EMPIRICAL STUDIES OF CONTEMPLATIVE PRACTICES

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EMPIRICAL STUDIES OF CONTEMPLATIVE PRACTICES

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NOTICE TO THE READER

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INTRODUCTION

This book aims to serve as a forum to inspire empirical studies of contemplative practices that address the complexity and variety of such practice in a thoughtful way. Drawing on expertise from a range of disciplines, including psychology, applied statistics, health sciences, neuroscience, communication, computer science, and information technology, this book explores theorizing and modeling methodologies for the scientific study of contemplative practices. The book includes pedagogical and experimental aspects of studies such as research design, measurement, program assessment, statistical modeling, data mining, technology integration, and evaluation as well as the compiled interpretation of bodily manifestations of contemplative practices, psychological analysis of contemplative practices, and systematic studies of the effect of contemplative practices through data analysis. Together, the chapters of this book offer first steps along a path to deeper understanding of contemplative practices.

Empirical Studies of Contemplative Practices can serve as a reference book for scholars, researchers, and graduate students across fields of natural and social science. Specifically, this book may be of interest in scholarly arenas such as life sciences, psychology, communication, healthcare,

education, and data science. We also hope to draw attention from meditation practitioners as well as those who are interested in religious and philosophical studies.

We hope that the systematic study of contemplative approaches will make a positive impact on the daily lives of everyday people.

ACKNOWLEDGMENTS

We dedicate this book to those working to create a more compassionate world. May it benefit all beings.

We would like to acknowledge Syracuse University's Contemplative Collaborative, with which many of our authors are affiliated, and its founding director, Bonnie Goldstein. In creating this book, we are especially grateful for the guidance and support of Grace Buchbinder, Jennifer Phillips, and Dan Huston.

The Editors

I'd like to thank my students who are, of course, the true teachers, my Syracuse University and Department of Communication and Rhetorical Studies colleagues, past, present and incoming, as well as Arthur Jensen and Kim Pearce of the CMM Institute. I thank my family on their various planes of existence, as well as my teachers and the Lexington Shambhala and Syracuse Zen communities, for lessons intended and observed. Also, to a whole host of joyful friends who support and nurture me—activist friends, salsa and yoga friends, Ferry Beach, Syracuse, and Kentucky friends, thanks to you all.

Diane Grimes, PhD

I deeply appreciate all the love and support from my family, my CUSE (Collaboration for Unprecedented Success and Excellence) Grant supported mindfulness project members (Drs. Dessa Bergen-Cico, Rachel Razza, Mark Costa and Leanne Hirshfield), my colleagues (Director Dr. Diane Grimes, Buddhist Chaplain Bonnie Shoultz, Drs. Joshua Felver and Nicole Fonger) from the Contemplative Collaborative at Syracuse University. I also sincerely thank my peer attendees and brilliant instructors, for what I had learnt from them, during the 2017 Annual Summer Session on Contemplative Learning in Higher Education at Smith College. My deepest appreciation goes to my Vipassana Teachers, Zen Masters, and Gurus, who have guided me in the past, present and future. May the merit and virtue accrued from this work, if there is any, transfer back to and help all sentient beings.

Qiu Wang, PhD

I am grateful for my colleagues who share the same vision in integrative practices and their insights. Personal thanks to the editors. I appreciate my collaborators and students who have made great contributions to the work presented in this book. Lastly but most importantly, I give thanks to the gurus of meditation who have guided me in contemplative practices in my life.

Hong Lin, PhD

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Chapter 1

CONTEMPLATIVE SCIENCE: ARE WE MEASURING THE IMMEASURABLE?

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ABSTRACT

What constitutes mindfulness practice and how can we best study its effects? This question organizes much of the work of contemplative science; a field dedicated to elucidating the mechanisms and outcomes of change related to activities such as meditation and yoga. Attending to the present moment is fundamental to most wisdom and faith traditions. Consequently, there is considerable variability in the nature of mindfulness-informed practices, and a lack of consensus regarding how to best define and rigorously evaluate their impact. This is further compounded by the culturally and contextually diverse landscape in which these programs are offered. This chapter touches upon each of these issues, and asks whether it is possible to measure what many believe to be an immeasurable phenomenon.

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Keywords: contemplative science, contemplative practice, mindfulness-based research, mindfulness-based intervention, intervention science, prevention science, assessment, research methods

INTRODUCTION

What is contemplative practice and how can we best study its effects? This question is of great interest to researchers, educators, clinicians, practitioners and all those seeking to elucidate for whom, and under what conditions these practices might be beneficial, or ill-advised.

The exercise of intentionally bringing one's attention to the present moment is fundamental to most wisdom and faith traditions including Christianity, Buddhism, Taoism, Islam, Judaism and Hinduism (Armstrong, 1993; Goleman, 1988). Consequently, there are a wide range of practices such as sitting or movi[illegible]ation, prayer, breath mo[illegible]ication, guided [illegible]on, [illegible]nidra, m[illegible]tra, [illegible]anti[illegible]e[illegible]ci[illegible]and [illegible]rit[illegible], a[illegible]ero[illegible] [illegible]idie[illegible]ha[illegible]xamine a [illegible]ud[illegible]f sl[illegible]e and lon[illegible]m p[illegible]he[illegible]ical (e.g. attention, awareness, compassion, kindness, empathy, mindfulness, interpersonal skill, distress tolerance, implicit bias, self-regulation, self-compassion, cognitive efficiency), neural (e.g., brain volume, function, interconnectivity, neuroplasticity, neurochemical, neurocognitive), physiological (e.g., hormonal, biochemical, cardiac, respiratory, immune function), and genetic (e.g., NF-κB, $RIPK_2$, COX_2, HDAC) mechanisms and outcomes. From an empirical perspective, this diversity presents a notable challenge to researchers seeking to define, operationalize, measure, and interpret the broad ecology of contemplative experience (see Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006; Park, Reilly-Spong, & Gross, 2013; Sauer et al., 2013). This edited volume offers a multidisciplinary collection of work that considers the pedagogical and experimental aspects of contemplative science, with the goal of inspiring practitioners, clinicians, researchers and scholars to consider novel strategies for implementing and evaluating mindfulness-informed principles and practices.

As a contemplative scientist, practitioner, educator, consultant, and former editor-in-chief of a mindfulness-focused empirical journal, the challenge of understanding the nature of mindfulness and its effects has been the subject of many years of inquiry. I have listened intently to the arguments of those advocating for a universal definition of mindfulness and the need to deconstruct, differentiate and compare its active ingredients to better understand its mechanisms and outcomes, and the calls of those who fervently assert that the dismantling of a transformational experience into a compartmentalized set of thoughts, behaviors, and physiological, biochemical, genetic and neural events is excessively reductionistic. In essence, the latter contingent believes that we are attempting to measure the immeasurable. Although there is inherent value in both propositions, neither quench our thirst for knowledge or fully advance our understanding of the subtlety and complexity of contemplative experience.

Mindfulness by definition encourages us to find the middle way. This begs the question of whether it is possible reconcile what can seem like an ar[illegible]ed m[illegible]e of sci[illegible]e a[illegible]practice. The offering in this book explo[illegible]s is[illegible]f[illegible]m a numbe[illegible]d[illegible]irici[illegible]ica[illegible]a[illegible]ph[illegible]so[illegible]h[illegible]se s[illegible]ng li[illegible]t not only [illegible]the f[illegible]d's [illegible]nt ob[illegible]les, [illegible]al[illegible]ering a number of novel pedagogical and empirical approaches for exploring and understanding contemplative practice.

THE EMERGENCE OF CONTEMPLATIVE SCIENCE

Contemplative science is now a recognized and rapidly expanding discipline. Although sometimes conceptualized as the intersection of Buddhist practice, philosophy and Western science (Wallace, 2006), the field also considers principles and practices from a breadth of traditions (Goleman et al., 2008). In recent years, interest in mindfulness-informed interventions and their outcomes has risen sharply, leading to a prolific compendium of studies assessing the neural, behavioral, cognitive, psychosocial, and physiological, biochemical and genetic mechanisms and outcomes of meditation, yoga, tai chi, and other mind-body approaches.

Consistent with the value of self-inquiry, this growth has compelled us to examine whether our principles, practices and values are attuned with what we are studying, resulting in as many intriguing questions as answers (e.g., Baer, 2003; Bishop, 2002; Bullock, 2016; Coronado-Montoya et al., 2016; Dimidjian & Segal, 2015; Goldberg et al., 2017; Van Dam et al., 2018). This inquiry becomes even more necessary as mindfulness-informed approaches become ubiquitous in mental health, education and medicine.

