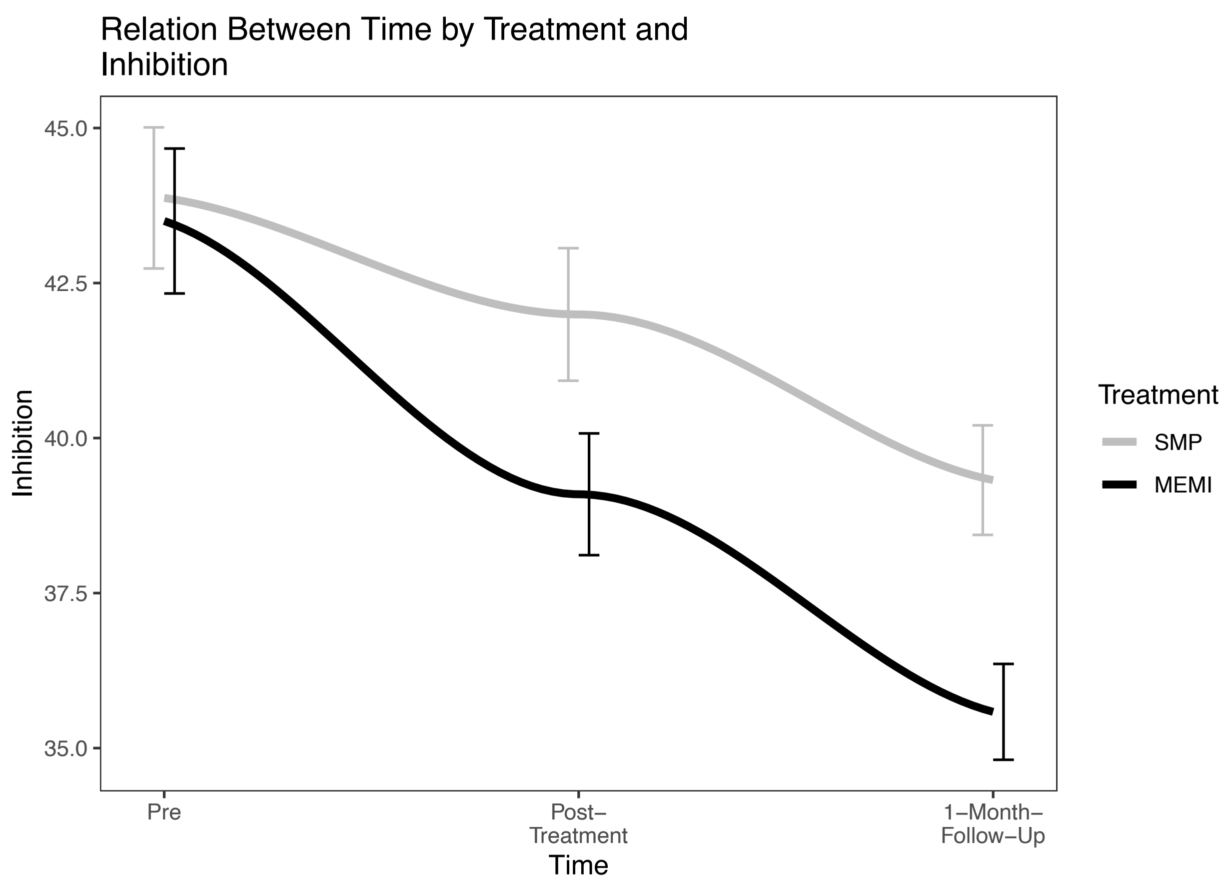

Figure 4: Time by Treatment Effect on Inhibition EF Facet
Note. 1MFU = 1-month follow-up; EF = executive functioning; MEMI = mindfulness ecological momentary intervention; SMP = self-monitoring placebo.

Working memory

No significant time × treatment effects on WM emerged during pre-post-treatment (*b* = -0.943, *p* = .373, *d* = -0.12) and pre-1MFU (*b* = -0.03, *p* = .959, *d* = -0.0069) (refer to Figure 5). Unexpectedly, during pre-post-treatment, both SMP (*b* = 3.12, $p < .001$, *d* = 0.81) and MEMI (*b* = 2.18, *p* = .001, *d* = 0.58) significantly increased WM. From pre-1MFU, this pattern continued such that both MEMI (*b* = 1.67, $p < .001$, *d* = 0.80) and SMP (*b* = 1.70, *p* = .006, *d* = 0.63) had a significant positive effect on WM.

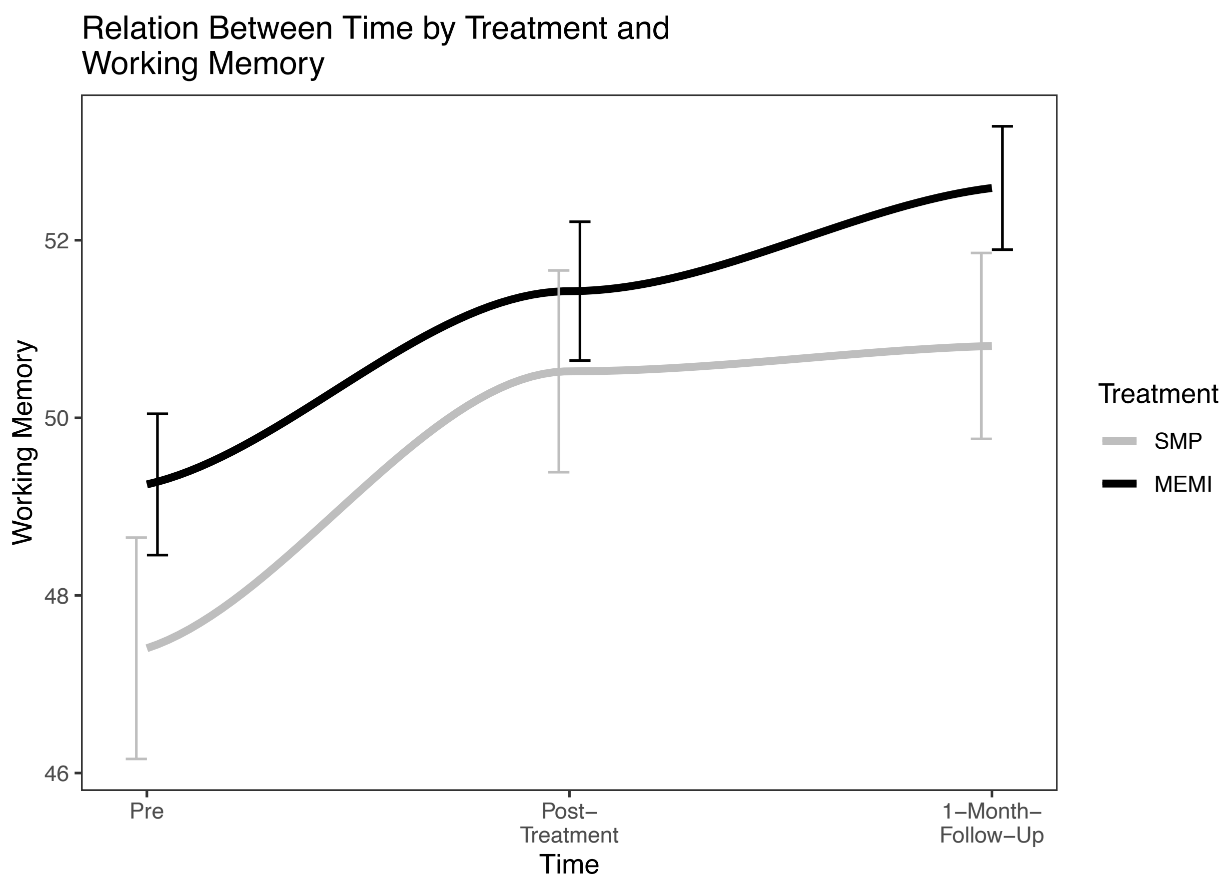

Figure 5: Time by Treatment Effect on WM EF Facet
Note. 1MFU = 1-month follow-up; EF = executive functioning; MEMI = mindfulness ecological momentary intervention; SMP = self-monitoring placebo; WM = working memory.

