LOYOLA UNIVERSITY CHICAGO

POSITIVE AFFECT FACILITATES A REDUCTION IN DEPRESSION SYMPTOMS DURING A MOBILE MINDFULNESS-BASED INTERVENTION

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ABSTRACT

Depression negatively impacts the lives of many, and the rates are continuing to rapidly increase. Identifying patterns of modifiable affective psychological mechanisms that contribute to reducing depression symptoms is critical to improve the effectiveness of wellbeing interventions for individuals with depressive disorders. Depression has been characterized by valanced patterns of low positive affect and high negative affect, yet the extent to which these relative patterns of affectivity change in response to intervention remains less clear. The present study evaluated affective patterns in college students (n = 127) with elevated depression symptoms who participated in a randomized controlled trial (RCT) of a mindfulness-based intervention (MBI) delivered via a mobile application (app; Headspace). We used an exploratory approach to evaluate the role of affective patterns (e.g., positive affect, negative affect, and emodiversity) in facilitating a reduction in depression symptoms during the RCT. Results showed that only change in positive affect significantly mediated the relation between RCT study group and depression symptoms, such that an increase in positive affect was related to reduced depression symptoms for the treatment group. It is critical that future clinical science research identifies evidenced-based strategies and interventions that enhance the capacity for experiencing positive affect and emotions in individuals with depression symptoms.

CHAPTER ONE

REVIEW OF THE RELEVANT LITERATURE

Introduction

In a world faced with active societal threats including pandemics, climate change crises, social injustices, and inequities, as well as growing economic disparities, depressive disorders have increased three-fold compared to pre-pandemic levels (Ettman et al., 2020). Yet prior to the pandemic, depression levels were already steadily increasing (American Psychological Association 2016), with an estimated 20% of adults in the United States meeting criteria for major depressive disorder (MDD) within their lifetime (Hasin et al., 2018). Many available treatments for depression do not fully alleviate symptoms or prevent relapse (Breedvelt et al., 2020; Steinert et al., 2014), not to mention that a large proportion of people with depression do not receive mental health services due to various perceived barriers (Kazdin & Blase, 2011; Mohr et al., 2014). Thus, it should not be entirely surprising that in 2018, the United States economic burden associated with MDD was estimated at $326.2 billion, encompassing the cost of treatment, suicide-related costs, and indirect workplace costs (Greenberg et al., 2021). Depression is an extremely painful and frequently disabling disorder for those who are impacted by it, and/or live with someone who is depressed. In order to improve the effectiveness of psychological treatments and interventions, we urgently need to work toward identifying modifiable psychological mechanisms that reduce depression symptoms, which is the primary goal of the present study.

To this extent, the present study focuses on exploring how distinct patterns of affectivity facilitate a reduction in depression symptoms over the course of an eight-week mobile mindfulness-based intervention (MBI; Headspace: www.headspace.com) randomized controlled trial (RCT). Headspace is a mindfulness-based mental health app that has attracted millions of users in over 190 countries (Headspace Inc., 2020), and offers multitudes of guided meditations and psychoeducation about mindfulness and mindfulness-related topics (Headspace Inc., 2020). Previous research has shown that Headspace use is associated with reductions in depression symptoms (Flett et al., 2019; Howells et al., 2016), reductions in distress (Bostock et al., 2019; Kubo et al., 2018), reductions in irritability and negative affect (Economides et al., 2018), and ultimately enhances overall wellbeing (Bostock et al., 2019; Yang et al., 2018) as well as quality of life (Kubo et al., 2018).

Positive and Negative Affect and Depression

In general, relatively high levels of positive affect and low levels of negative affect have been associated with decreased depression symptoms, and improved mental health and wellbeing outcomes, in the context of the United States (Anton & Miller, 2005; Billings et al., 2000; Clark & Watson, 1991; Cohn et al., 2009; Fredrickson, 2001; Kahrilas et al., 2020). While individuals with depression frequently experience negative emotions and have increased exposure to negative stimuli (perceived or actual) in daily life contexts (Benning & Oumeziane, 2017; Vanderlind et al., 2020), it is also critical to consider the role of positive emotions in depression (Silton et al., 2020). Depression has been frequently characterized by anhedonia, or reduced pleasure in most activities (Treadway & Zald, 2011), as well as low positive affectivity, or lacking the tendency to experience intense and frequent episodes of pleasant moods (Clark &

Watson, 1991; Kendall et al., 2015; Lewinsohn & Graf, 1973; Raes et al., 2012; Watson et al., 1995). These disturbances in the experience of positive emotion may exacerbate the course of depressive symptomatology (Clark & Watson, 1991; Davidson, 1998).

Previous research from our lab showed a pattern of high negative affectivity and low positive affectivity in individuals with depression symptoms (Kahrilas et al., 2020). This pattern of affective co-occurrence is related to other research that has illustrated that velanced affective dimensions are closely intertwined and should not be conceptualized as entirely isolated and distinct dimensions (Dunkley et al., 2017; Vaccaro et al., 2020). For example, positive and negative affective experiences often co-occur, either through experiencing a mixed emotion (e.g., "bittersweet"), or when simultaneously experiencing more than one emotion (Vaccaro et al., 2020). The blurring of boundaries between affective dimensions is also evident in the implementation of affect in the brain. For example, evidence from a meta-analysis shows that valence is flexibly implemented by a set of valence-general limbic and paralimbic brain regions, rather than valence-specific regions (Lindquist et al., 2016). Thus, it is important to identify metrics that capture affective variability in an effort to explore how the complexity of affective experience might be related to mental health and wellbeing (Barrett, 2017; Werner-Seidler et al., 2020), including metrics that characterize the diversity and range of affective experiences. As described in more detail below, emodiversity (i.e., the variety, or range of emotions that humans experience) is a psychological construct that characterizes diverse patterns of both positive and negative emotions (Quoidbach et al., 2014). In many ways, the construct of emodiversity has been igniting affective science research in a new direction that transcends more basic conceptualizations and related metrics (e.g., mean levels of valenced affectivity) that have

frequently been used in past research. However, additional research is needed to clarify which affective metrics (e.g., mean affective levels, or various emodiversity metrics) might best facilitate change in depression symptoms, which is the primary aim of the present exploratory study.

Emodiversity and Depression

The framework for emodiversity was originally derived from principles of natural science research in biodiversity postulating that greater biodiversity within an ecosystem is associated with adaptive flexibility and greater resilience. Emerging psychological research has posited that greater emodiversity is associated with positive mental and physical health outcomes, above and beyond constructs that only measure absolute levels of positive and negative emotional experiences (Danovaro et al., 2008; Elmqvist et al., 2003; Heller & Zavaleta, 2009; Quoidbach et al., 2014; Rammel & van den Bergh, 2003; Tilman et al., 2006; Werner-Seidler et al., 2020). Thus, changes in emodiversity are anticipated to modulate depression symptoms over the course of the present study's MBI trial. However, there are various metrics that have been used to characterize emodiversity, and a primary aim of the present study is to evaluate which metrics are the best predictors of a reduction in depression symptoms.