The 20th century marked the rapid expansion of mindfulness-informed interventions in Western medicine and mental health. Beginning with mindfulness-based stress reduction ([MBSR]; Kabat-Zinn, 1982), numerous therapies have been proposed that address a variety of conditions including depression (mindfulness-based cognitive therapy [MBCT]; Segal, Williams, & Teasdale, 2002), smoking cessation (mindfulness training for smokers [MTS]; Davis et al., 2014), disordered eating (mindfulness-based eating awareness training [MB-EAT]; Kristeller & Wolever, 2011), and chronic pain and opiate abuse (mindfulness-oriented recovery enhancement [MORE]; Garland et al., 2014). Reviews of these approaches suggest that they may be beneficial [illegible] (Chiesa et al., 2011; Khoury et al., 2013; and Smith, Hogman, Goldberg, Boyce, & Miller, 2015). Though promising, systematic reviews, meta-analyses and commentaries frequently point to numerous methodological problems in the extant research, suggesting that claims of the benefits of mindfulness practice may be premature or overstated (Baer, 2003; Bishop, 2002; Bullock, 2016; Coronado-Montoya et al., 2016; Goldberg et al., 2017; Van Dam et al., 2018).

One of the biggest impediments to creating a unified field of contemplative science rests in the considerable heterogeneity of approaches and philosophies that fit under the umbrella of "mindfulness-based research." Although there have been attempts to separate practices or therapies into distinct categories or intervention types such as MBSR, MBCT, meditation (mindfulness, Theravada, Tibetan, Buddhist, Taoist, Christian, Transcendental, etc.), mindful self-compassion (MSC), and yoga (Hatha, Kundalini, Kripalu, Iyengar, Viniyoga, etc.), many of these approaches use similar, often overlapping strategies (single-pointed focus,

breath awareness, movement, meditation, mantra, etc.), and implement them in different ways (Brown, Creswell, & Ryan, 2015). To date, we neither understand the independent or collective function of each practice, nor fully comprehend the specific mechanisms and outcomes that they effect (Shapiro, Carlson, Astin, & Freedman, 2005).

THE MURKY DEFINITION OF MINDFULNESS

Although the variability of contemplative practice is not a problem in and of itself, the lack of an agreed-upon definition of mindfulness, which is often viewed as a primary outcome, is a growing concern (Van Dam et al., 2018). This is not unique to contemplative science, however. Other scientific domains like psychology have various subdisciplines that examine human phenomena such as consciousness, cognition, emotion, behavior, development, physiology, relational dynamics through distinct or overlapping lenses, and have developed theoretical models and assessments to gauge parallel constructs. Contemplative science will, thus, follow in the footsteps of psychology and similar fields wherein a lack of universal agreement about the nature, definition and operationalization of human experience is an accepted part of scientific discourse. Such an approach reflects the evolution and maturation of a field, and the agreement to disagree; ground that contemplative science has yet to cover.

An important lesson to be learned is that mindfulness meditation practices do, indeed, operate differently. For example, in a clever study, a team of researchers at the Max Plank Institute in Germany embarked on a large-scale study of the effects of 3 months of different types of mindfulness training; attention (Presence), compassion (Affect), and social intelligence (Perspective). In the study, a total of 322 healthy adults (197 women) between the ages of 20 and 55 years were recruited and assigned to participate in 1 of 4 groups (Valk et al., 2017). Group 1 and 2 participants began with Presence training. Group 1 then received Affect and Perspective instruction. Group 2 received identical training in the reverse order. Group

3 underwent only 3 months of Affect training, and group 4 received no instruction. Participants from all groups underwent fMRI brain imaging and completed tests of attention and social function at the end of each module.

The Presence module emphasized attention and introspective awareness. Core practices included breathing meditation and body scan exercises, as well as walking meditation, and practices designed to heighten attentiveness to vision, sound, or taste. The Affect module focused on loving-kindness meditation, and dyadic interaction. Loving kindness practices involved fostering loving feelings toward a benefactor, self, and others, and using phrases such as, "May you be healthy," "May you be safe," and "May you live with ease." Pairs of participants also performed face-to-face, in-person, and video-supported exercises during which they examined difficult situations, and practiced acceptance, compassion, and empathic listening. The Perspective module accentuated observing one's thoughts during meditation, and engaging in perspective taking with another person. Observation practices entailed labeling mental events such as thinking, and judging, categorizing thoughts into opposing domains (e.g., self/other, positive/negative), and [illegible] Participants also performed exercises where they were asked to view an experience from the perspective of another person, and reflect on how their viewpoint differed. Each training module began with a 3-day intensive retreat, followed by weekly group instruction and daily home practice that was supported by a custom-made online platform and smartphone apps.

Imaging results confirmed that structural changes in the brain were directly related to the form of mental training practiced. Immediately following 3 months of Presence training, participants showed significantly greater thickness in the anterior prefrontal cortex and anterior cingulate cortex; both are linked to attention and executive function (Fox et al., 2014). Performance on computer-based tasks that measure attention and executive function also increased. Notably, changes in social domains such as compassion and perspective-taking were not detected following Presence module training.

Affect and Perspective modules both focused on social behaviors, the first targeting emotion, and the second social cognition. Immediately following Affect training, participants showed significant changes in cortical thickness from the brain's right insula to the temporal pole; regions previously linked with empathy (Kanske, Böckler, Trautwein, & Singer, 2015), compassion (Singer & Klimecki, 2014), and emotion regulation (Ochsner, Silvers, & Buhle, 2012). These changes correlated with participant's enhanced compassion ratings. Following the Perspective module, adults showed significantly increased cortical thickness in the brain's left parietal regions, which are associated with perspective taking and Theory of Mind (Kanske et al., 2015). As expected, these brain changes were associated with better performance on tasks measuring perspective taking.

The relationship between the form of training and physiological and psychological stress also differed by practice type. Only the modules that focused on social competencies (Affect and Perspective) were linked to significant decreases in the release of the stress hormone cortisol. This suggests that the daily practice of perspective taking and compassion with a stranger, even if awkward or pathic understanding and non-judgment, may be linked to a significant drop in physiological stress. Nevertheless, participants reported feeling less stressed after all 3 of the training modules regardless of the order in which they were experienced (Valk et al., 2017).

Similar to research showing that social, cognitive, or behavioral skills are not interchangeable, results of this study propose that distinct forms of mindfulness practice may have very different effects. This raises the questions: What do we mean when we say that we are measuring the effects of "contemplative practice"? Is there a supraordinate construct of "mindfulness," or is an attempt to collapse mindfulness into a single dimension overly reductionistic? Is our desire for a universal definition or preferred contemplative practice impeding our ability to discern its mechanisms and outcomes?

At the very least, there is some agreement within the field that mindfulness is characterized by an awareness of one's experience as it is unfolding; an ongoing cognizance of how the mind, body and brain shape our reality. At a deeper level, mindfulness is a way of being that is framed by moment-by-moment attention to one's relationship with self and other, and a willingness to examine one's thoughts, feelings and assumptions rather than be governed by them (Bullock, 2016). Whether or not this conceptualization will be universally accepted is subject to debate, and will likely be so for the foreseeable future.

CONTEXT AND CULTURE

When considering how to best study contemplative interventions, one also needs to address the significant influence of the social ecology or context where instruct[illegible]s including demand characteristics and [illegible]ded [illegible]rchical [illegible]ctures (C[illegible]e, 201[illegible] Pu[illegible]f, [illegible]rbe[illegible]e[illegible]ur[illegible] 16) [illegible]s w[illegible]l as the cu[illegible]ra[illegible]eva[illegible]e of what [illegible]opo[illegible]d ([illegible]oulx et al. 2018; Bergen-Cico & Proulx chapter in this book).

Mindfulness-informed interventions are offered in an exhaustive assortment of venues including hospitals, doctor's offices, community clinics, mental health centers, pre-schools, K-12 schools, colleges and universities, businesses, prisons, short-and long duration retreats, and yoga and meditation studios/facilities, among others. They are delivered in person, online via webinars, courses, through e-learning platforms, with apps (Fish, Brimson, & Lynch, 2016), and likely through artificial intelligence and machine learning in the near future (Michie et al., 2017).

Although a detailed exploration of the implications of context and culture are beyond the scope of this chapter, Drs. Bergen-Cico and Proulx's examination of the relevance of culture and context draw attention to the need for contemplative scientists and educators to recognize the importance of the social context and the cultural relevance of intervention, measurement and assessment approaches, as well as our analysis and interpretation of the

data. This includes an acknowledgement of the potential for benefit and/or harm embedded within the practices themselves, and/or the research milieu.