Verbal fluency

There were no substantial time × treatment effects on verbal fluency at pre-post-treatment (*b* = 1.26, *p* = .660, *d* = 0.059) and pre-1MFU (*b* = 0.15, *p* = .916, *d* = 0.014) (refer to Figure 6). Nevertheless, at pre-post-treatment, significant rise in verbal fluency was found for MEMI (*b* = 5.31, *p* = .002, *d* = 0.54) but not SMP (*b* = 4.05, *p* = .104, *d* = 0.36). In addition, at pre-1MFU, significant increases in verbal fluency were found for both MEMI ($b = 4.33$, $p < .001$, $d = 0.92$) and SMP ($b = 4.18$, $p = .002$, $d = 0.71$).

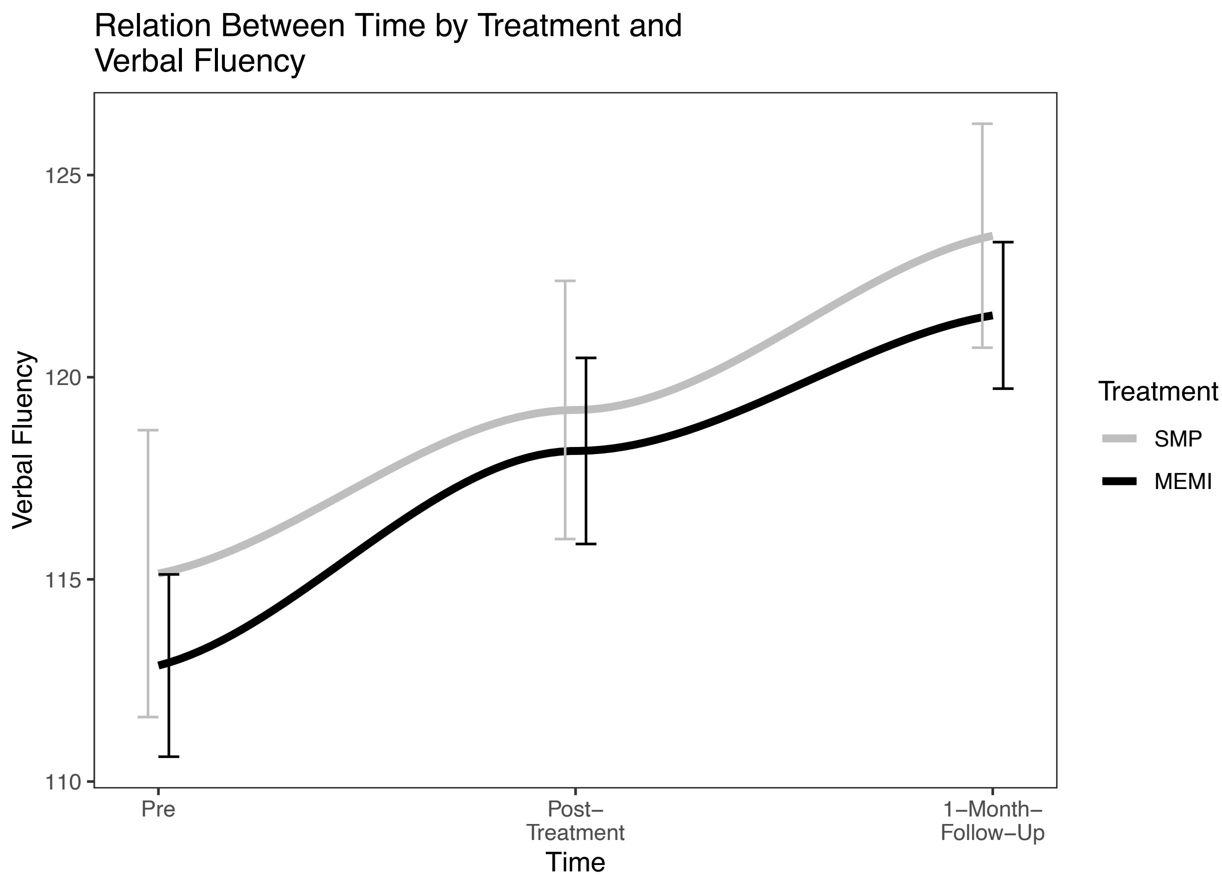

Figure 6: Time by Treatment Effect on VF EF Facet
Note. 1MFU = 1-month follow-up; EF = executive functioning; MEMI = mindfulness ecological momentary intervention; SMP = self-monitoring placebo; VF = verbal fluency.

EF errors

Although no substantial time × treatment effect was found at pre-post-treatment ($b = -0.53$, $p = .590$, $d = -0.073$), a significant time × treatment effect emerged at pre-1MFU ($b = -1.49$, $p = .008$, $d = -0.36$) (refer to Figure 7). EF errors did not change significantly for MEMI ($b = -0.57$, $p = .351$, $d = -0.16$) and SMP ($b = -0.048$, $p = .949$, $d = -0.014$) during pre-post-treatment. However, during pre-1MFU, reduction in EF errors were significantly greater for MEMI ($b = -1.38$, $p < .001$, $d = -0.65$) compared to SMP ($b = 0.11$, $p = .784$, $d = 0.060$).