Global emodiversity, representing a mix of positive and negative emotions, is theorized to provide a metric that can help understand the emotional experience and its relation to wellbeing above and beyond absolute values of positive and negative affect (Quoidbach et al., 2014; Urban-Wojcik et al., 2020). Consistent with this theory, global emodiversity has been shown to be associated with lower levels of depression (Quoidbach et al., 2014; Werner-Seidler et al., 2020). Emodiversity has also been subdivided into "negative emodiversity" and "positive

emodiversity." More specifically, enhanced negative emodiversity, or emodiversity for negative emotions, has been shown to be a protective factor in depression (Banty, 2020; Quoidbach et al., 2014), greater negative emotion in general is associated with higher levels of depression (Quoidbach et al., 2014). Individuals with chronic depression may experience increased complexity and diversity among negative emotions due to substantial immersion in negative affective constructs (Werner-Seidler et al., 2018), and enhanced diversity among negative emotions may contribute to supporting recovery from depression symptoms, as the ability to conceptualize a diverse emotional experience - even if they are predominantly negative - implies a heightened awareness of one's own emotions and greater overall emotional intelligence (Quoidbach et al., 2014). Additional research is still needed to replicate these initial findings.

Alternatively, greater positive emodiversity has also been shown to be associated with fewer depression symptoms (Quoidbach et al., 2014; Urban-Wojcik et al., 2020), indicating that the diversity of the emotional experience, regardless of its absolute value, may provide a crucial target in alleviating depressive symptoms in psychological treatment. Thus, boosting positive emodiversity, or emodiversity for positive emotions, may be an important psychological mechanism to target for reducing depression symptoms since individuals with depression typically experience positive emotions less frequently and encounter fewer positive stimuli (Khazanov et al., 2019), which may reduce the diversity of positive emotions experienced. However, the role of various emodiversity metrics in relation to depression symptoms still remains opaque as emerging studies have shown mixed results. Specifically, one study examining the role of emodiversity in predicting depression and anxiety in older adults, found that global emodiversity did not predict lower levels of depression or anxiety, but higher

negative emodiversity scores at baseline predicted lower levels of depression over time, indicating negative emodiversity to be protective in the development and maintenance of depression (Banty, 2020). Contrarily, another study showed that greater negative emodiversity is associated with increased symptoms of depression and anxiety (Urban-Wojcik et al., 2020). These contradictory outcomes may be a result of a range of emodiversity metrics used in previous literature. Furthermore, depression and anxiety symptoms are heterogeneous, and previous research may have measured these symptoms in a myriad of ways that varies from study to study. While studies investigating the association of emodiversity and depression during treatment are rare, one meta-analysis examined the impact of Cognitive Behavioral Therapy (CBT) on emodiversity and found that CBT was effective in decreasing negative emodiversity and increasing positive emodiversity in adults with a history of depressive symptoms (Yu, 2018). Thus, emodiversity is an important targetable affective mechanism underlying empirically supported depression treatments. Given that a clear picture is yet to emerge regarding the relation between emodiversity and depression symptoms and considering that minimal research has been conducted in this area in depression treatment contexts, the present study will use an exploratory framework to guide the analytical plan.

Emodiversity Metrics in Psychological Science

In biological science, an extensive literature exists concerning the utility and measurement of diversity (Benson, 2016; Magurran, 2013). In general, all widely used diversity metrics indicate evenness of species (e.g., distribution of emotional experiences across emotion types), richness of species (e.g., the total number of emotion types), or a combination of the two (Budescu & Budescu, 2012). Some of the most common metrics used in the diversity literature

are the Gini Coefficient (Gini, 1912), Shannon's Entropy (Shannon, 1948), Simpson's Index (Simpson, 1949), and the Richness Index (Blondel, 2003). Shannon's Entropy, the Gini Coefficient, Simpson's Index, and the measure of the relative "richness" (Blondel, 2003) of affectivity have all been used to quantify emodiversity across different studies.

In seeking to apply these metrics to psychological science, it is critical to first understand what each metric indexes, and also to carefully consider how the choice of index may influence empirical conclusions and/or limit generalizability (Benson, 2016). Specifically, Quoidbach et al. (2014) was the first to examine and define the term emodiversity using Shannon's entropy, which is based off the Shannon biodiversity index that quantifies the number of species and distribution/evenness of species in an ecosystem (Werner-Seidler et al., 2018). The Gini coefficient examines the evenness/unevenness of emotion states (Ong et al., 2018). Simpson's Index can be interpreted as the probability that any two randomly selected experiences are of different emotion types and provide relative scores of emodiversity (Benson, 2016). And lastly, the richness index is quantified simply as the total number of emotion types an individual experiences (Benson, 2016).

One study sought to examine the similarity/dissimilarity among metrics and calculated emodiversity using the aforementioned metrics (Benson, 2016). They concluded that choosing a diversity metric relies on whether a study's theoretical question is grounded in prioritizing the evenness, richness, or a combination approach to conceptualizing emodiversity. Benson argued that the Gini coefficient, which focuses more on evenness of diversity, may be best suited for research questions that seek to ascertain differences in abundances across types rather than the actual number of represented emotions. Alternatively, studies that are interested in evaluating

only the range of emotional experiences across types may favor indices that only measure richness (i.e., the richness index). Additionally, Shannon's entropy and Simpson's index may be useful metrics for studies interested in both the richness and evenness components of diversity (Benson, 2016).

The choice of biodiversity metric is also dependent on the practical aspects of the study involved such as how emotions are sampled. When there are many "species," Simpson's index may be better at differentiating between emotions than Shannon's entropy (Benson, 2016; Magurran, 2013). Additionally, Shannon's entropy, the richness index, and Simpson's Index may be more useful when emotions are sampled openly (e.g., which emotions do you feel today?). Alternatively, the Gini coefficient may be the most useful when measurement of all entities occurs on all occasions (e.g., a fixed-length adjective list). Given the heterogeneity in emodiversity metrics used in previous research, paired with limited research on depression outcomes in the context of intervention studies, the present study will conduct initial exploratory analyses to evaluate all emodiversity indices (Gini Coefficient, Shannon's Entropy, and Simpson's Index) in relation to depression outcome scores, in order to ensure that we do not overlook the identification of key psychological mechanisms that contribute to reducing depression symptoms.

Mindfulness refers to a process that encompasses a mental state characterized by non-judgmental awareness of the present moment, which includes one's sensations, thoughts, bodily states, consciousness, while simultaneously encouraging openness, curiosity, and acceptance (Bishop, 2002; Bishop et al., 2004; Hofmann et al., 2010; Kabat-Zinn, 2003; Melbourne Academic Mindfulness Interest, 2006). Mindfulness involves striving to be present in everyday

life moments and it is positively associated with higher sleep quality, wellbeing, and life satisfaction, and it is negatively associated with anxiety, depression, and impulsiveness (Felder et al., 2018; Grant et al., 2018; Jong et al., 2017; Mathad et al., 2019). Possessing a high level of trait mindfulness is associated with an open and receptive attitude to current experiences while also combating the negative effects of stressors (Zhang et al., 2020). Using a similar eight-week MBI intervention, one study showed that increasing state mindfulness over repeated meditation sessions was associated with increased trait mindfulness and decreased psychological distress at post intervention (Kiken et al., 2015).