IMPLICATIONS FOR MEASUREMENT

As discussed previously, the heterogeneity of contemplative philosophies, practices and contexts presents a formidable challenge for those looking to create an integrated body of research pointing to their effects. In terms of measurement, the term "mindfulness," a widely used construct and the cornerstone of much research to date, can refer to anything from activities that cultivate attention, awareness and the retention of information, to acceptance, nonjudgment, empathy, self-compassion or compassion directed toward others. Indeed, to date there nine self-report surveys that assess mindfulness in adults, and several more for youth. These measures often reflect the philosophical orientation or values of their developers, as to be expected, they do not correlate strongly with each other (Grossman, 2011). Consequently, one study's measure of mindfulness may represent a very different construct from the next, making it challenging if not impossible to build a consistent evidence base using a common language. What's more, these inconsistencies may hinder the impact of contemplative research as a whole (Goldberg et al., 2017; Van Dam et al., 2018).

This does not mean that important attempts have not been made to operationalize and measure mindfulness. Baer and colleagues (2006) systematically examined a number of questionnaires and discovered that five factors appeared to cluster from these independent measures: (1) non-reactivity to experience; (2) observing, noticing and attending to thoughts, feelings, perceptions and sensations; (3) acting with awareness; (4) describing; and (5) refraining from judging experience. Although observing was not found to be a statistically reliable construct, it has emerged as an important skill that can be learned with practice.

In Chapter 2, Felver and colleagues tackle the issue of measurement in detail, making several important suggestions regarding how to improve rigor

including using multiple informants to reduce bias. As part of their multi-informant strategy, we may also consider the use of observational measures that objectively[1] explore mindfulness as an interpersonal skill. For example, Duncan and colleagues (2015) developed an observational measure of mindful parenting (The Iowa Family Interaction Ratings Scales [IFIRS]) that showed a direct relationship between mothers' reports of mindful parenting and observed positive engagement with their adolescent children (Duncan, Coatsworth, Gayles, Geier, & Greenberg, 2015). In studying mindfulness behaviorally, we may be able to identify the intrapersonal and interpersonal attributes that characterize a mindful individual, rather than relying solely on theoretically-derived definitions or self-report measures.

The extent to which we can draw reliable conclusions about the impact of mindfulness depends on the quality of the research methods and measures (Creswell & Creswell, 2018). There are myriad factors that go into determining a study's quality including whether or not the program was delivered consistently, whether a control group was used, and whether adverse events were monitored and reported. Many mindfulness studies lack rigor, making it difficult to draw conclusions about the effectiveness of mindfulness. Importantly, the credibility of research in its entirety is reliant on the ability to replicate findings to ensure that the results did not occur by chance. The outcome of a single study is not sufficient proof that a mindfulness program is beneficial.

The ability to replicate study results may be particularly challenging for mindfulness researchers due to the lack of an agreed upon definition of what mindfulness is, and what a practice entails. There is also considerable variability in the number of hours of training received among mindfulness programs and therapies, leaving us with little knowledge about how much meditation is enough to achieve a desired effect. These issues are not unique to contemplative science, and do not negate that in fact empirical rigor within the field is increasing (Goldberg et al., 2017). They do, however, require our ongoing attention.

To that end, several groups of researchers have carefully analyzed the mindfulness-based intervention literature (e.g., Dimidjian & Segal, 2015;

[1] It should be noted that objective measures of this nature are never entirely free of subjective bias.

Goldberg et al., 2017; Van Dam et al., 2018) leading to a variety of recommendations. Among them: (1) paying specific attention to the intervention targets and populations to assure that there is a clear rationale for recommending specific practices, and that candidate mediators and moderators of outcomes are considered; (2) not conflating "promise with efficacy" meaning that the enthusiasm expressed regarding a study's positive effects be considered in the context of similar evidence-based interventions for the same condition; (3) operationalizing and measuring the clinical training necessary to deliver a mindfulness-based intervention; (4) specifically assessing dosage and intervention duration to ascertain what is minimally sufficient to achieve a reliable effect; (5) making certain to conduct well-controlled, internally valid studies in community settings with front line therapists/providers; and (6) systematically examining both the efficacy and effectiveness of an intervention (Dimidjian & Segal, 2015). Further, acknowledgement of issues of publication bias - "the file drawer problem" – are also warranted (Burton, Burgess, Dean, Koutsopoulou, & Hyde Jones, 2017).

MEASURING THE IMMEASURABLE

At this point the reader may question whether contemplative science will be able to satisfactorily resolve all of the challenges inherent in this work. Like most fields dedicated to cognizing the tapestry of human experience, there will likely be an ongoing debate regarding what constitutes high-quality, evidence-based contemplative programs, who is qualified to deliver them, under what circumstances, at what dose, for what duration, in what form and in what context, and for whom the philosophies and practices are beneficial or harmful, not to mention whether or not mindfulness can be reliably defined and measured, and how to best assess the mechanisms and outcomes of these efforts. Undoubtedly it will take many years of well-funded, high-quality studies for a resolution to manifest. This book represents a step along the continuum of effort needed to bring these issues to light.

The chapters in this volume address the scientific study of contemplative practices, and the pedagogical and experimental considerations pertaining to program design, development, implementation and evaluation from a variety of vantage points in the hope of serving as a catalyst for an emerging discipline. The book is divided into two sections: Methods and Contexts.

The Methods section begins with an overview of key measurement issues encountered in the study of contemplative practice (Chapter 2). This is followed by a discussion of research design and statistical modeling issues (Chapter 3), and a subsequent examination the role of scientific measurement in our understanding of contemplative practice (Chapter 4). The section concludes with an exploration of the measurement of the neural correlates of mindfulness using functional near-infrared spectroscopy technology (Chapter 5).

The Context section leads with a thorough enumeration of how culture and socio-economic considerations affect the delivery and study of mindfulness-based practices for diverse populations (Chapter 6). This is followed by a study detailing the effects of a mindfulness-based intervention for students with maternal anxiety (Chapter 7), across-sectional exploration examining the associations between several facets of mindfulness and problematic smartphone behavior among college students (Chapter 8), and an investigation of the combined effects of mindfulness and communication training on students' trait mindfulness, emotional regulation, and emotional intelligence (Chapter 9). The book concludes with a detailed discussion of the process undertaken by a collaborative of faculty at a major university to create a campus-wide, comprehensive assessment framework for studying the relationship between mindfulness-informed content and student learning and wellbeing (Chapter 10).

Collectively the offerings in this volume represent important advances in our understanding of contemplative practice. Although we have yet to establish whether we are measuring the immeasurable, this compilation serves as a model of progress toward a greater understanding of the myriad ways in which living mindfully can enhance our individual and collective wellbeing.

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Chapter 2

RECONCEPTUALIZING THE MEASUREMENT OF MINDFULNESS

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ABSTRACT

This chapter proposes several alternative conceptualizations and methodologies regarding the measurement of mindfulness. Contemporary approaches to the measurement of the construct are reviewed and critically analyzed. Following this, several procedures are detailed to introduce novel measurement approaches. This chapter argues for a critical reexamination of how the field of contemplative science currently measures the construct of mindfulness in both basic and applied settings, and proposes innovative conceptualizations and methodologies for how to advance the scientific investigation of mindfulness.

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INTRODUCTION

Psychology as a scientific discipline has a long-standing tradition of studying human behavior and the psychological attributes that characterize behavior. The objective measurement of psychological attributes poses a unique challenge in that, unlike physical attributes such as height and weight that can be *directly* measured, psychological attributes by definition must be *indirectly* measured as *constructs*. The seminal test theory book by Crocker and Algina (1986) explains that constructs:

> are hypothetical concepts – products of the informed scientific imagination of social scientists who attempt to develop theories for explaining human behavior. The existence of such constructs can never be absolutely confirmed. Thus, the degree to which any psychological construct characterizes an individual can only be inferred from observations of his or her behavior. (4)

To measure any construct, psychologists choose *behaviors* that can be measured, and then use these quantifiable behavioral measurements to empirically develop a deeper understanding of the construct under investigation. It is worth noting that a behavior is not necessarily a physical activity, rather in its most technical sense, a behavior is any observable action that can be recorded, which includes self-observations of thoughts and emotional states (although these behaviors are obviously less objective than discrete physical activities or physiological responses).