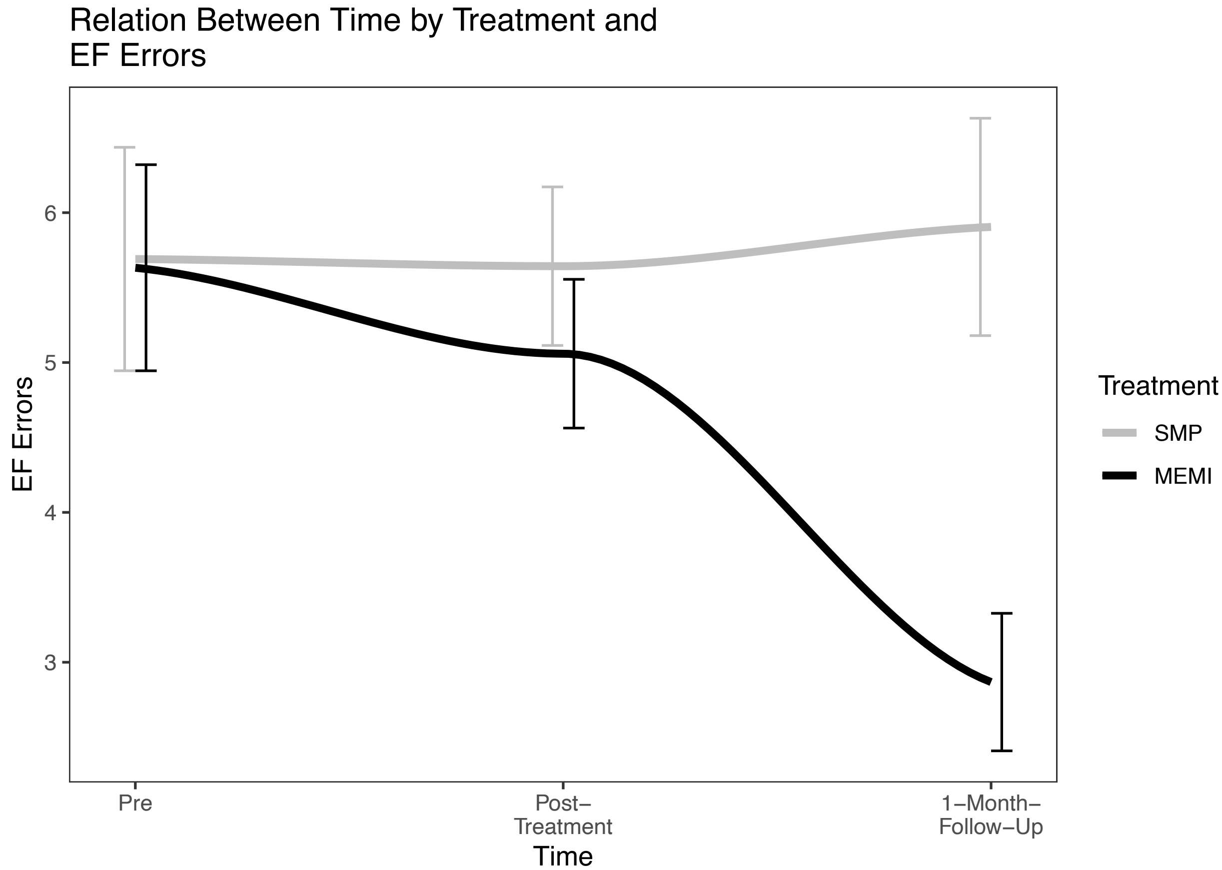

Figure 7: Time by Treatment Effect on EF Errors
Note. 1MFU = 1-month follow-up; MEMI = mindfulness ecological momentary intervention; EF = executive functioning; SMP = self-monitoring placebo.

Table 4 shows the results during post-1MFU.

Table 4: Hierarchical Linear Modeling with Random Intercepts for Post-1MFU Time-points, Group, and Their Interaction Predicting Primary Treatment Outcomes

Outcome	β	(*SE*)	*t*	*d*
GADQ-Dims				
Intercept	44.190***	(3.64)	12.140	1.637
Group	-0.238	(2.273)	-0.105	-0.014
Time	-2.052	(4.63)	-0.443	-0.060
Group × Time	-3.338	(2.891)	-1.155	-0.156
PCQ-Total				
Intercept	16.398***	(1.587)	10.334	1.393
Group	0.365	(1.002)	0.365	0.049
Time	-0.240	(2.018)	-0.119	-0.016
Group × Time	-1.688	(1.274)	-1.325	-0.179
Inhibition				
Intercept	44.666***	(1.982)	22.534	3.039
Group	-2.672**	(1.005)	-2.658	-0.358
Time	-2.064	(2.521)	-0.819	-0.110
Group × Time	-0.837	(1.279)	-0.654	-0.088
WM				
Intercept	47.405***	(1.107)	42.822	5.774
Group	1.702	(0.511)	3.334	0.450
Time	1.845	(1.408)	1.311	0.177
Group × Time	-0.033	(0.649)	-0.051	-0.007
VFS				
Intercept	114.881***	(4.456)	25.784	3.477
Group	4.310*	(1.960)	2.198	0.296
Time	-0.057	(5.667)	-0.010	-0.001
Group × Time	-0.957	(2.493)	-0.384	-0.052
EF Error				
Intercept	5.381***	(0.964)	5.582	0.753
Group	0.262	(0.563)	0.465	0.063
Time	1.869	(1.226)	1.525	0.206
Group × Time	-2.453***	(0.716)	-3.427	-0.462

Note. * $p < .05$; ** $p < .01$; *** $p < .001$.
β = regression weight; *d* = Cohen's *d* effect size; 1MFU = 1-month follow-up; EF = executive functioning; GADQ-IV = generalized anxiety disorder questionnaire – fourth edition; GAD-Q-Dims = GADQ-IV-dimensional score; PCQ = perseverative cognitions questionnaire; VFS = verbal fluency score; WM = working memory.

Discussion

We observed that a brief MEMI compared to SMP across two weeks led to greater increases in state mindfulness, reductions in state anxiety, and reductions in state depression pre-post-treatment. At the same time, although MEMI was also significantly better than SMP in reducing GAD symptoms, repetitive negative thinking, and EF errors at pre-1MFU, there was no differential treatment efficacy on these measures at pre-post treatment. Further, we found significant between-treatment effects favoring MEMI on greater inhibition at both pre-post-treatment and pre-1MFU. All statistically significant effect sizes were small-to-large. No significant between-treatment effects emerged at all time-lags for WM and verbal fluency as outcomes. The current novel study builds on prior literature (Bry et al., 2018) and is aligned with previous EMI RCTs. Data pooled across mainly self-directed CBT and relaxation training-focused EMI RCTs for GAD and related anxiety disorders similarly showed small-to-moderate effects in reducing anxiety severity vs. active controls (cf. reviews by Firth et al., 2017; Gee et al., 2015). Our findings were consistent with small yet notable effect sizes of smartphone and meditation apps (vs. active and non-specific controls) targeting anxiety and depressive symptoms (Goldberg et al., 2022). However, our study built on these prior trials by testing and providing some initial evidence for the efficacy of a short-term, low-intensity MEMI for GAD. Also noteworthy were the high retention and compliance rates, a stark contrast to most mHealth platforms that demonstrate low degrees of engagement and completion (Christensen et al., 2009).

Why were there larger pre-1MFU than pre-post-treatment reductions in GAD severity and perseverative cognition tendencies in MEMI than SMP? One reason might be that, unlike SMP, MEMI offered opportunities to acquire and exercise mindfulness skills regularly in everyday life and emphasized the importance of cultivating those skills throughout life. Perhaps MEMI participants needed to regularly practice various mindfulness skills beyond the two-week intervention to reap notable benefits. Stated differently, monitoring symptoms and exercising mindfulness repeatedly in real-time persistently via the MEMI might have assisted habitual worriers in identifying moments where practicing slowed breathing, non-judgment, and non-reactivity strategies were required. Continual practice of mindfulness skills could avert unhelpful repetitive thoughts from perpetuating and negative affect states from emerging. In addition, improvements in worry severity and thinking patterns likely coincided with increased engagement in values-oriented, goal-directed activities in the here-and-now, as explicitly instructed by the MEMI. Future studies could extend our analysis by including assessments on the degree of mindfulness skill use following treatment.