Considerable research has shown that mindfulness meditation ameliorates depressive symptomatology in a myriad of samples such as undergraduate medical students (Breedvelt et al., 2020; Daya & Hearn, 2018), chronic pain patients (Jong et al., 2017), adults with mental disorders (Klainin-Yobas et al., 2012), and expectant mothers (Hicks et al., 2018; Sbrilli et al., 2020). A related meta-analysis found that MBIs are more effective than standard care in reducing depressive symptoms and preventing relapse (Klainin-Yobas et al., 2012). MBIs have also been shown to have clinically significant antidepressant and anti-anxiety effects in addition to a reduction in overall psychological distress (Flett et al., 2019; Jong et al., 2017; Marchand, 2012). Thus, there is clear evidence that supports the therapeutic effects of MBIs on subsequent improvements in depression symptoms across a range of samples.

While mindfulness likely enhances the capacity for and the experience of positive emotions and also decreases negative emotions (Dahl et al., 2015; Garland et al., 2015; Wielgosz et al., 2019), the psychological mechanisms that facilitate a reduction in depression symptoms are yet to be concretely identified. Mindfulness meditation practices are theorized to modify

positive valence systems through enhanced emotion awareness, modulations in emotional reactivity, increased use of cognitive reappraisal, and alterations in reward processes (Wielgosz et al., 2019). Additionally, one study sought to investigate how negative emotion regulation mechanisms, such as worry and rumination, mediates reductions in depression (Parmentier et al., 2019). They found that both worry, and rumination were significant mediators between MBIs and symptoms of depression. Other studies have found that MBIs directly affect attentional distribution of emotion regulation and reduce negative emotions (Ding et al., 2015, 2021; Tang et al., 2007). For example, Ding et al (2021) theorizes that more mindful individuals have a better capacity to regulate their moods with emotional awareness and are more protected against the influence and persistence of negative affect and related symptoms. Thus, mindfulness meditation might modify emotion regulation in part by increasing emotional awareness to nuances between emotional experiences in the present moment (Goleman, 2004; Hill & Updegraff, 2012). Taken together, these findings suggest that focusing research more specifically on patterns of affectivity as well as the diversity of specific emotions at play may contribute to identifying key targetable mechanisms of change associated with MBIs and subsequent reductions in depression symptomatology.

Do Mindfulness-Based Interventions (MBIs) modulate patterns of positive affect, negative affect, and/or emodiversity while reducing depression symptoms?

The Present MBI RCT Study

The primary aim of the present MBI RCT study was to identify whether any key affective mechanisms (i.e., positive affectivity, negative affectivity, and emodiversity) mediated the relation between study group (wait list control and treatment group) and change in depression

outcome in a sample of college students. Since we did not have strong a priori hypotheses, we used an exploratory approach to guide initial analyses regarding selection of an emodiversity metric. We pre-registered our study aims and analytical plan on Open Science Framework (OSF; https://osf.io/ftbjn). Per our a priori pre-registered analysis plan, we selected the emodiversity metric (Shannon's Entropy) that accounted for the largest relation with change in depression score for use in subsequent mediation analyses. Our primary analytical strategy involved using longitudinal mediation analyses to evaluate whether changes in positive affect, negative affect, and emodiversity mediated the relation between study group and change in depression symptoms.

CHAPTER TWO

METHODS

Study Overview

Participants were randomly assigned to a Headspace intervention group or waitlist control group. All participants were evaluated at the same points via self-report assessment measures. Self-report data collection occurred one week prior to the intervention (T1), four weeks into the intervention (T2), after the eight-week trial of Headspace (T3), and a follow-up survey a month after study completion (T4). EEG data were collected at T1 and T3; however, these data are not used in the present analyses. Headspace provided user data for all participants. Data collection occurred between September 2017 - May 2021. The study was approved by the University's IRB and all participants provided informed consent. The present study used self-report data from T1 and T3, and user data provided by Headspace.

Participants

Participants (n = 127 college students; 115 women (91%); 9 men (7%); 1 non-binary (1%); 1 transgender (1%); 1 other (1%); M age = 19.5 (SD = 1.2, range 18-24) were recruited via the psychology participant pool and flyers posted on campus. This sample was composed of 61.4% White, 17.3% Asian, 14.2% Hispanic/Latine, 2.4% African American, 1% Native Hawaiian/Pacific Islander, 9.4% reported an identity not specified in our survey. Please see Table 1 for characterization of study groups.

Table 1. Means, Standard Deviations, and Bonferroni-Corrected One-Way Analyses of Variance in Depression Symptoms, Positive Affect, Negative Affect, Positive Emodiversity, Negative Emodiversity, Global Emodiversity

	Waitlist Control Group		Treatment Group		Total Sample	
	(n = 36)		(n = 91)		(N = 127)	
	M	SD	M	SD	M	SD
Age	18.83	1.11	18.96	1.22	18.92	1.19
Gender						
Men	5 (13.9%)		4 (4.4%)		9 (7.1%)	
Women	31 (86.1%)		84 (92.3%)		115 (90.6%)	
Nonbinary	0 (0%)		1 (1.1%)		1 (1%)	
Transgender	0 (0%)		1 (1.1%)		1 (1%)	
Other	0 (0%)		1 (1.1%)		1 (1%)	
Ethnicity						
White	21 (58.3%)		57 (37.4%)		78 (61.4%)	
Asian	8 (22.2%)		14 (15.4%)		22 (17.3%)	
Latine	5 (13.9%)		13 (14.3%)		18 (14.2%)	
Black	1 (2.8%)		2 (2.2%)		3 (2.4%)	
Native Hawaiian/Pacific Islander	0 (0%)		1 (1.1%)		1 (1%)	
Other	1 (2.8%)		4 (4.40%)		5 (3.94%)	
Depression T1	12.00	4.52	12.40	4.60	12.28	4.57
Depression T3	12.42	4.49	8.61*	5.68	9.68	5.62
Δ Depression	-.13	.52	.28*	.46	.17	.51
Positive Affect T1	3.00	.63	2.74	.70	2.81	.69
Positive Affect T3	2.79	.72	2.91	.77	2.88	.80
Δ Positive Affect	.06	.19	-.09*	.26	-.05	.26
Negative Affect T1	2.61	.71	2.43	.72	2.49	.72