Among the many modern applications of psychological measurement, the measurement of mindfulness has received increasing attention in recent years due to the dramatic increase in the Western scientific study on the topic (Bishop et al., 2004). This exponential increase in peer-reviewed publications investigating the topic of mindfulness (Felver, in press; Felver & Jennings, 2016) has been driven in large part by the mounting evidence that mindfulness-based interventions frequently benefit participants. For

example, the most widely studied mindfulness-based intervention, Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 1990), has been studied in hundreds of clinical trials. Multiple meta-analyses have consistently indicated benefits to both clinical (e.g., patients with chronic disease) and normative populations following the completion of MBSR, including reductions in internalizing disorder symptoms such as depression and anxiety, decreased levels of perceived stress and psychological distress, and improvements in quality of life (Bohlmeijer, Prenger, Taal, & Cuijpers, 2010; Chiesa & Serretti, 2009; Goyal et al., 2014; Grossman, Niemann, Schmidt, & Walach, 2004; Keng, Smoski, & Robins, 2011; Khoury et al., 2013). The evidence supporting the utility of mindfulness-based intervention such as MBSR has increased interest in investigating mindfulness generally as a topic of scientific inquiry among psychologists and social scientists.

Given the surge of basic and applied research into mindfulness, measurement of mindfulness as a construct is critically important to the emerging field of contemplative science. Without objectivity, specificity, and accuracy in methods and processes that construct scientific knowledge, advancement can become stymied. As such, a great deal of work has gone into the measurement of mindfulness in recent years; however, the vast majority of the existing research to-date has focused on a limited range of measurement methodologies, particularly self-report questionnaires (Sauer et al., 2013). By relying upon this restricted array of measurement procedures, the field may be overlooking alternative measurement methods that could open new and innovative directions in scientific inquiry, thus advancing the emerging discipline of contemplative science.

The intention of this chapter is to suggest a reconceptualization of the contemporary measurement of the construct of mindfulness, and to propose alternative measurement approaches. It is worth noting at the outset that this chapter intentionally focuses on Western scientific methodologies, although we respectfully acknowledge that in doing so we are not including the valued contributions of religious scholarship. This chapter begins with a critical review of the existing approaches in the measurement of mindfulness. We then focus on introducing alternative measurement conceptualizations and

methodologies. The chapter concludes with an offering of suggestions for future directions for basic and applied measurement of the construct of mindfulness.

CONTEMPORARY MEASUREMENT OF MINDFULNESS

This section is intended to give a broad overview of the contemporary measurement of mindfulness as a construct and to call attention to several shortcomings with the current approaches employed. However, before delving into the specifics regarding mindfulness measurement procedures, it is important to discuss and establish the relation between the theoretical construct and the observable attributes that will be used to capture the construct, also known as establishing an *operational definition* (Crocker & Algina, 1986).

The most commonly cited definition in the Western scientific tradition is attributable to the cre[illegible]BSR, Jon Kabat-Zinn, who described the [illegible]t o[illegible]ndfulnes[illegible]ws: Mindfulness [illegible]ar[illegible]ay[illegible], a[illegible]ti[illegible] a[illegible]ar[illegible]ular way: On purpose, in the [illegible]ese[illegible]nt moment, and nonjudgmentally" (p. 4, 1994). Although this definition continues to be employed and referenced, particularly by lay audiences, it lacks the precision required for thorough scientific investigation. Therefore, to further refine the definition of mindfulness, and to bring greater specificity to its measurement, Bishop and colleagues (2004) held a series of meetings with many of the leaders in the field of contemplative science to establish a more precise operational definition. The result of these meetings was a consensus two-component model defining mindfulness as "the self-regulation of attention so that it is maintained on immediate experience…adopting a particular orientation toward one's experiences in the present moment, an orientation that is characterized by curiosity, openness, and acceptance" (p. 232). Bishop and colleagues' definition has been widely adopted by contemplative scientists and it has had an enormous impact on the field of mindfulness research over the past decade; indeed, according to the PsycINFO database, as of 2017, Bishop et al. (2004) has been cited by over 1,000 peer-reviewed scientific publications.

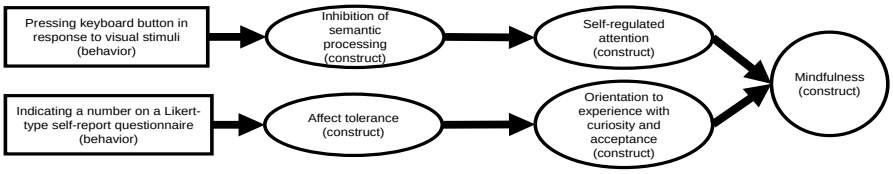

Figure 1. Measurement models for the construct of mindfulness. Note: We have adopted the commonly used statistical modeling symbols of ovals to represent constructs (i.e., latent variables) and rectangles to represent behaviors (i.e., measured variables). Arrows indicate directionality in the quantifiable relations between constructs and behaviors.

Beyond simply establishing an operational definition of mindfulness, Bishop and colleagues' (2004) model provided some specific recommendations for how to measure mindfulness in their two-component operationalization, and these recommendations have also been widely adopted. Figure 1 visually depicts Bishop et al.'s operationalization of the two-component model. Despite the great benefit Bishop et al.'s 2004 model has provided to the field of contemplative science, we argue that the [illegible] proposed in this foundational article [illegible] is limited in the scope of [illegible] and relies on secondary constructs as a proxy for the construct of interest. Not unique to Bishop et al.'s work, we believe that contemplative scientists have also been over reliant on self-report questionnaire technology to measure mindfulness directly. We argue that the aforementioned three limitations may be slowing the progress in the field of contemplative science. As such, a more critical interpretation of these issues is warranted and is discussed in the following sections.

Limited Scope of Measurement Methodology

The first limitation of Bishop et al.'s model (2004) is that *it is narrow in terms of the scope of the measurement methodology proposed.* To illustrate this criticism, consider the first component in the model (i.e., self-regulated attention). Although Bishop and colleagues propose multiple ways in which self-regulated attention can be measured, all the methods proposed rely upon

highly controlled laboratory tasks (e.g., the Emotional Stroop task; Williams, Mathews, & MacLeod, 1996) developed for the most part by cognitive psychologists. These tasks are typically administered in a controlled laboratory environment with stimuli delivered via computer that subjects respond to by pushing buttons on a keyboard.

Although laboratory tasks derived from cognitive psychology may reliably measure self-regulated attention in a laboratory setting, it is worth noting that these tasks actually only sample a narrow topography of behavior (i.e., button pressing in response to visual stimuli), and therefore may not be sampling the desired breadth or full topography of behavior for the construct mindfulness. Said differently, pushing a button in a laboratory to capture self-regulated attention may measure self-regulated attention in this contrived context, however such a task may *not* be measuring the full expression of self-regulated attention in one's day-to-day experiences. This criticism of laboratory-based assessment is not unique to the measurement of self-regulated attention; indeed, such a critique could be leveled against any laboratory-based assessment of human behavior. However, it is particularly germane to the current investigation given the emphasis of mindfulness in mindfulness-based intervention studies to evaluate the benefits of mindfulness-based intervention in one's day-to-day life. Given that the interest in mindfulness stems in such a large part from understanding the benefits of mindfulness-based intervention in one's daily experience (e.g., reductions in perceived stress), it is particularly important that self-regulated attention or any proposed measurement capture mindfulness in the naturalistic environment that is of most interest to social scientists, namely, the way mindfulness is expressed in one's typical life.

Utilizing Secondary Constructs to Measure the Construct of Interest

A second limitation in Bishop et al.'s model (2004) is that *the operationalizations proposed for measuring the construct of self-regulated attention utilize the measurement of secondary constructs* (e.g., the

inhibition of semantic processing) which are then typically measured by either a laboratory task (e.g., the Emotional Stroop task) or a self-report questionnaire. Thus, the behavior being measured (e.g., button pressing in Emotional Stroop task) is *twice* removed by theoretical constructs (e.g., first the inhibition of semantic processing, and then self-regulated attention) from the actual construct of interest, namely mindfulness (see Figure 1 for a visual depiction).

Relying on secondary constructs to capture the targeted construct of interest does offer strengths of relying upon well-established constructs and well-developed nomological networks, however by doing so it introduces a complexity which could obfuscate a more direct measure of the target construct of interest. Given that any behavioral measurement of a construct requires an abstraction by its very nature, we argue that by introducing this secondary level of abstraction, the field may be unnecessarily introducing imprecision into the measurement of mindfulness. An approach that *directly* measures the construct in question is thus more ideal toward advancing the more precise measurement of mindfulness.

The aforementioned criticisms of applying reflective models to behavior as indirectly measuring the construct of interest with a second construct also apply to the second component in Bishop et al.'s 2004 model (i.e., orientation to experience with curiosity and acceptance). The measurement of this quality of self-regulated attention employs only two methodologies: self-report questionnaires and qualitative coding schemes. The measurement proposed also heavily relies upon secondary constructs (e.g., affect tolerance) to measure the primary construct of interest (i.e., orientation to experience with curiosity and acceptance).