Relatedly, what are plausible change mechanisms via which MEMI outperformed SMP in targeting reductions in GAD severity and perseverative cognitions at pre-1MFU? Practicing mindfulness could lessen excessive worry and perseverative thoughts by emphasizing being present-minded and using metacognition (i.e., non-reactively observing emotions and thoughts in real-time) vs. being preoccupied with them as happens while brooding or worrying (Segal et al., 2012). Prior trials indeed showed that decrements in rumination and related repetitive thoughts mediated the impact of MBI on anxiety, depression, and distress-linked symptoms (cf. review by van der Velden et al., 2015). Other conceivable mechanistic accounts are that MEMI disrupted reactive worry and repetitive thought cycles by enhancing one's curiosity about various experiences and feelings (including negative ones) and shifting focus toward rewarding goals and activities (Brewer et al., 2020). These ideas are consistent with evidence that therapist-led MBIs raised trait-like specificity of life goals and perseverance (Crane et al., 2012) and enhanced state-level positive emotions, gratitude, and constructive responses to pleasant everyday activities in persistently depressed adults (Batink et al., 2013; Geschwind et al., 2011). To further empirically test these mechanism of change ideas in digital mental health, future EMI studies should heed calls to include process measures (Hollis et al., 2018) and examine therapeutic processes through an idiographic lens (Wright & Woods, 2020). Such efforts to examine predictors, moderators, and mechanisms of change could shed light on why and for whom MEMI would be effective for GAD and related conditions.

Consistent with *mindfulness-cognitive enhancement models* (Kral et al., 2022; Lindsay & Creswell, 2017), MEMI (vs. SMP) had a more significant effect on enhancing inhibition and reducing EF errors across pre-1MFU and inhibition at pre-post treatment. Such data are congruous with evidence that exercising mindfulness breathing techniques for three weeks could enhance inhibition and the ability to identify and resolve conflicts among healthy controls (Pozuelos et al., 2019) and patients diagnosed with a psychotic disorder (Lopez-Navarro et al., 2020). The possibility that MEMI optimized attention, cognitive control, and EF-related brain pathways, and such alterations might have dampened non-constructive repetitive thinking neural correlates (Barredo et al., 2021; Guidotti et al., 2018) could explain the findings. Stated differently, our results might be accounted for by the *integrated neurocognitive framework of mindfulness* (Raffone et al., 2019; Raffone & Srinivasan, 2017). Further support for these propositions is prior evidence that MEMI strengthened resting-state functional connectivity among brain regions related to EF (e.g., dorsal and ventral frontoparietal and hippocampal networks) and emotion regulation (e.g., amygdala, insula, anterior cingulate cortex) (Kral et al., 2019; Young et al., 2018). Moreover, such patterns have been observed in habitual worriers (Holzel et al., 2013). Future RCTs could test these conjectures and extend the current study by including neuroimaging markers throughout the intervention.

Despite the salutary benefits of MEMI for EF errors and inhibition, we observed no treatment effects for verbal fluency and WM. Findings suggest that neither continually monitoring thoughts, feelings, and distress nor explicitly practicing mindfulness yielded superior outcomes over one another to improve the capacity to keep track of information and update it in real-time. Such findings were partially consistent with data aggregated across 111 RCTs showing that MBIs improved global cognition, WM accuracy, and inhibition accuracy, but not response time-based EF tests, verbal fluency, and cognitive errors (Zainal & Newman, 2021b). Perhaps a more intensive psychologist-guided MBI is necessary to improve WM for persons with GAD since MBI studies that demonstrated a positive impact on WM tended to be therapist-led and last four weeks or more (e.g., Bachmann et al., 2018; Quach et al., 2016). Upcoming MBI RCTs can build on the present and prior studies that recruited clinical or distressed samples (e.g., military men, patients with severe mental illnesses; Jha et al., 2019; Langer et al., 2020) to test the dose-response effect hypothesis concerning WM and related EF facets by increasing study duration. Also, theory and evidence indicate that consistent null treatment effects on verbal fluency might be because MBIs typically impact cognitive domains linked to attention and encoding rather than a measure that depends on acquired oral information thus far (Lueke & Lueke, 2019).

Some unanticipated impacts of SMP emerged during pre-post-treatment. Whereas MEMI reduced state depression and anxiety and increased state mindfulness, SMP raised state depression and decreased state mindfulness across pre-post-treatment. Such results were inconsistent with literature showing that self-monitoring alone could positively affect worry severity (LaFreniere & Newman, 2016) and state negative affect (van Knippenberg et al., 2018). Future research could test the conjecture that self-monitoring could, at times, lead to increased distress in the short term as participants become more acutely aware of their emotions. Simultaneously, it is plausible that the SMP instructions that explicitly requested participants to focus on distress related to their thoughts and feelings might contribute to these results.

Findings need to be construed in light of the strengths and limitations of the current study. First, the two-week treatment duration might be insufficient to produce more immediate improvements in GAD severity, perseverative cognitions, and most EF abilities; nonetheless, the findings appeared more promising for habitual worriers during pre-1MFU. Second, our study did not include measures to evaluate how MEMI participants continued to practice mindfulness skills from post-treatment to 1MFU. Future studies should thus consider if unceasing use of mindfulness techniques, even in the absence of repeated instructions via the MEMI, might have contributed to any positive treatment effects at follow-up. Limitations notwithstanding, study strengths included the gold standard RCT design with active control, high compliance rate, recruitment of a well-powered sample, and inclusion of a 1MFU assessment. In addition, our attrition rate of 11% was lower than the average of 24% to 50% in smartphone-delivered RCTs (Lakhtakia & Torous, 2022;

Linardon & Fuller-Tyszkiewicz, 2020). The low attrition rate might be due to the pro-rated design of the reimbursement schedule of the current study.

If our pattern of findings is replicated, some clinical implications merit consideration. Promoting the use of MEMI in treatment for GAD provides the potential to bridge the chasm between the therapist's office and chronic worriers' everyday life. As clients continually use mindfulness skills, new helpful action repertoires and mindsets would likely replace old limiting habits, such as chronic avoidance of allowing shifts from positive to neutral or negative emotion states (Newman et al., 2019) or using worry as a pseudo-problem-solving strategy (Llera & Newman, 2020). Therapists can also emphasize that these practices might assist with alleviating anxiety, reducing GAD symptoms and perseverative thoughts, and improving specific EF abilities. On that note, the current MEMI could facilitate the dissemination of low-cost and effective unguided MBIs, rendering it a favorable mental health treatment delivery approach as an independent treatment, an adjunct, or part of a stepped-care model (Ho et al., 2016; Newman, 2000). Other digital health clinical trials could expand on the present study by examining how individualized feedback (Myin-Germeys et al., 2016), event-contingent triggers, and passive sensors (Mohr et al., 2017) might increase the efficacy of MEMI in targeting pathological worry (cf. just-in-time adaptive interventions) (Nahum-Shani et al., 2018). Based on mounting evidence (Wang & Miller, 2020), these approaches could augment and optimize MEMI to effectively target GAD and frequently comorbid depression and related mental health issues.