Negative Affect T3	2.38	.79	2.00*	.68	2.11	.73
Δ Negative Affect	.08	.24	.14	.30	.12	.29
Positive Emodiversity T1	2.26	.042	2.25	.035	2.25	0.37
Positive Emodiversity T3	2.26	.040	2.26	.035	2.26	.036
Δ Positive Emodiversity	.011	.013	.013	.011	.013	.011
Negative Emodiversity T1	2.22	.043	2.21	.044	2.22	.044
Negative Emodiversity T3	2.22	.039	2.21	.044	2.22	.044
Δ Negative Emodiversity	.015	.014	.016	.013	.016	.013
Emodiversity T1	2.92	.035	2.91	.033	2.91	.034
Emodiversity T3	2.91	.040	2.89*	.040	2.90	.040
Δ Emodiversity	.002	.012	.006	.014	.005	.014

Note. $N = 127$ ($n = 36$ for waitlist control group, $n = 91$ for treatment group)
*Treatment group significantly different from waitlist group; $p < .05$

Study Inclusion and Exclusion Criteria

Prior to enrolling in the study, participants were pre-screened for depression symptoms using the Patient Health Questionnaire Measure (PHQ-8; Kroenke et al., 2001) and all participants had a PHQ-8 score greater or equal to 10 (equivalent to moderate levels of depression; Shin et al., 2019). Participants were eligible for the study if they had minimal previous experience with mindfulness meditation, and if they were not participating in psychotherapy at the time of admission into the study. Participants with a history of epilepsy and

seizure disorder were excluded from the study since a subset of participants also completed an EEG session that involved viewing uncomfortable flashing stimuli. We only recruited participants who were right-handed, not color-blind, and learned English as a first language due to following older recommendations for neuroimaging/EEG data collection. Please note that we strongly recommend that these guidelines are no longer followed in order to enhance inclusivity in scientific research.

Materials and Procedure

Questionnaire Measures

Depression symptoms were measured using the Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001) is a nine-item instrument that assesses the degree of the respondent's physical and emotional symptoms of depression. These items include symptoms such as "little interest or pleasure in doing things," "feeling down, distressed, or hopeless," and "poor appetite or overeating" (Kroenke et al., 2001). Respondents were asked to rank how bothered they were by each item on a Likert scale ranging from zero (not at all) to three (nearly every day). The nine items are summed to produce a total score ranging from 0-27. This measure was used to assess changes in depressive symptoms over the course of the eight-week intervention.

At T1 and T3, participants completed the trait Positive and Negative Affect Scale (PANAS; Watson et al., 1988) in order to assess state changes in affective valence and emodiversity over the course of the intervention. This measure contains 20 positive and negative items for respondents to subjectively rate and is widely used in psychological research due to its high test-retest reliability and internal consistency (α = .89 for PA, α = .85 for NA; (Crawford & Henry, 2004). Using a five-point Likert scale (ranging from 1 = very slightly to 5 = extremely),

respondents rated the extent to which they experienced feelings and emotions over the previous week (i.e., “excited” and “guilty”). A mean positive and negative score was aggregated from the ten positive and ten negative items respectfully.

We used four emodiversity metrics for the purpose of this exploratory study. Following Budescu & Budescu (2012), the Gini coefficient (Gini, 1912) can be used to quantify diversity across categories.

$$\text{Gini Coefficient} = Gi = 1 - ((2\sum_{j=1}^{m}(jc_{ij})/(m\sum_{j=1}^{m}(c_{ij}) - (m+1)/m)$$

Where:

cij = the count of individual i’s experiences with j = 1 to m categories (e.g. emotions types) indexed in non-decreasing order ($c_{ij} \leq c_{ij+1}$) (Benson, 2016). Levels of diversity range from 0 to 1, with higher numbers indicating more emodiversity.

Additionally, emodiversity will be computed using the following formula derived from Shannon’s entropy that is consistent with previous research (Quoidbach et al., 2014):

$$\text{Shannon's Entropy} = \sum_{i=1}^{s}(P_i \times \ln P_i)$$

Where:

s = total number of emotions

Pi = proportion of S made up of the *i*th emotions

High values are representative of more diverse emotional experiences. An individual experiencing only one type of emotion would have an emodiversity value of 0. If an individual is experiencing all the emotions evenly, emodiversity would be maximal. Hence, the value of

emodiversity encompasses the number of emotions an individual experiences (*richness*) in addition to the relative abundance - or relative diversity - of emotions the individual experiences (*evenness*).

Lastly, emodiversity was computed using the Simpson's Index, which denotes the probability that any two randomly selected experiences are different emotion types. The index is calculated as follows and represents ranges from 0 to 1 with higher scores indicating greater diversity:

$$\text{Simpson's Index} = Di = 1 - \sum_{j=1}^{m} p_{ij^2}$$

CHAPTER THREE

RESULTS

Missing Data

A total of $N = 145$ participants completed the study; however, $n = 15$ participants had missing PANAS data, and they were not included in the analyses. We used listwise deletion to handle missing PANAS data since each PANAS item represents a specific emotion, and we determined that mean imputation would not have been an appropriate solution for this questionnaire. However, if a participant was missing one PHQ-9 item, then we used mean imputation. This algorithm will be used to address missing PHQ-9 data across all our publications that come from the larger project. Finally, some participants were excluded from analyses across all studies due to missing Headspace user data ($n = 3$). Thus, the total sample for the subsequent analyses was $n = 127$.

Data Reduction Processes

Emodiversity metrics and correlations were calculated in R (4.1.2; R Core Team, 2016). Mediation analyses were run using PROCESS for SPSS 27, with $k = 5000$ bootstrap samples for 5ias corrected confidence intervals (Hayes, 2013). All syntax and data are available on Open Science Framework (https://osf.io/ftbjn). Study groups were dummy coded as follows: Waitlist Control Group = 0; Headspace Intervention Group = 1. In order to capture change over time, proportional change scores were calculated for all affective mechanisms, using the following

formula: [(T1-T3)/T1]. Descriptive statistics and histograms were inspected to ensure data validity prior to conducting the subsequent analyses.

Overall Study Efficacy: Headspace Reduces Depression Symptoms in College Students

We have conducted previous studies to evaluate the efficaciousness of our RCT. Results from those studies illustrated that our RCT is efficacious in reducing depression symptoms in college students. We also replicated those findings in the present analyses, showing that students who were in the treatment group experienced a significant reduction in depression symptoms compared to students in the waitlist control group (see Table 2). This pattern of results is also observable in the series of regressions that were conducted (with study group as a predictor) that constitute the mediation analyses.

Table 2. Correlations Among PHQ-9, Gini Coefficient, Shannon's Entropy, and the Simpson's Index for Global Emodiversity

Variable	1	2	3	4
1. Δ PHQ-9	1	.23*	.24*	.20*
2. Δ Gini Coefficient	.23*	1	.97*	.96*
3. Δ Shannon's Entropy	.24*	.97*	1	.99*
4. Δ Simpson's Index	.20*	.96*	.99*	1

*$p < .05$; all variables represent proportional change.