Overreliance on Self-Report Questionnaires

Since the publication of Bishop and colleague's seminal measurement paper (2004), Western scientists have also focused on *directly* measuring the construct of mindfulness, although this measurement has *almost entirely relied on self-report questionnaire methodology*. Self-report questionnaire

technology has been widely utilized by psychologists and other behavioral scientists since the inception of these scientific disciplines, as they offer a valid method for measuring any construct. Self-report questionnaires typically involve an individual reading a statement (e.g., "I am able to notice thoughts as they come and go") and then evaluating the statement using a quantitative value, which is typically their level of agreement or disagreement (e.g., "Not true for me," "Somewhat true for me," "Very true for me"). Scale developers employ procedures to create multiple items that are theoretically implicated with a given construct, and then use statistical analytic and modeling techniques to psychometrically evaluate the validity of this collection of items in measuring a given construct.

With regards to the measurement of mindfulness, self-report questionnaires offer a unique value that addresses the first two limitations detailed above. Individuals can be asked questions about their day-to-day lives as they perceive them in context, and as such, mindfulness can be measured as a naturally occurring phenomenon in one's daily experience. Individuals may also be asked to respond to self-report items that *directly* measure the construct of mindfulness, such as survey items that ask participants to report on secondary constructs in measurement

Given these unique properties, behavioral scientists have devoted a great amount of effort towards creating and validating self-reports to measure the construct mindfulness, and currently there are several self-report questionnaires available for measuring mindfulness. As an illustrative example, perhaps the most widely utilized scale is the Five Facet Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). The FFMQ was created by combining the items from several other popular existing mindfulness self-reports into a multivariate statistical analysis of their underlying attributes. The scales were selected with the intention of utilizing a diverse pool of items to fully sample the range of operationalizations for the construct of mindfulness, and included items from the following scales: The Mindful Attention Awareness Scale (Brown & Ryan, 2003); the Freiburg Mindfulness Inventory (Buchheld, Grossman, & Walach, 2001); the Kentucky Inventory of Mindfulness Skills (Baer, Smith, & Allen, 2004); the Cognitive and Affective Mindfulness Scale

(Feldman, Hayes, Kumar, & Greeson, 2004); and the Mindfulness Questionnaire (Chadwick, Hember, Mead, Lilley, & Dagnan, 2005). The resulting 39-item FFMQ self-report questionnaire was found to contain five underlying dimensions for the construct mindfulness, namely: nonreactivity (e.g., "I perceive my feelings and emotions without having to react to them"), observing (e.g., "when I'm walking, I deliberately notice the sensations of my body moving"), acting with awareness (e.g., "when I do things, my mind wanders off and I'm easily distracted"), describing (e.g., "I'm good at finding words to describe my feelings"), and nonjudging (e.g., "I criticize myself for having irrational or inappropriate emotions"). The FFMQ may be especially useful for examining these different sub-components of the construct mindfulness, and this fact combined with its strong psychometric properties (Baer et al., 2008) have made it one of, if not the most, widely utilized self-report questionnaires employed to measure mindfulness.

Self-report questionnaires are a useful tool for measuring the construct mindfulness and there currently exist a growing number of scales from which researcher may choose (for reviews see Baer et al., 2006; Sauer et al., 2013; Rau & Williams, 2016). However, these methodological approaches have significant shortcomings. First, the diversity of scales has stemmed in part from multiple differing operational definitions of the construct. There are several possible explanations for why different developers have elected to define mindfulness in different ways (Grossman, 2008; Grossman & Van Dam, 2011), however, the end result is that these final questionnaires are quite variable and, not surprisingly, they do not correlate strongly (Grossman, 2011). This diversity in questionnaire measurement also results in an inability of researchers to compare findings across studies. Second, by their very nature, all self-report forms rely on one's ability to accurately self-perceive experience. This general shortcoming is particularly salient when considering the construct mindfulness, as most accepted definitions of the construct include an element of being able to accurately self-perceive one's own experience (i.e., self-regulate attention to the present moment). Thus, one's experience with mindfulness practice, or one's dispositional trait level of mindfulness, may systematically alter how items are responded to. As an

illustrative example, we have found in our own work teaching MBSR to individuals without any prior experience that, prior to beginning practice, people commonly rate themselves as moderately mindful on questionnaires. However, following a few weeks of dedicated practice, these same individuals will often rate themselves as being very *low* on mindfulness, as they quickly realize via mindfulness practices (e.g., self-regulating attention to immediate experience) just how often they are actually not-mindful. Said differently, without practicing mindfulness, one is less able to notice how mindless one actually may be. This pattern of responses can also be seen with experienced meditators and non-meditators (Grossman, 2011). These and other limitations have led to our opinion that alternative non-self-report procedures should be more carefully considered, developed, and empirically evaluated in order to accurately and reliably obtain a quantifiable measurement of the construct mindfulness.

ALTERNATIVE MEASUREMENT APPROACHES AND METHODOLOGIES

In the previous section, we articulated several problems in the contemporary measurement of mindfulness, namely a limited scope of measurement methodologies, utilization of secondary constructs, and an overreliance on self-report questionnaires. In the next section, we offer three alternative conceptualizations of how to measure mindfulness that have the potential for addressing these limitations, as well as some specific methodological procedures that could be employed to measure mindfulness with these reconceptualizations in mind.

Measuring Mindfulness Outside of the Laboratory

A limitation of the existing measurement procedures is that mindfulness is often measured in the laboratory setting. This artificial environment

controls for the variability that exists in the real-world, however, sampling behavior in this context is limited in that it may not be actually measuring mindfulness in one's day-to-day life. We argue that any form of measurement that can occur in the naturalistic environment is actually measuring mindfulness in a more meaningful context. By measuring mindfulness in a naturalistic environment, psychologists and social scientists may be obtaining a more accurate measurement of mindfulness for individuals. With the advent of less expensive and more portable technology, we believe that mindfulness can be measured in such a way, and we offer two suggestions for how this may be accomplished.

Ecological Momentary Assessment

With the proliferation of smartphones and portable electronics, researchers are increasingly using this technology to sample human behavior. Ecological momentary assessment (EMA) is the process of using real-time samples of a subject's behavior over the course of hours, days, weeks, or longer (Shiffman, Stone, & Hufford, 2008). As an example, human subjects can be asked to engage in something about themself, perception, or actions in the moment (e.g., "please rate how mindful you are noticing your bodily-somatic experience *right now*"). Behavior samples collected with EMA are varied, but are often in the form of diaries, questionnaires, or ambulatory monitoring. The advantages of EMA over the retrospective self-report technique that is often used in psychological research is that EMA samples subjects' behavior in their own environment at the time it is occurring. It is well known that people are not always accurate when recalling past events or behaviors (Bradburn, Rips, & Shevell, 1987); therefore, assessments administered in the moment can address the issue of recall bias. EMA measures also have an advantage over retrospective self-reports given in a laboratory environment because they are given in the subjects' natural environment and thus more likely to be applicable to everyday lived experience.

EMA is often used in habit change studies (e.g., smoking cessation, dietary and exercise changes), and psychophysiology data collection studies (e.g., salivary cortisol, heart rate monitoring), where cravings, feelings, and

physiological behaviors are easily assessed in real-time (Shiffman et al., 2008). For example, Ruscio, Muench, Brede, MacIntyre, and Waters (2016) sent smokers reminders to complete daily assessments at random sampling times to report affect and cravings. EMA is especially useful for these studies when looking for trends in data over time.

Mindfulness studies, which regularly use retrospective self-assessments, could benefit from EMA. Mindfulness could be directly measured in the moment rather than asking subjects to recall how they have felt over the past several weeks or months. Instead of getting reminders throughout the day or week to ask about their cravings or feelings, subjects in mindfulness experiments could be randomly asked questions, such as "Are you paying attention to what's happening right now?" Assessments, such as the state-version of the Mindful Attention Awareness Scale (Brown & Ryan, 2003), could similarly be administered randomly throughout the day to get a more accurate assessment of the subjects' present-moment mindfulness.

Preliminary evidence suggests that EMA could be greatly beneficial for mindfulness studies who use this measure. For example, Mo... Dey... ethod, and Lenze (... ...mpared EMA-... mindfulness... and ... pressi... question... res... th... traditional paper ques... ..., and found that the EMA measures outperformed the traditional method. Additionally, if EMA were to be combined with basic stress reactivity measures (a common outcome of interest in mindfulness-based intervention studies), continuous ambulatory monitoring of physiological measures like heart rate and cortisol levels could provide further insight into mindfulness and stress reactivity in daily life. Whether through present-moment self-reports, physiological monitoring, or some other method, EMA could provide behavioral data that could be used to measure the construct of mindfulness.