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Appendix A

Script for Treatment Condition

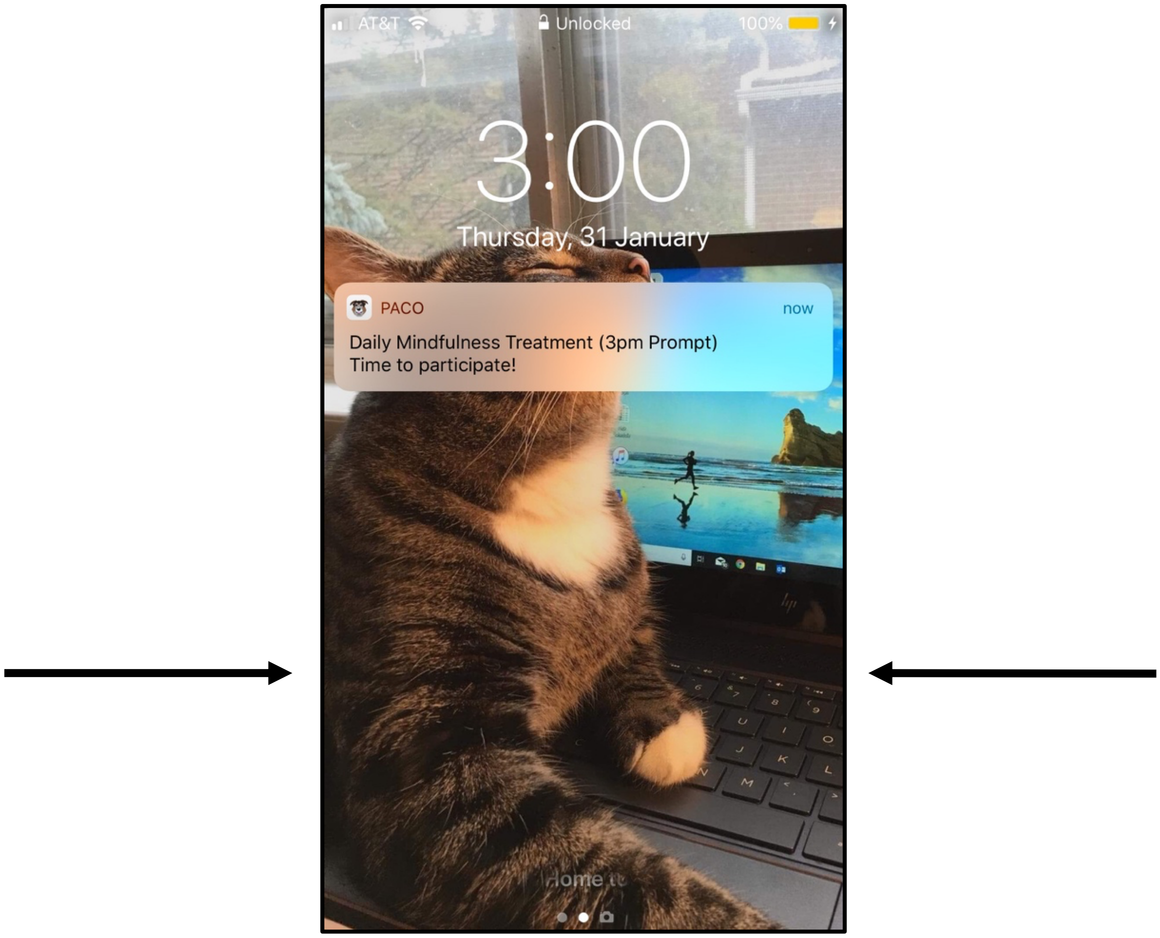
We will now introduce the treatment to you. To begin, this treatment aims to equip you with mindfulness skills. *Mindfulness* refers to paying attention to the present moment in a way that helps you to be *fully engaged* with the tasks that you are doing, whether it is having a cool glass of water, reading a book chapter, or talking to a friend. Focusing on the here-and-now helps you as you will not be dwelling on the negative things that happened in the past, worrying about bad events that may happen in the future, or allowing your mind to wander off aimlessly. Grounding yourself in the present moment therefore helps you to manage your emotions by making you feel less depressed and anxious.

At the same time, this mindfulness treatment is designed to help you learn to breathe more optimally. Optimal breathing requires you to breathe in a *slow*, *steady*, and *rhythmic* way. When you breathe in, your abdomen below your belly button expands (*study personnel uses body language to demonstrate*), and when you breathe out, your abdomen contracts. Throughout the whole time, *your chest should remain relatively steady*. Breathing in a *slow*, *steady*, and *rhythmic* way creates a sense of well-being because it counteracts the brain systems responsible for fight, flight, or freeze responses. The *fight* system tells you to be overly self-critical, the *flight* system tells you to engage in social withdrawal, and the *freeze* system tells you to take part in self-absorption and think less about the concerns of others. Practicing mindful breathing and attentiveness to the present moment and the tasks you're engaging in habitually allows you to feel more self-confident instead of self-critical. It also helps you to be better able to see the big picture that others too are struggling and empathize as well as relate better with your friends, family, and acquaintances. Instead of letting depression or anxiety immobilize you, practicing mindfulness helps you to do what you need to do in terms of taking the right steps in this moment to reach your full potential, personal, and career aspirations. Instead of being absorbed in your thoughts, practicing mindfulness helps you become more aware of the world around you.

As you become more present and observe your experience as it is, you will notice that some negative emotions, anxious, and depressive symptoms arise. Examples include feelings of nervousness, being keyed up, anger, sadness, guilt, disappointment, regret, and self-blame. We ask you in this treatment to let go of judgments that do not serve you. Negative and unhelpful judgments include thoughts of worthlessness (e.g., "I'll never be good enough") and resentment (e.g., "I hated how so and so treated me."). These kinds of judgments only create and amplify negative mood states. Letting go of such judgments prevents you from going into a downward anxious or depressive spiral. Also, let go of judging your emotions as good or bad, but simply allow and accept your emotions to be as they are as you're experiencing them.

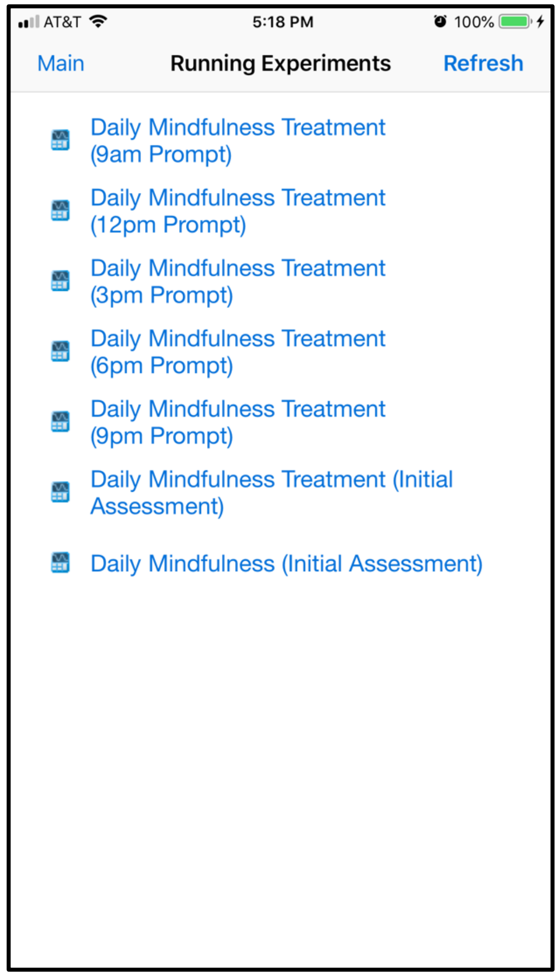
Most importantly, *remember that the goal of therapy is to be your own therapist*. On top of engaging in the mindfulness prompts 5 times daily for 14 consecutive days, know that practicing mindfulness habitually in between the prompts and beyond participation in this study helps you with improving your mood, concentration abilities, attaining your life goals, and enhancing your quality of life. Research evidence has documented many benefits of practicing mindfulness.