Aim 1: Identify potential emodiversity mechanisms associated with change in depression symptoms

We ran Bonferroni-corrected correlation analyses to identify significant relations between depression symptoms and mean negative/positive affect scores, emodiversity indices (Gini Coefficient, Shannon's Entropy, and Simpson's Index). These correlations were conducted with the proportional change score described above to identify how change over time in emodiversity metrics was related to a change in depression symptoms. Notably, change in depression score

was significantly related to change in global and positive emodiversity score for all metrics. Negative emodiversity was not related to change in depression scores (see Table 3). We observed that Shannon's Entropy (for global emodiversity) had the largest relation with proportional change in depression scores (r = .24); therefore, Shannon's Entropy was used in subsequent emodiversity analyses. As expected, all emodiversity metrics were highly correlated with each other.

Table 3. Correlations Among PHQ-9, Gini Coefficient, Shannon's Entropy, and the Simpson's Index for Positive Emodiversity

Variable	1	2	3	4
1. PHQ-9	1	-.23*	-.22*	-.25*
2. Δ Gini Coefficient	-.23*	1	.95*	.92*
3. Δ Shannon's Entropy	-.22*	.95*	1	.99*
4. Δ Simpson's Index	-.25*	.91*	.99*	1

*p < .05; all variables represent proportional change.

Table 4. Correlations Among PHQ-9, Negative Emodiversity, Gini Coefficient, Shannon's Entropy, and the Simpson's Index for Negative Emodiversitty

Variable	1	2	3	4
1. Δ PHQ-9	1	-.12	-.13	-.08
2. Δ Gini Coefficient	-.12	1	.95*	.90*
3. Δ Shannon's Entropy	-.13	.95*	1	.98*
4. Δ Simpson's Index	-.08	.90*	.98*	1

*p < .05; all variables represent proportional change.

Aim 2: Evaluate whether change in positive affect mediates the relation between intervention group status and change in depression symptoms?

We evaluated whether the proportional change in mean positive affect (derived from the 10 positive items on the PANAS) mediated the relation between intervention group status and

proportional change depression symptoms (derived from the PHQ-9). Proportional change in mean negative affect was a covariate in this model. Results showed that proportional change in positive affect significantly mediated the relation between study group and proportional change in depression symptoms. The indirect effect (0.094) was significantly different from zero as indicated by a 95% CI (.0367 to .158) that was above zero (see Figure 1 and Table 5). The full model was significant and showed that 37.9% of variance was accounted for.

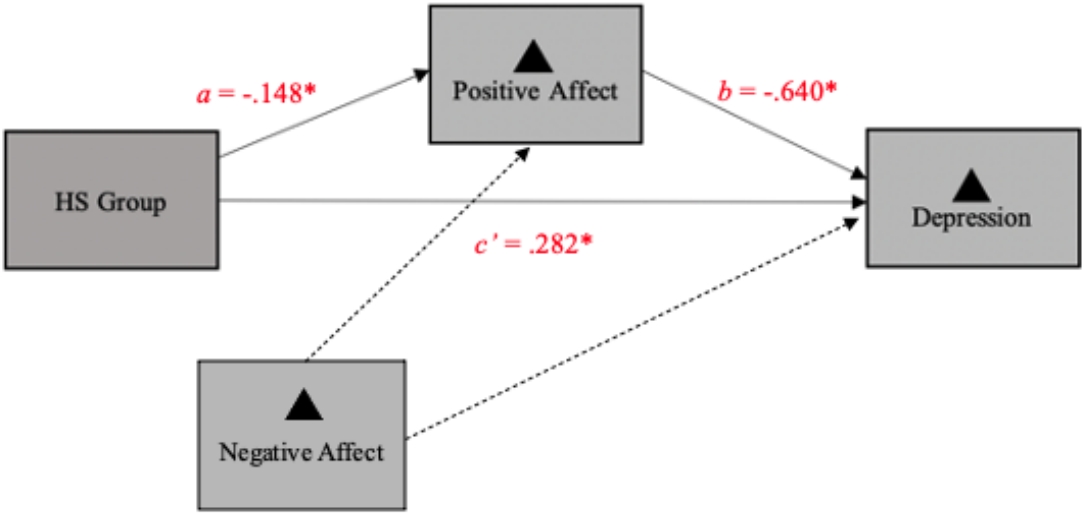

Figure 1. Conceptual model of Aim 2

Table 5. Mediation Analysis: Positive Affect and PHQ-9

Antecedent		Change in Positive Affect (M) Coeff.	*SE*	*p*		Change in Depression Symptoms (Y) Coeff.	*SE*	*p*
Headspace Group (X)	*a*	-.148	.049	.003	*c'*	.282	.083	.001
Change in Positive Affect (M)	---	---	---	---	*b*	-.640	.147	.000
Change in Negative Affect (C)	*f*	-.080	.077	.304	*g*	.629	.128	.000
Constant	I_1	.066	.042	.115	i_2	-.143	.069	.041
		R^2=.081 $F(2, 124) = 5.429, p = .006$				R^2=.379 $F(3, 123) = 25.007, p = .000$		

Note. Model coefficients for the mediation analysis with negative affect as a covariate.

Aim 3: Evaluate whether change in negative affect mediates the relation between study group status and change in depression symptoms

We evaluated whether the proportional change in mean negative affect (derived from the 10 negative items on the PANAS) mediated the relation between intervention group status and changes in depression symptoms (derived from the PHQ-9). Proportional change in positive affect was a covariate in this model. Results showed that proportional change in negative affect did not significantly mediate the relation between study group and proportional change in depression symptoms. The indirect effect (.030) was not significantly different from zero as indicated by a 95% CI (-.029 to .135) that included zero (see Figure 2 and Table 6).