Collecting High-Quality Data Outside of the Laboratory

As previously mentioned, one reason that social scientists collect data in a laboratory environment is to minimize the influence from uncontrolled external factors (e.g., the naturalistic setting). Another reason that data is collected in the laboratory is that the instruments used to collect such data

are often expensive and cumbersome, and thus measurement cannot occur outside of this setting without risking damaging valuable equipment or because it would be impossible to move the equipment to another location.

Recent years have seen a dramatic decrease in the price and size of computers. To capitalize on this shift in technology, researchers interested in utilizing high-quality measurements that have previously been conducted in laboratory settings should consider creating "mobile laboratories" that would enable data to be collected in other locations. Sampling behavior in this way may give a more accurate measurement of a construct of interest, such as mindfulness, while still utilizing high-quality and valid measurement methodology. It also offers the advantage of being able to sample behavior from individuals who may not be able to physically visit a laboratory due to logistical constraints (e.g., transportation, lack of childcare).

As an illustrative example of how high-quality data could be collected outside of the laboratory setting, our own Mind Body Laboratory at Syracuse University uses a mobile laboratory protocol we developed to collect data in school settings. One focus of our laboratory is to evaluate the effects of mindfulness-based interventions in school settings, particularly those of high-risk populations (e.g., children who live in poverty and communities with high-rates of community violence). A problem that we and other like-minded school psychologists face is that although we would like to collect computer administered assessments of behavior (e.g., self-regulated attention), we are unable to given that it is implausible to transport all youth in a school setting to a distant laboratory, and even if this were feasible, it would greatly disrupt their school day and educational routine. Furthermore, administering assessments to youth in a controlled laboratory environment may not actually capture what their behavior is actually like in the naturalistic environment. Said differently and using the example of self-regulated attention, we are *not* interested in whether youth are able to pay attention in our laboratory, however we are *very interested* in whether youth can pay attention in their classroom. To measure constructs of interest, we have capitalized on the availability of inexpensive and transportable tablet computers to collect data from youth in their naturalistic setting. We utilized a classroom set of tablet computers each programmed with standardized

batteries taken from the National Institute of Health Toolbox (Gershon et al., 2013), including the Flanker Task (Zelazo et al., 2013), which is perhaps the most widely implemented laboratory-based measurement of self-regulated attention. To measure how an entire school's worth of youth responds to a mindfulness-based intervention, at several time points throughout the year, we set up small desk dividers, headphones, and the aforementioned tablet computers in a single classroom. We then administered the Flanker Task to entire classrooms of students to ascertain whether changes in self-regulated attention occur as a function of participating in a mindfulness-based intervention. Sampling behavior in this manner allows us to best understand how youth respond to mindfulness-based interventions in the context of their school environment.

Using Mindfulness Practice as a Measure of Mindfulness

Mindfulness as a construct is best defined as active and engaged process. It involves *paying attention* to what happens in the present moment and becoming aware of how each bit of attention alters one's understanding of the environment and consequently oneself as a function of the environment, and as such it can and perhaps should be measured as an activity and not as a static variable. We would thus assert that the activities that are described as mindfulness practices (e.g., mindful breathing meditation), *can be equated* with the actual construct of mindfulness. Said differently, mindful practices can and should be considered a direct behavioral operationalization of the construct of mindfulness.

To illustrate this argument with a metaphor, one could state that "fitness" as a construct is directionally correlated with the operationalized behavior "jogging" (i.e., changes to fitness cause changes to one's ability to go jogging). One could also reverse causality in this relation, stating that "jogging" as a behavior is causally related to the construct "fitness" (i.e., changes to one's jogging ability cause changes to one's fitness), and thus jogging serves as an operationalized behavior for the construct fitness. Both perspectives are defensible and valid, and we would argue that this same

logic applies to the construct of mindfulness such that the related correlation of changes *to* mindfulness resulting *from* mindfulness practices may in fact be equally reversible, such that mindfulness practice can be considered a behavioral operationalization of the construct mindfulness. With this in mind, we offer several suggestions for how one may measure mindfulness practice as a direct operationalization of the construct mindfulness.

Breath Counting

Breath counting is a mindfulness practice at least 1500 years old, and has recently been introduced as a behavioral measure of mindfulness that can potentially avoid some of the aforementioned limitations with self-report or questionnaire measures (Levinson, Stoll, Kindy, Merry, & Davidson, 2014). In particular, breath counting has been presented as a technique to measure mindfulness with increased efficiency and decreased bias. Breath counting has been proposed as a method for operationalizing the construct mindfulness as the task includes (1) a direct observation that the experience of breathing is occurring in the present moment and (2) awareness that performance such as task interruption-and-return measures (counting) this process as individual return attention to the breath when attention wanders.

While breath counting is not essential for the practice of mindfulness, Levinson and colleagues (2014) propose that mindfulness may be associated with increased accuracy in breath counting. Specifically, Levinson et al., (2014) evaluated the construct validity of breath counting as an index of mindfulness by examining the relations between breath counting and known consequences of mindfulness that include more meta-awareness, less mind wandering, better mood, and increased non-attachment. Overall, empirical research conducted by the authors suggests that accuracy in breath counting tasks is related to self-reported levels of mindfulness (i.e., increased breath counting accuracy is associated with increases in self-reported mindfulness), can distinguish expert meditators from novices, and accuracy rates increase following a mindfulness training. These results indicate that breath counting tasks may be a viable and valid behavioral technique to measure the construct of mindfulness.

Behavioral Topography of Mindfulness Practice

Another way to obtain a behavioral measure of the construct of mindfulness would be to evaluate the topography of behaviors included in mindfulness practices. The topography of behavior refers to an operational definition used to describe the target behavior(s) in precise and observable terms. For example, let us use an example in which a mindfulness intervention asks participants to perform a sitting meditation task and pay attention to their breath. It is difficult to objectively determine if attention drifts off away from the somatic sensations of breathing during such a meditation practice. However, it would be possible to obtain a measure of the topography of the behavior by variables such as posture (e.g., subject displaying the instructed physical pose), participant stillness (e.g., absence of subject fidgeting), or the length of time a participant remains seated seemingly practicing the meditation. These outward behaviors (e.g., posture) may actually serve as a measurement of inward behavior (e.g., attention to breathing), and could be a valid measurement for the construct mindfulness. While it remains challenging to directly measure covert variables such as the number of times a person has gotten distracted while practicing a meditation, observing the topography of behavior may provide an overt and measurable index of the behavioral activities of mindfulness, and thus mindfulness as a measurable construct.

Utilizing Mindfulness Practice Logs

Particularly in the context of mindfulness interventions, home practice logs have been utilized as a behavioral measure of the mindfulness dosage. Specifically, home practice logs have been used with adolescent and adult populations in clinical and school settings (Carmody & Baer, 2008; Quach, Gibler, & Mano, 2017). In general, home practice logs are included in empirical evaluations of mindfulness interventions to gain insight into the frequency, duration, and intensity of mindfulness activities completed at home (i.e., outside of scheduled intervention sessions). Home practice of mindfulness activities (e.g., body scan meditations, sitting meditations, yoga) have been observed to be significantly related to increases in mindfulness variables such as observing and non-reactivity, decreases in

interpersonal sensitivity and anxiety, and increases in psychological well-being (Carmody & Baer, 2008).

As previously discussed, mindfulness is a construct that by definition is an active and dynamic process, thus mindfulness activities should be equated with the actual construct. Using this framework, we can expand on this previous discussion by suggesting that mindfulness home practice logs can be utilized within a mindfulness intervention context to obtain a behavioral measure of the construct. Put another way, the practice of mindfulness activities is synonymous with the construct of mindfulness, thus home practice logs can provide a behavioral measure within mindfulness intervention research, in addition to serving as a measure of mindfulness dosage.

Using a Multi-Informant Questionnaire Approach

Self-report questionnaires are one of the most prevalent measures of mindfulness in Western research. However, this measurement is limiting. Given the potential for bias, an alternative approach is the use of multi-informant questionnaires. Multi-informant approaches are common when a subject's reliability or objectivity is questionable, such as with children (De Los Reyes et al., 2015). Similarly, as previously described, any individual's ability to assess their own mindfulness may be unreliable, particularly in the context of mindfulness-based interventions. Although there are currently no multi-informant versions of mindfulness questionnaires that have been empirically validated using multiple informants, developing such questionnaires could be highly useful in obtaining a valid measurement of the construct of mindfulness. In what follows, we propose two such strategies that could be utilized.