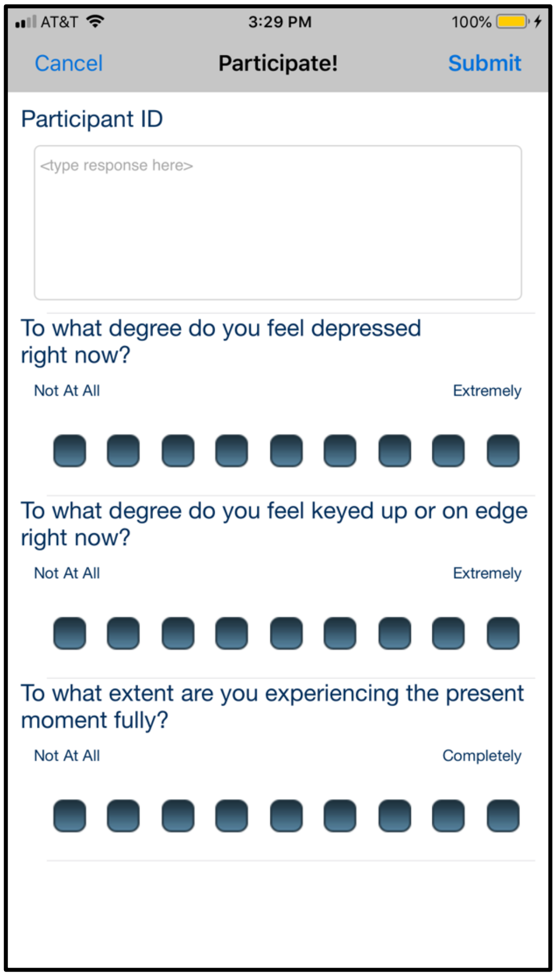
These include achieving better grades in school, lower anxiety and depression, as well as greater self-esteem, cognitive flexibility, relationship satisfaction, perspective-taking skills, and more.

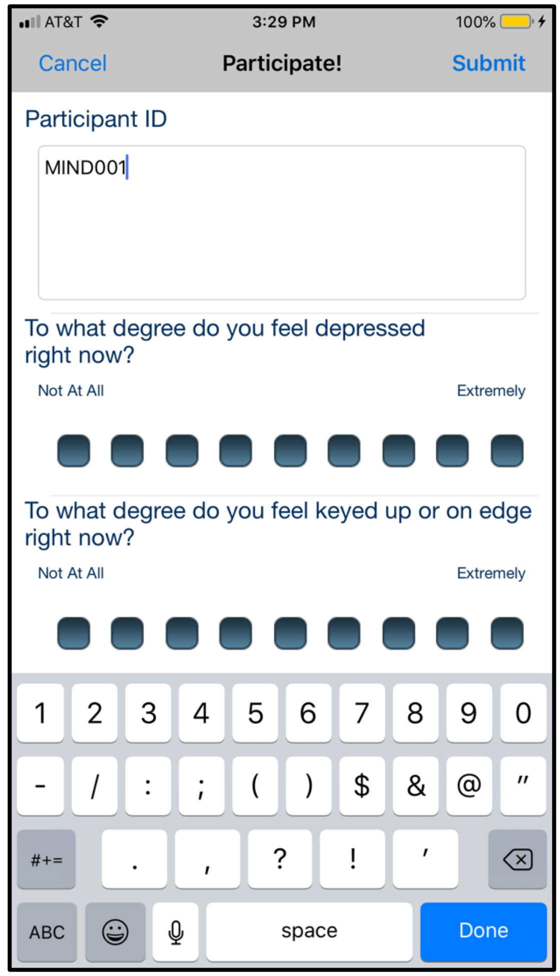


Appendix B

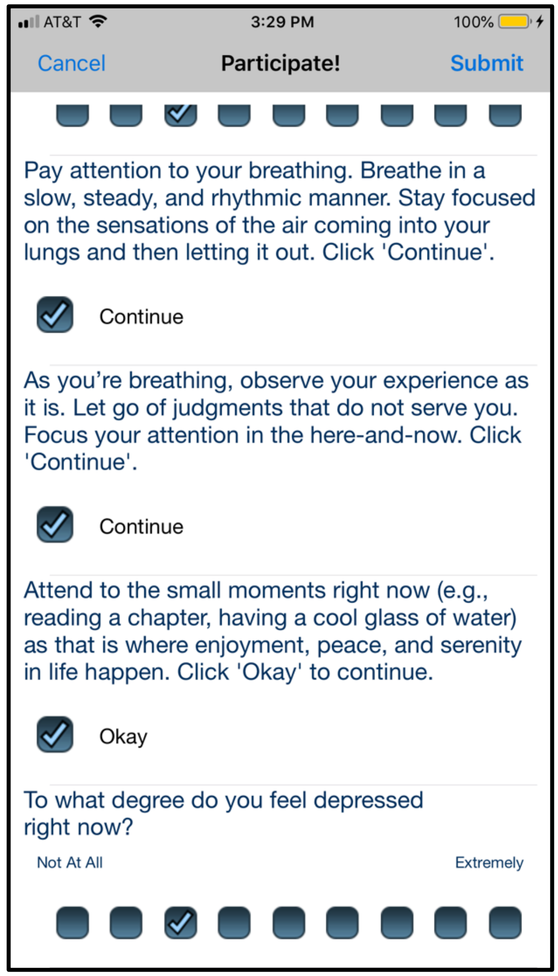
Screenshots for Treatment Condition



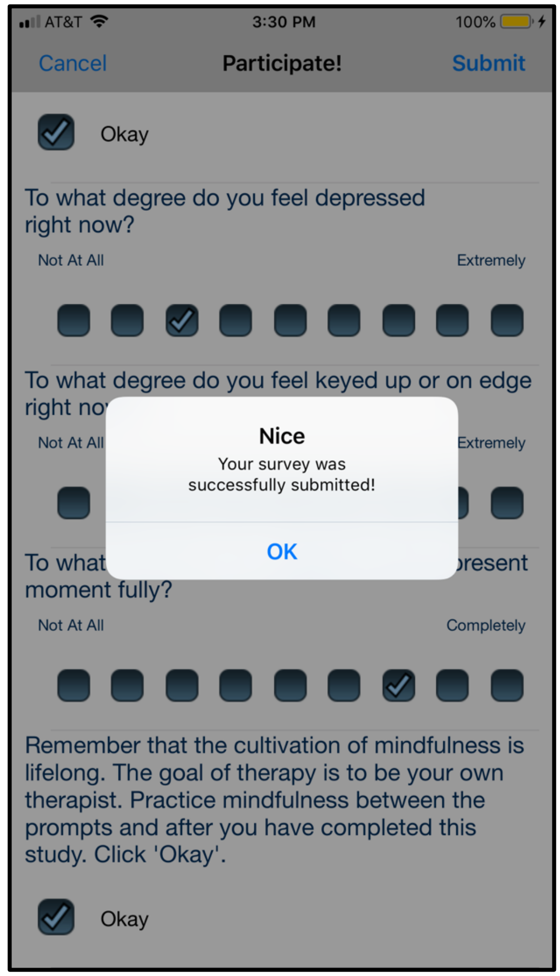

AT&T
3:29 PM
100%
Cancel
Participate!
Submit
Participant ID
<type response here>
To what degree do you feel depressed right now?
Not At All
Extremely
To what degree do you feel keyed up or on edge right now?
Not At All
Extremely
To what extent are you experiencing the present moment fully?
Not At All
Completely


AT&T
3:29 PM
100%
Cancel
Participate!
Submit
Participant ID
MIND001
To what degree do you feel depressed right now?
Not At All
Extremely
To what degree do you feel keyed up or on edge right now?
Not At All
Extremely
1 2 3 4 5 6 7 8 9 0
- / : ; ( ) $ & @ "
#+= . , ? ! '
ABC
space
Done


AT&T
3:29 PM
100%
Cancel
Participate!
Submit
Participant ID
MIND001
To what degree do you feel depressed right now?
Not At All
Extremely
To what degree do you feel keyed up or on edge right now?
Not At All
Extremely
To what extent are you experiencing the present moment fully?
Not At All
Completely
Pay attention to your breathing. Breathe in a slow, steady, and rhythmic manner. Stay focused on the sensations of the air coming into your lungs and then letting it out. Click 'Continue'.