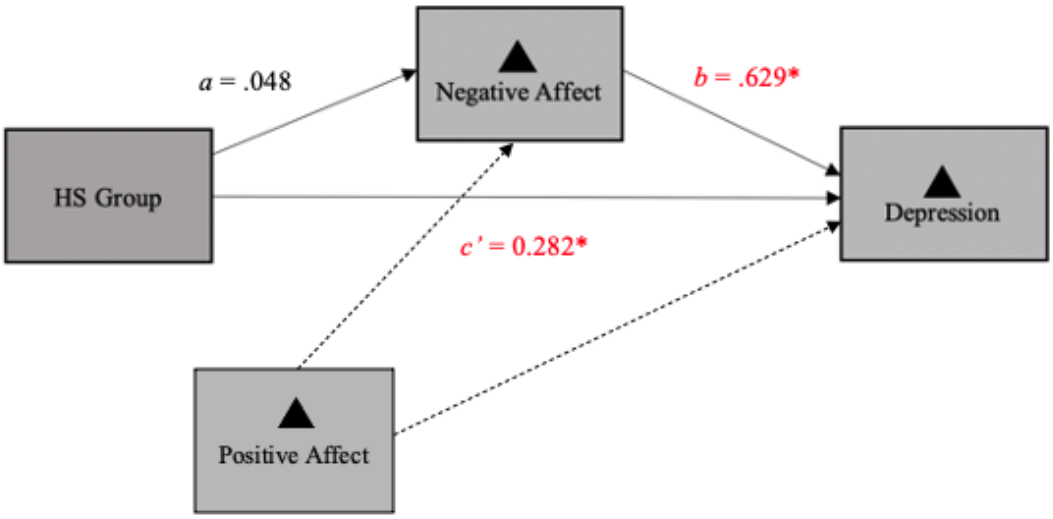

Figure 2. Conceptual model of Aim 3

Table 6. Mediation Analysis: Negative Affect and PHQ-9

		Change in Negative Affect (M)				Change in Depression Symptoms (Y)		
Antecedent		Coeff.	*SE*	*p*		Coeff.	*SE*	*p*
Headspace Group (X)	*a*	.048	.059	.411	*c'*	.282	.083	.001
Change in Negative Affect (M)	--	---	---	---	*b*	.629	.128	.000
Change in Positive Affect (C)	*f*	-.107	.103	.304	*g*	-.640	.147	.000
Constant	I_1	.083	.048	.086	i_2	-.143	.069	.041
		R^2= $F(1.189, 124) = 1.189, p = .308$				R^2= $F(3, 123) = 25.007, p = .000$		

Note. Model coefficients for the mediation analysis with positive affect as a covariate.

Aim 4: Evaluate whether emodiversity is an affective mechanism of change associated with the relation between intervention group status and changes in depression scores?

Based on results from the correlation analyses, Shannon's Entropy had the largest relation with proportional change in depression scores, and thus will be used in all emodiversity-related mediation analyses. Results showed that proportional change in Shannon's Entropy for global emodiversity did not significantly mediate the relation between study group and proportional change in depression symptoms. The indirect effect (.028) was not significantly different from zero as indicated by a 95% CI (-.005 to .086) that included zero (see Figure 3 and Table 7).

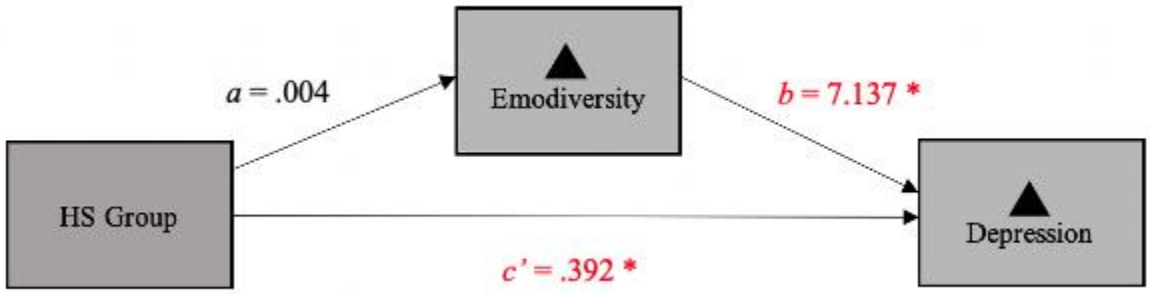

Figure 3. Conceptual model of Aim 4

Table 7. Mediation Analysis: Global Emodiversity and PHQ-9

Antecedent		Change in Global Emodiversity (M) Coeff.	*SE*	*p*		Change in Depression Symptoms (Y) Coeff.	*SE*	*p*
Headspace Group (X)	*a*	.004	.003	.142	c'	.392	.093	.000
Change in Emodiversity (M)	---	---	---	---	*b*	7.137	3.070	.027
Constant	I_1	.002	.002	.435	i_2	-.146	.078	.064
		R^2= .017 $F(1, 125) = 2.18, p = .142$				R^2= .175 $F(2, 124) = 13.167, p = .000$		

Note. Model coefficients for the mediation analysis.

Exploratory Analyses to Evaluate the Role of Change in Positive Emodiversity as a Mediator

We evaluated whether proportional change in positive emodiversity (derived from Shannon's Entropy) mediated the relation between intervention group status and changes in depression symptoms. Results showed that proportional change in positive emodiversity did not significantly mediate the relationship between study group and proportional change in depression symptoms. The indirect effect (.005) was not significantly different from zero as indicated by a 95% CI (-.016 to .040) that included zero (see Figure 4 and Table 8).

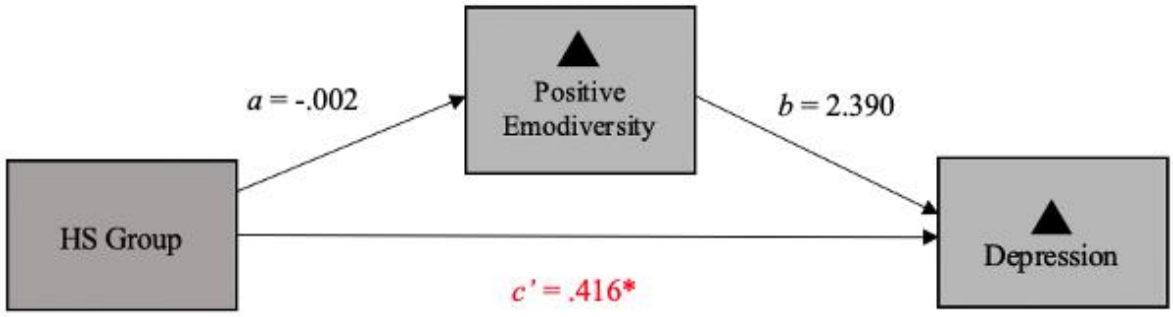

Figure 4. Conceptual model of positive emodiversity mediating the relationship of Headspace intervention group and change in depression

Table 8. Mediation Analysis: Positive Emodiversity and PHQ-9

		Change in Positive Emodiversity (M)				Change in Depression Symptoms (Y)		
Antecedent		Coeff.	*SE*	*p*		Coeff.	*SE*	*p*
Headspace Group (X)	*a*	-.002	.002	.372	*c'*	.416	.094	.000
Change in Positive Emodiversity (M)	--	---	---	---	*b*	2.390	3.730	.523
Constant	I_1	.011	.002	.000	i_2	-.160	.090	.078
		R^2= .006 $F(1, 125) = .801, p = .372$				R^2= .142 $F(2, 124) = 10.266, p = .000$		

Note. Model coefficients for the mediation analysis.

Exploratory Analyses to Evaluate the Role of Change in Negative Emodiversity as a Mediator

We evaluated whether the proportional change in negative emodiversity (derived from Shannon's Entropy) mediated the relation between intervention group status and changes in depression symptoms. Results showed that proportional change in negative emodiversity did not significantly mediate the relation between study group and proportional change in depression

symptoms. The indirect effect (-.013) was not significantly different from zero as indicated by a 95% CI (-.060 to .0189) that included zero (see Figure 5 and Table 9).