Administering Mindfulness Questionnaires to a Third Party

Developing multi-informant measures of mindfulness may reduce the bias of people catering to what they believe to be correct answers (Grossman, 2011). Furthermore, if those completing the questionnaires are

highly knowledgeable about the target person whose mindfulness is being measured, the third-party informant may be a more reliable and less biased reporter of the target individual's mindfulness. Such third-party informants in the context of measuring mindfulness in children typically include parents and teachers, as these adults are able to provide a valid appraisal of the target child's behaviors. Similarly, third-party informants for adults may include intimate partners and close friends, who may be able to appraise the target adult's thoughts, actions, and emotions as they relate to the construct of mindfulness. Using a third-party informant would address several of the aforementioned limitations of using self-report questionnaires (e.g., Grossman & Van Dam, 2011); however, the development of such a questionnaire would necessitate careful and detailed psychometric scale development in order to empirically ascertain whether the third party is able to provide a valid and reliable measure of the target individual's mindfulness.

Administering Mindfulness Questionnaires to an "Expert" in Mindfulness

Questionnaires inherently may be interpreted and responded to differentially as a product of one's experience in, knowledge, and understanding of mindfulness, regardless of whether it is a self or multi-informant report. People without meditation or mindfulness experience may interpret questions and constructs differently than those with extensive experience (Grossman, 2008; Keng et al., 2011). To control for this, an expert mindfulness practitioner or someone with extensive mindfulness experience may be an especially valid and reliable informant to evaluate one's degree of manifesting mindfulness. Ideally a mindfulness practitioner with a psychological background would administer a semi-structured interview. Interviews allow for clarification and in-depth responses, and carry the benefit of standardization when a professional rater utilizes a standard scoring rubric. Questions could be extracted from mindfulness questionnaires with good psychometrics, such as the FFMQ (Baer et al., 2006).

Extant research has not looked at self-reports in conjunction with informant reports of mindfulness constructs, and this is a fruitful area of research. Future research may benefit from developing informant questionnaires and interviews, and one day it may be standard to use a multi-informant platform in conjunction with behavioral measures to increase the validity of measures. Concurrent with interviewing to evaluate current mindfulness constructs, the qualitative reports from interviews could be used to fine-tune and further develop measures and constructs of mindfulness, which may be particularly advantageous for progress in the field of mindfulness measurement (Grossman, 2008).

CONCLUSION

Valid and reliable measurement in any scientific discipline is one of, if not the most, important [illegible] of conducting empirical research. The measurement of mindfulness [illegible] a construct, [illegible] thus [illegible] with [illegible] to [illegible] old [illegible] international science. [illegible] both [illegible] constructs [illegible] mindfulness [illegible] has several features that make it particularly challenging to measure. This chapter has argued for a reconceptualization of some of the relevant topics related to the measurement of mindfulness, and has offered several suggestions for how future work may include alternative conceptual and methodological approaches. Mindfulness research is truly a nascent field of scientific discovery, and there are many exciting empirical questions that have yet to be answered. By considering alternative approaches to measurement, novel directions in research will become available which may not come into existence at all without innovative procedures being considered, implemented, and empirically evaluated.

Given that any construct is, by definition, an intangible object, we believe that the rigorous scientific evaluation of multiple and varying conceptualizations and approaches to measurement will only clarify the construct that is called “mindfulness.” This being said, we do want to acknowledge that all issues related to the measurement of mindfulness are very similar to the classic Buddhist parable of “the finger pointing at the

moon." In this metaphor, the "moon" represents an experiential truth that is explained and discussed using words which are metaphorically represented by the "finger." This metaphor is meant to highlight the fact that the finger/words are not equivocal with the moon/truth, and that to only understand an experiential truth in terms of words and thoughts, one will in essence never fully understand the truth itself.

The measurement of mindfulness is essentially a finger pointing at the moon. Mindfulness can never fully be defined, as it is an *experiential* phenomenon that any measurement procedure, no matter how well-refined, will ever be able to truly capture. We argue that multiple and diverse fingers (behavioral measurements) pointing at this moon (construct) will help to best, but never fully, define and measure mindfulness. This being said, we recognize the fact that the only way to completely understand or "measure" mindfulness for oneself is to look beyond the fingers pointing at the moon, and to look at the moon *directly* without any preconceived referents, intellectual abstractions, or theories regarding nomological networks of related constructs. Experiencing mindfulness directly does prohibit objective measurement (and often times subjectively by definition) and ar[illegible] conceptualize the very phenomenon under investigation); however, it may lead to greater understanding and insight of the phenomenon by the beholder. We therefore encourage anyone who is interested in contemplative science and the measurement of mindfulness to continue in their scholarly pursuits, and in parallel, to take a look at the "moon" directly to experience mindfulness in its true unmeasurable and experiential form.

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Chapter 3

RESEARCH DESIGN AND STATISTICAL MODELING IN CONTEMPLATIVE MEDITATION STUDIES

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ABSTRACT

This chapter discusses latent variable based design and statistical modeling on contemplative measures. We first review the operationalization and dimensionality of the latent construct of mindfulness, followed by a synthesis of the research design and statistical modeling found in recent (2012-2018) empirical studies. After discussions of explicit-macro and implicit-micro explorations in contemplative research, we examine the rhythm decomposition of Electroencephalogram (EEG) in physiological/ contemplative conditions and the differences through statistical modeling. We further discuss the main challenges that need to be addressed in latent

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variable based research. Finally, after discussing the principal component analysis and common factor analysis of EEG data, we briefly introduce structural equation modeling based time-series analysis for causality inference and intervention effect estimation in contemplative practices.

Keywords: contemplative practice, latent variable, research design, statistical modeling

INTRODUCTION

Meditation, a critical Buddhism ritual practice, has been described as "a path leading to the cessation of personal suffering" (Thera, 2014, p. 142). Meditation can spiritually help an individual to reach the stage of mindfulness (Bishop et al., 2004; K. W. Brown & Ryan, 2003), which "means paying attention in a particular way: on purpose, in the present moment, and nonjudgm[illegible] (Kabat-Zinn, 1994). Bish[illegible] et al. (2004, p. 2[illegible]) fin[illegible]ndfuln[illegible]as [illegible] a[illegible] [illegible] f[illegible]inc[illegible]si[illegible] aw[illegible]n[illegible] a[illegible] spo[illegible]ng skillfully t[illegible]me[illegible] p[illegible]esses tha[illegible]ntrib[illegible]e [illegible]emotiona[illegible] distress and maladaptive behavior" and operationalized mindfulness through a *two-component model*. Among the 10 most commonly used mindfulness instruments (Park, Reilly-Spong, & Gross, 2013), four are based on the *four-dimensional* structure, three the *two-dimensional*, two the *unidimensional*, and one the *five-dimensional*. Van Dam et al. (2018) discussed the difficulties and problems of operationalizing mindfulness. As Bishop et al. (2004, p. 231) pointed out:

> As long as fundamental questions concerning construct specificity and operational definitions remain unaddressed, it is not possible to undertake important investigations into the mediating role and mechanisms of action of mindfulness or to develop instruments that allow such investigations to proceed.

Therefore, it is critically important to answer several research questions regarding the operational definitions and dimensionality of mindfulness.

How has mindfulness, as a latent construct, been operationalized in the research design of existing empirical studies? And, how many dimensions should it have? Should an overall mindfulness score or multiple sub-scores be used in data collection and statistical modeling?

In the last thirty years, cumulative evidence from scientific research has strengthened mindfulness' position as "an alternative and complementary method of practice within medicine for enhancing health and well-being" (Mantzios & Giannou, 2018, p.1). Mindfulness, as an independent variable (IV), has been experimentally designed in the intervention studies of Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 1982; Kabat-Zinn et al., 1998) to examine psychological well-being (Astin, 1997; Shapiro, Schwartz, & Bonner, 1998; Williams, Kolar, Reger, & Pearson, 2001) and to reduce emotional disorders and behavioral symptoms (Carlson, Ursuliak, Goodey, Angen, & Speca, 2001; Ietsugu et al., 2015; Reibel, Greenson, Brainard, & Rosenzweig, 2001; Speca, Carlson, Goodey, & Angen, 2000). In a recent systematic review of mindfulness literature in the last 16 years, Goldberg et al. (2017) pointed out "the body of scientific evidence supporting the mindfulness intervention has been [illegible] being of poor methodological quality" (p. 1). They summed down six areas that need improvement: "1) using active control conditions, 2) larger sample sizes, 3) longer follow-up assessment, 4) treatment fidelity assessment, 5) reporting of instructor training, and 6) intent-to-treat (ITT) analyses" (p. 1). However, Goldberg et al. (2017) may have missed a deep review on two rigorous research quality features: specific research designs (experimental or associational) and statistical modeling approaches. So, there is a need to understand and answer the question: What are the trends in terms of study design and statistical methods of the recent contemplative practices and mindfulness studies in the field?