AT&T
3:29 PM
100%
Cancel
Participate!
Submit
Pay attention to your breathing. Breathe in a slow, steady, and rhythmic manner. Stay focused on the sensations of the air coming into your lungs and then letting it out. Click 'Continue'.
Continue
As you're breathing, observe your experience as it is. Let go of judgments that do not serve you. Focus your attention in the here-and-now. Click 'Continue'.
Continue
Attend to the small moments right now (e.g., reading a chapter, having a cool glass of water) as that is where enjoyment, peace, and serenity in life happen. Click 'Okay' to continue.
Okay
To what degree do you feel depressed right now?
Not At All
Extremely


AT&T
3:30 PM
100%
Cancel
Participate!
Submit
Okay
To what degree do you feel depressed right now?
Not At All
Extremely
To what degree do you feel keyed up or on edge right now?
Not At All
Extremely
To what extent are you experiencing the present moment fully?
Not At All
Completely
Remember that the cultivation of mindfulness is lifelong. The goal of therapy is to be your own therapist. Practice mindfulness between the prompts and after you have completed this study. Click 'Okay'.
Okay


AT&T
3:30 PM
100%
Cancel
Participate!
Submit
Okay
To what degree do you feel depressed right now?
Not At All
Extremely
Nice
Your survey was successfully submitted!
OK
Not At All
Completely
Remember that the cultivation of mindfulness is lifelong. The goal of therapy is to be your own therapist. Practice mindfulness between the prompts and after you have completed this study. Click 'Okay'.
Okay

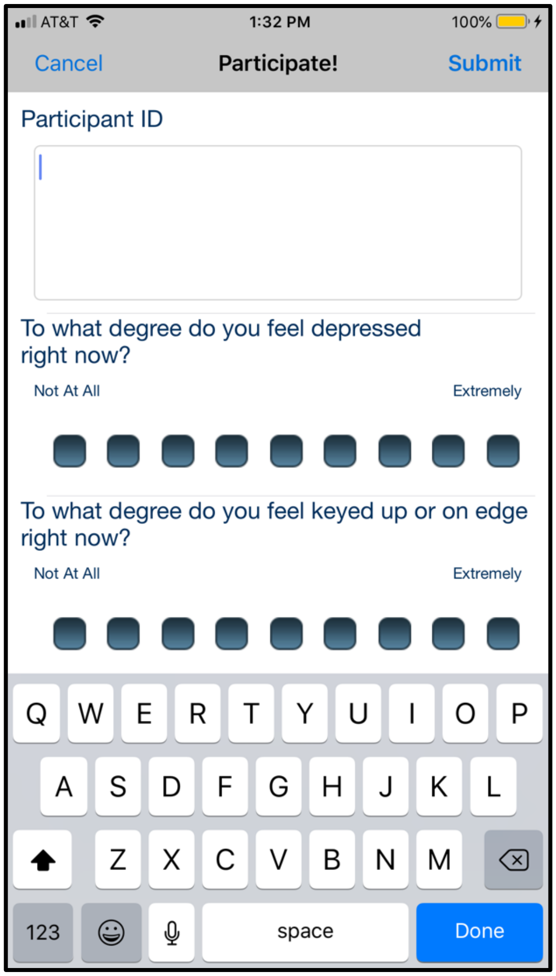
Appendix C

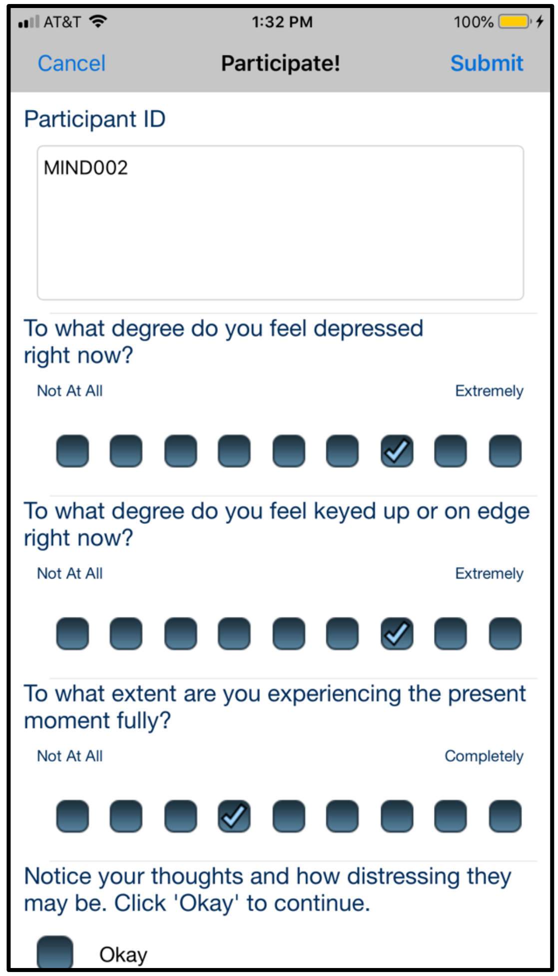
Script for Placebo Condition

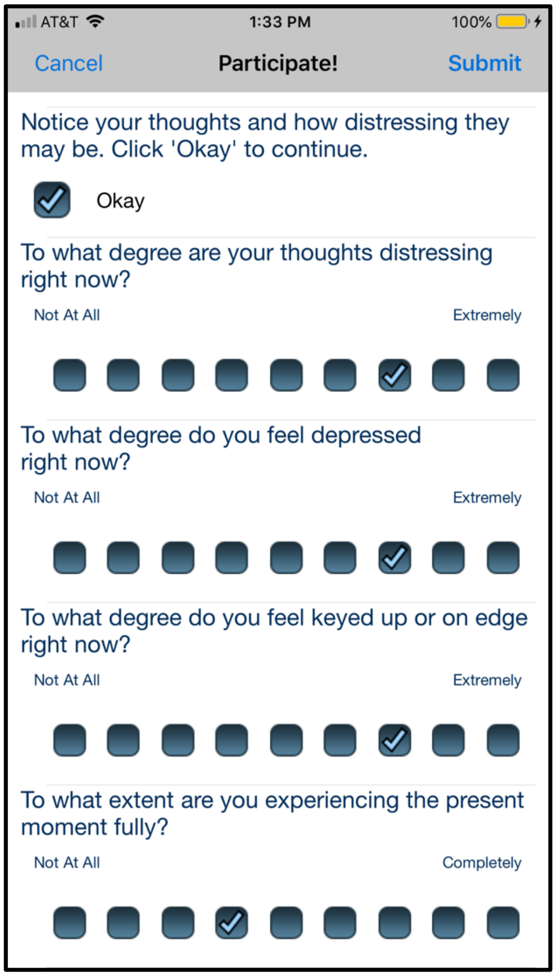
We will now introduce the treatment to you. To begin, this treatment aims to equip you with self-monitoring skills. Self-monitoring refers to being highly attentive of one's cognitions and emotions. Research demonstrates that self-monitoring can help to decrease unhelpful thoughts and actions. Simply being more aware of one's thoughts can alter cognitions. By tracking your thoughts and recording any distress linked to them, you may experience thinking in healthier ways. To this end, this can reduce any anxious feelings.