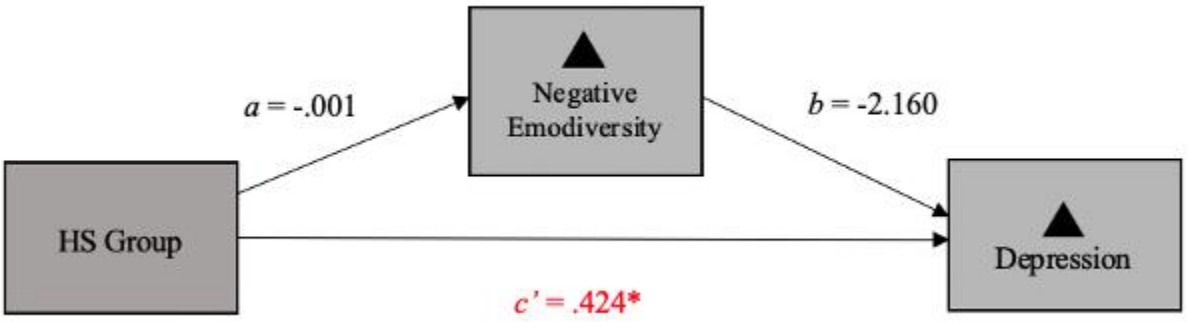

Figure 5. Conceptual model of negative emodiversity mediating the relationship of Headspace intervention group and change in depression

Table 9. Mediation Analysis: Negative Emodiversity and PHQ-9

		Change in Positive Emodiversity (M)				Change in Depression Symptoms (Y)		
Antecedent		Coeff.	*SE*	*p*		Coeff.	*SE*	*p*
Headspace Group (X)	*a*	.001	.002	.583	*c'*	.424	.094	.000
Change in Negative Emodiversity (M)	--	---	---	---	*b*	-2.160	3.280	.512
Constant	I_1	.015	.002	.000	i_2	-.104	.093	.276
		R^2= .050 $F(1, 125) = .303, p = .583$				R^2= .377 $F(2, 124) = 10.279, p = .000$		

Note. Model coefficients for the mediation analysis.

CHAPTER FOUR

DISCUSSION

Depression is often characterized by patterns of low positive affect and high negative affect (Anton & Miller, 2005; Billings et al., 2000; Clark & Watson, 1991; Cohn et al., 2009; Fredrickson, 2001; Kahrilas et al., 2020; Khazanov et al., 2019; Silton et al., 2020), yet the extent to which these relative patterns of affect change in response to intervention remains unclear. The primary aim of the present study was to identify patterns of malleable affective psychological mechanisms that contribute to reducing depression symptoms in order to improve the effectiveness of wellbeing interventions for individuals with depressive disorders. To this end, we evaluated the role of positive and negative affect, as well as various emodiversity mechanisms in facilitating a reduction in depression symptoms following an RCT that was designed to use a mindfulness-based intervention (MBI) delivered via a smartphone App (Headspace) to college students with depression. As illustrated in this study, along with our previous work, our RCT was effective in significantly reducing depression symptoms for the treatment group. Notably, our present study illustrated that increased positive affect was an active causal mechanism in reducing depression symptoms in the college students who participated in our study.

Results from our primary analyses illustrated that change in mean positive affect significantly mediated the relation between study group and depression symptoms, such that an increase in positive affect was associated with a reduction in depression symptoms for students

in the treatment group. All paths were significant in this model, and the regression analysis that was used to ascertain path b indicated that both positive affect and negative affect (included as a covariate in this model) significantly predicted a reduction in depression symptoms beyond the variance associated with the observed significant effect of the treatment group. While negative affect did not mediate the relation between study group and depression symptoms, the path between negative affect and depression symptoms was significant. No other mediation analyses (i.e., models with emodiversity variables) were significant. Together, these findings indicate that positive affect specifically mediated the relation between study group and depression outcome.

Consistent with previous cross-sectional studies that have observed a relation between emodiversity and depression (Banty, 2020; Benson, 2016; Quoidbach et al., 2014; Rivera et al., 2020; Urban-Wojcik et al., 2020; Werner-Seidler et al., 2020), our results also point toward a link between emodiversity and depression symptoms. The relation between global emodiversity and depression symptoms (path b) was significant in the model that included global emodiversity. Related, correlation analyses illustrated those changes in global and positive emodiversity scores were significantly related to changes in depression scores across the whole sample.

Despite previous research suggesting that emodiversity may function as an agent of change in depression treatment studies, our present study results suggested otherwise. This may be due to a myriad of factors. Notably, there is significant methodological heterogeneity among previous studies using emodiversity metrics (Banty, 2020; Quoidbach et al., 2014; Rivera et al., 2020; Urban-Wojcik et al., 2020; Werner-Seidler et al., 2018). Previous studies investigating the effects of emodiversity used various metrics. Additionally, the only intervention-based study that

showed evidence of emodiversity's association with depression symptoms was a CBT-based RCT (Yu, 2018); whereas the present study was an MBI RCT. Previous studies used samples that predominantly consisted of older adults (Banty, 2020; Benson, 2016) and depressed adults (Werner-Seidler et al., 2018; Yu, 2018); however, participants in our study were college-aged adults. Lastly, emotional variance has been sampled using differing measures such as the Differential Emotion Scale (DES; Quoidbach et al., 2014), Life Structure Card Sort Task (Werner-Seidler et al., 2018), daily emotion reports (Ong et al., 2018), as well as the PANAS (Urban-Wojcik et al., 2020; Yu, 2018), which was used in the present study. Importantly, the present study sought to build upon previous emodiversity research by calculating three commonly used emodiversity metrics in our analyses and subsequently identifying the metric that was associated with the most variance with regard to depression symptoms. All of the emodiversity metrics were highly correlated with one another. However, based on our pre-registered analytic plan, our study used Shannon's Entropy for mediation analyses, which is recognized in the extant literature for its normalized distribution (Martín & Rey, 2000).

While our mediation results were not significant, we did observe a relation between emodiversity and depression. Thus, we recommend that emodiversity remains a variable of interest in future depression research given that it represents emotional variability. This affective construct has largely been ignored in previous literature, despite its significant associations with positive health outcomes and wellbeing (Banty, 2020; Benson, 2016; Ong et al., 2018; Quoidbach et al., 2014; Urban-Wojcik et al., 2020; Werner-Seidler et al., 2020). Recognizing the value of negative and positive emotions in resilience, coping, recovery from disease and illness and revitalization, we hope that emodiversity-related constructs are studied more frequently in

the psychological literature moving forward in order to advance our understanding of the role of diverse affective experiences on health and wellbeing.

Notably, increased positive affect was a significant agent of change in reducing depression symptoms for the treatment group. Anhedonia is a hallmark symptom of depression (Forbes & Dahl, 2005; Khazanov et al., 2019; Silton et al., 2020; Treadway & Zald, 2011), and it is a criterion symptom in the DSM-5 (American Psychiatric Association, 2013). Anhedonia likely involves distinct, but related constructs of low positive affect as well as loss of interest; (Snyder et al., Under Review; Treadway & Zald, 2011). Research dating back to the early 1970s characterized a behavioral theory of depression, such that depression onset was theorized to be associated with a decrease in experiencing pleasant events (Lewinsohn & Graf, 1973; Lewinsohn & Libet, 1972), and recent research has supported this theory using ecological momentary assessment methods (Khazanov et al., 2019). Khazanov and colleagues observed that individuals with depression reported lower levels of positive affect and they experienced fewer positive events compared to controls. While research studying the role of positive affect and emotion in depression is slowly increasing, research focusing on positive emotions as both an etiological factor and a target for intervention has been largely overlooked by clinical science research which has been guided by a pathogenesis framework that focused on ameliorating negative affect and emotions in depression.

Focusing on therapeutic contexts, Dunn (2012) suggested that treatment outcomes for depression are more likely to be improved via focusing on augmenting positive emotions. Specifically, in a study with a sample of outpatients with MDD being treated with antidepressant medication (ADM) or cognitive therapy (CT), results showed that both ADM and CT were more

effective in reducing negative affect than increasing positive affect (Dunn, 2012). However, individuals with lower levels of positive affect at pre- and post-intervention showed increased functional impairments relative to individuals with high levels of negative affect. Thus, Dunn suggested that improved outcomes may result if interventions target positive affect in addition to negative affect given that anhedonia symptoms are highly predictive of future prognosis, functional impairments, and suicide rates (Dunn et al., 2020).

MBIs, which are theorized to enhance the capacity for and experience of positive emotions (Garland et al., 2015), may offer a therapeutic component that increases positive affect. As evidenced in our present study, changes in positive affect significantly mediates the relation between study group and changes in depression symptoms. However, minimal research has explored *why* MBIs might modulate positive affect and emotions. Garland et al. theorized that MBIs might enhance metacognition, which in turn facilitates positive reappraisal and enhances individuals' capacity for savoring positive experiences. For example, by nonjudgmentally accepting experiences rather than perseverating on them, additional attentional resources are available to encompass pleasurable and meaningful events. Thus, it is plausible that participants in the treatment condition of the present study experienced an increased capacity to implement positive reappraisal strategies, which contributed to increased positive affect and a reduction in depressive symptoms, relative to controls.

More generally, future research is needed to advance our understanding of effective positive emotion regulation strategies for individuals with depression (Silton et al., 2020), such as savoring the moment (Kahrilas et al., 2020) as well as other strategies established by the field of positive psychology (Quoidbach et al., 2015). Additional research is also warranted to expand

the evidence base for existing therapeutic treatments that may enhance positive emotion regulation strategies such as Behavioral Activation (BA) and positive CBT. BA is an effective evidenced-based therapy for individuals with depression that increases the frequency of experiencing positive reinforcement via increasing the frequency of engagement in pleasant activities (Dimidjian et al., 2014). Positive CBT focuses on integrating behavioral activation with identifying strategies from the field of positive psychology in order to advance a strengths-based approach for individuals with depression (Bannink, 2014).

Limitations

Despite the strengths and novelty of the present study, some limitations exist. First, the present study's exclusionary criteria for EEG research[1] along with a predominantly White college student sample limits the generalizability of these findings to a diverse population. Future research should seek to address the impact of MBIs in individuals with minoritized and/or intersecting identities who have been historically excluded from this narrative such as individuals from communities of color and/or the LGBTQ+ community. Notably, we had a very small sample of men and non-binary individuals in our study, and it remains important that individuals from all gender identities are included in future MBI studies. Secondly, considering that our study involved two sampling timepoints, future intervention research may benefit from using ecological momentary assessment (EMA) methods to sample affect at a more frequent rate. For example, recent research has demonstrated the feasibility of using EMA to sample symptomatology more frequently in order to provide a more continuous picture of

[1]We only recruited participants who were right-handed, not color-blind, and learned English as a first language due to following older recommendations for neuroimaging/EEG data collection. Please note that we strongly recommend that these guidelines are no longer followed in order to enhance inclusivity in scientific research.

symptomatology patterns over time in the context of an intervention study (Jacobson & Bhattacharya, 2021).

It is important to acknowledge that current Western mindfulness-based interventions are rooted in the cultural appropriation of Buddhist traditions, which some scholars have argued has diluted the benefits of these practices and thus, may point to unreasonable inflation of expectations regarding MBIs therapeutic benefits (Farb, 2014). However, while mounting evidence suggests that MBIs facilitate quantifiable therapeutic benefits (Khoury et al., 2013), many unanswered research questions remain for future intervention studies to address, such as further investigating the role of "dosage," and further studying which types of mindfulness-based practices and strategies are most effective. Finally, additional research is needed to better understand how mobile health apps and digital therapeutics can most effectively harness MBIs in order to deliver these interventions at scale in an impactful manner.

While our present study illustrated that increased positive affect was a causal mechanism in reducing depression symptoms in college students during an eight week RCT study of Headspace (which impressively reaches over two million users across the globe), other research has found that specific types of mindfulness meditation such as loving-kindness (Fredrickson et al., 2008) can cultivate feelings and acts of kindness and compassion that in turn, may also have a positive impact on others (Hutcherson et al., 2008; Kearney et al., 2013). It would be beneficial for future research studies to investigate how MBIs and mindfulness meditation practices might have a broader influence on building a kinder and more compassionate and empathetic society, perhaps via increasing the capacity for experiencing positive events and emotions, which remains as critical as ever in our current society wrought with significant daily stressors.

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VITA

Mr. Rauch is a doctoral student at Loyola University Chicago studying clinical psychology with a specialty in neuropsychology. He received his B.S. in Management Science and Psychology with a specialization in Clinical Psychology from the University of California, San Diego (UCSD) in 2016. During his time as an undergraduate, Mr. Rauch conducted research at UCSD spending two years becoming adept at data scoring, data entry, and statistical analysis for Dr. Amy Jak's interventional aging study investigating the effects of physical exercise, computer programming, or a combination of the two in older adults. After graduation, Mr. Rauch joined the BRASS (Brain Research on AUD Stimulation Study) and BRAVE (Brain Research on AUD and Veterans Emotions) labs at Stanford University. Spending two years working on a double blind, placebo-controlled clinical trial of repetitive Transcranial Magnetic Stimulation in Veterans solidified his desire to investigate groundbreaking therapeutic approaches to ameliorate clinical symptoms. Since starting graduate school at Loyola, Mr. Rauch has been a member of Dr. Rebecca Silton's research lab striving to understand the optimization of positive emotions and intertwined cognition function from a salutogenesis framework. Mr. Rauch's master's thesis showed that positive affect specifically mediated the relation between the RCT study group and depression symptom outcome. Collectively, through these aforementioned experiences, Mr. Rauch has had the immense privilege of sharing his teams' innovative research via the dissemination of presentations and peer-reviewed articles.