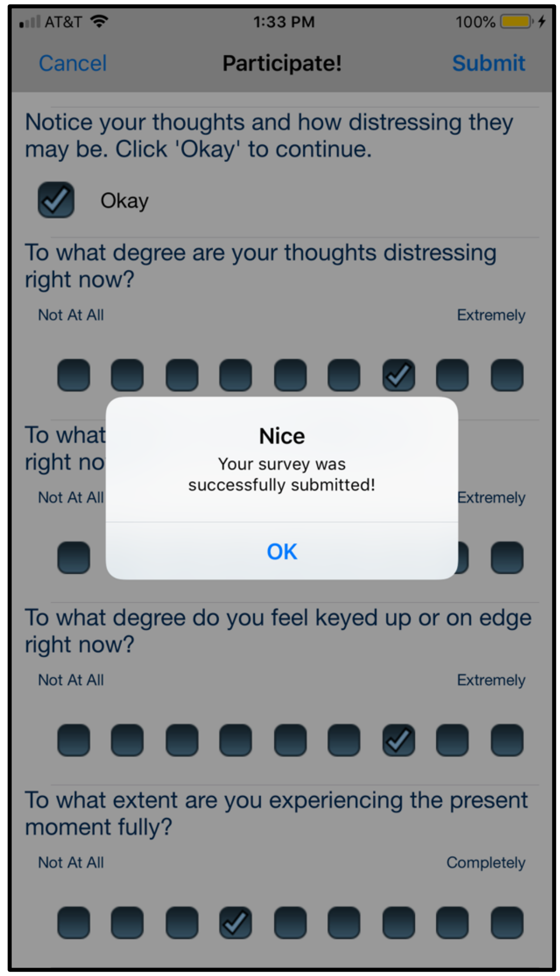
Appendix D

Screenshots for Self-Monitoring Placebo Condition






AT&T
1:33 PM
100%
Cancel
Participate!
Submit
Notice your thoughts and how distressing they may be. Click 'Okay' to continue.
Okay
To what degree are your thoughts distressing right now?
Not At All
Extremely
To what degree do you feel depressed right now?
Not At All
Extremely
To what degree do you feel keyed up or on edge right now?
Not At All
Extremely
To what extent are you experiencing the present moment fully?
Not At All
Completely


AT&T
1:33 PM
100%
Cancel
Participate!
Submit
Notice your thoughts and how distressing they may be. Click 'Okay' to continue.
Okay
To what degree are your thoughts distressing right now?
Not At All
Extremely
Nice
Your survey was successfully submitted!
OK
To what degree do you feel keyed up or on edge right now?
Not At All
Extremely
To what extent are you experiencing the present moment fully?
Not At All
Completely

Appendix E

Attrition Analyses

Treatment (odds ratio (*OR*) = 0.86, p = .795), age (*OR* = 1.01, p = .436), gender (*OR* = 0.58, p = .580), and pre-treatment GAD-Q-IV (*OR* = 1.13, p = .448), GAD-Q-Dimensional (*OR* = 1.01, p = .761), PCQ-Total (*OR* = 1.06, p = .389), inhibition (*OR* = 1.00, p = .999), verbal fluency (*OR* = 1.00, p = .450), and EF errors (*OR* = 1.02, p = .328) did not significantly predict attrition. Further, neither treatment credibility (*OR* = 0.75, p = .125) nor expectancy (*OR* = 0.90, p = .100) predicted attrition. However, dropouts (vs. completers) were significantly more likely to be non-Whites than Whites (*OR* = 0.27, p = .029) and had lower baseline WM (*OR* = 0.70, $p < .001$).

In addition, there were five statistically significant Predictor by Treatment effects on attrition. MEMI, but not SMP participants, who were significantly more likely to drop out were females (vs. males or unknown gender) (*OR* = 25.25, $p < .001$) and those with higher baseline GAD-Q-Dimensional severity (*OR* = 1.07, p = .005) and lower verbal fluency (*OR* = 0.97, $p < .001$), WM (*OR* = 0.41, $p < .001$), and EF errors (*OR* = 0.93, p = .010). However, we observed no significant Predictor by Treatment effects on attrition for these predictors: age (*OR* = 1.10, p = .280), ethnicity (*OR* = 2.95, p = .409), pre-treatment PCQ-total (*OR* = 1.03, p = .598), inhibition (*OR* = 0.964, p = .117), treatment credibility (*OR* = 1.46, p = .343), and treatment expectancy (*OR* = 1.05, p = .605).

VITA

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SELECTED AWARDS AND HONORS

Mar 2022	Anxiety and Depression Association of America (ADAA) Alies Muskin Career Development Leadership Program (CDLP).
Jul 2021	American Psychological Association (APA) Student Excellence in Teaching.
Nov 2020	Association of Behavior and Cognitive Therapies (ABCT) 2020 Leonard Krasner Student Dissertation Award.
May 2020	FABBS Doctoral Dissertation Research Excellence Award 2020.
Apr 2020 – May 2021	PSU College of Liberal Arts Susan Welch/Nagle Family Graduate Fellowship.
Apr 2019	PSU CLA Superior Teaching and Research (STAR) Award.
Apr 2019	PSU CLA Dissertation Award.
Apr 2019	PSU Psychology Department Best Clinical Paper Award.

RECENT PUBLICATIONS

34. **Zainal**, N. H. & Newman, M. G. (in press). Elevated anxious and depressed mood relates to future executive dysfunction in older adults: A longitudinal network analysis of psychopathology and cognitive functioning. *Clinical Psychological Science*. doi:https://doi.org/10.31234/osf.io/hrfqa
33. **Zainal**, N. H. & Newman, M. G. (in press). Life satisfaction prevents cognitive decline: Latent change score analyses across 23 years. *European Psychiatry*. doi: 10.1192/j.eurpsy.2022.1932.
32. **Zainal**, N. H. & Newman, M. G. (in press). A cross-lagged prospective network analysis of common mental health and cognitive functioning components in midlife community adult women. *Psychological Medicine*. doi:https://doi.org/10.31234/osf.io/tevdq
31. **Zainal, N. H.** & Newman, M. G. (in press). Depression and worry symptoms predict future executive functioning impairment via inflammation. *Psychological Medicine*. doi:https://doi.org/10.1017/S0033291721000398 PMID: 33653430.
30. Marr, N. S., **Zainal**, N. H., & Newman, M. G. (2022). Focus on emotion and venting mediates the 18-year bi-directional major depressive disorder-generalized anxiety disorder relation. *Journal of Affective Disorders*, *303*, 10-17. doi:https://doi.org/10.1016/j.jad.2022.01.079.