More integrative and theoretical models are needed to operationalize mindfulness (Van Dam et al., 2018). The whole-student perspective (Barbezat & Bush, 2014) and whole-life perspective (Roeser & Eccles, 2015) are macro-level models, which can reveal individual's daily, weekly, yearly, or life-long contemplation changes and mindfulness development. Meanwhile, the field also needs a latent variable framework (LVF) based

implicit-micro model, specifically using questionnaire- and assessment-involved brain activity (see Figure 2 in Van Dam et al., 2018). Necessary examinations are needed to answer the question: What are the trends in implicit-micro data (e.g., EEG) collection and analysis?

Recently, contemplative practices have been implemented as a mediator to examine the indirect effect in adolescent/child populations (see Roeser & Eccles, 2015). This implies the possibility of using path analysis and/or structural equation modeling (SEM; Bollen, 1989; Jöreskog & Sörbom; 1996) to analyze the mediation and/or moderation effect of intentionally manipulated contemplative practices. The two most recent systematic reviews (Mantzios & Giannou, 2018; Van Dam et al., 2018) have all missed a critical issue of analytic models that are related to statistical approaches. Thus, the field still needs to pay attention to a few relevant issues including: 1) How to quantify and calculate an intervention effect in the mindful/ contemplative research? How can experimental design be implemented through the LVF? 2) What methods (principal component vs. common fa[illegible]) should be used to derive and define the latent construct/variable? 3) How large should the sample size be [illegible] SEM [illegible]? This chapter aims to address these important topics. We will review the operational definition and dimensionality of the latent construct of mindfulness, followed by a synthesis of research design and statistical modeling in the most recent empirical studies, then discuss explicit-macro and implicit-micro explorations in contemplative research, and examine the rhythm decomposition of EEG in physiological/contemplative conditions and the differences through statistical modeling, and finally discuss the main challenges that need to be addressed.

OPERATIONAL DEFINITION AND DIMENSIONALITY OF LATENT CONSTRUCT OF MINDFULNESS

Mindfulness is defined as "an approach for increasing awareness and responding skillfully to mental processes that contribute to emotional distress and maladaptive behavior" (Bishop et al., 2004, p. 230). They

operationalized mindfulness through a *two-component model* and specified each component "in terms of specific behaviors, experiential manifestations, and implicated psychological processes" (p. 230). The first component involves the self-regulation of attention so that it is maintained on immediate experience, thereby allowing for increased recognition of mental events in the present moment. The second component involves adopting a particular orientation toward one's experiences in the present moment. We will review the dimensionality of mindfulness of the ten most popular mindfulness instruments (Park et al., 2013). For the operationalization of mindfulness and contemplative practices in human development, see Roeser and Eccles (2015).

Dimensionality of the Latent Construct of Mindfulness before 2012

Using [illegible] keywor[illegible] *mi[illegible]l** [illegible] *sa[illegible] Z[illegible] m[illegible]itati[illegible], asig[illegible] edit[illegible]on, heravada, [illegible]t m[illegible]itation*, Park et al. 20[illegible], search[illegible] three databases: Ovid Medline®, CINAHLR, and PsycINFO and found 2,558 articles. They reviewed 79 separate studies that were derived from 46 full-text articles. They found 10 different mindfulness instruments, listed below in their order of popularity:

Mindfulness Attention Awareness Scale (MAAS; Cordon & Finney, 2008)

The *unidimensional instrument* is designed to measure mindfulness "as present-centered attention-awareness" (p. 5) in daily experience. Mindfulness is described as "a *state* [that] varies within and between persons, and an attribute that may be cultivated with practice" (Park et al., 2013, p. 5). However, Cordon and Finney (2008) find that some MAAS items do not load well on the single latent construct, which implies the non-unidimensional nature of mindfulness.

Kentucky Inventory of Mindfulness Skills (KIMS; Baer, Smith, & Allen, 2004)

The *four-factor instrument* is "designed to assess the skill/ tendency/ability/action to be mindful in daily life in areas corresponding to the skills taught in mindfulness interventions, particularly Dialectical Behavior Therapy" (Park et al., 2013, p. 5). Its 39 items fall into four subscales, namely, Observe, Describe, Act with Awareness, and Accept without Judgment, which implies a *four-dimensional nature* of mindfulness.

Freiburg Mindfulness Inventory (FMI; Buchheld, Grossman, & Walach, 2001)

Being normalized from a German instrument, FMI is designed to assess mindfulness as "attentional, unbiased observation of any phenomenon in order to perceive and to experience how it truly is, absent of emotional or intellectual distortion" (Buchheld et al., 2001). However, the original 4-factor structure is not well supported by an exploratory factor analysis in [illegible] Buchheld, Bu[illegible], K[illegible]ech & [illegible]lt (2[illegible] w[illegible] stead[illegible] the *one-g[illegible]er fact[illegible]* model and [illegible]ain[illegible]in[illegible]ness as unidimensional construct.

Cognitive and Affective Mindfulness Scale-Revised (CAMS-R; Feldman, Hayes, Kumar, Greeson, & Laurenceau, 2007)

CAMS-R, as a jargon-free measure of a layperson's meditation experience, includes four sub-dimensions (aspects): Attention, Present-focus, Awareness and Acceptance/No-judgment. The *four-factor* structure is moderately supported by exploratory factor analysis (Feldman et al., 2007).

Southampton Mindfulness Questionnaire (SMQ; Chadwick, et al., 2008)

A 16-item unidimensional scale that measures awareness of distressing images and thoughts, SMQ is operationalized from the following four correlated (bipolar) constructs (Chadwick et al., 2008, p. 452)

(a) decentered awareness (Safran & Segal, 1996, p. 117) of cognitions as mental events in a wider context or field of awareness (Teasdale et al., 2002, p. 276) versus being lost in reacting to them (Kabat-Zinn, 1990); (b) allowing attention to remain with difficult cognitions versus experiential avoidance; (c) accepting difficult thoughts/images and oneself, versus judging cognitions and self (Kabat-Zinn, 1990, p. 69); (d) letting difficult cognitions pass without reacting versus rumination/worry.

Five Facet Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006)

FFMQ includes five separate mindfulness scales: MAAS, KIMS, FMI, CAMS-R, and SMQ (Baer et al., 2006). This 5-factor instrument has a multilevel structure, that is, the first-level (overarching) factor mindfulness is revealed by the five inter-correlated second-level sub-factors (facets). The five facets consist of th[illegible]ub-factors (Observing, D[illegible]scribing, Acting w[illegible]war[illegible]and N[illegible]udg[illegible]of I[illegible]Exp[illegible]enc[illegible]fi[illegible]t th[illegible]S a[illegible]e fi[illegible](N[illegible]reactivity [illegible]m Exp[illegible]fro[illegible]t FM[illegible]an[illegible]Ba[illegible]et[illegible]2006) recommending *five subscale scores*, rat[illegible]r tha[illegible]overall total composite score.

Toronto Mindfulness Scale (TMS; Lau et al., 2006)

TMS operationalizes mindfulness to be a non-psychological-trait-but-*state*-like "quality maintained when attention is intentionally cultivated with an open, non-judgmental orientation to experience" (Lau et al., 2006). It must be administered after a mindfulness or contemplative practice; and *two sub-scores* (Curiosity and Decentering) rather than the total composite score will be reported. The two-factor structure has been supported by exploratory and confirmative factor analyses.

Experiences Questionnaire (EQ; Fresco et al., 2007)

The *unidimensional* instrument measures a construct named *decentering*, which is a sub-component of mindfulness and can be operationalized "as the *ability* to observe one's thoughts and feelings as

temporary, objective events in the mind, as opposed to reflections of the self that are necessarily true" (p. 234).

Mindfulness/Mindlessness Scale (MMS; Haigh, Moore, Kashdan, & Fresco, 2011)

Using a cognitive-information processing theory, the original four-factor (Novelty Seeking, Engagement, Novelty Producing, and Flexibility) structured instrument operationalizes mindfulness "as active awareness of and engagement with the environment" (Haigh et al., 2011). However, the factor analysis only could produce a *two-factor* (Mindfulness-Mindlessness) structure.

Philadelphia Mindfulness Scale (PHLMS; Cardaciotto, Herbert, Forman, Moitra, & Farrow, 2008)

Based on a *two-construct* (Awareness and Acceptance) model, this instrument operationalizes mindfulness as "the tendency to be highly aware of one's internal and external experiences in the context of an accepting, nonjudgmental stance toward those experiences" (Cardaciotto et al., 2008). The two-factor structure is supported by factor analyses.

A most recent review (see Table 1 in Van Dam et al., 2018) found the nine most popular mindfulness measures in the order of citation frequency were: 1) MAAS, 2) FFMQ, 3) KIMS, 4) TMS, 5) FMI, 6) CAMS-R, 7) PHLMS, 8) SMQ and 9) State Mindfulness Scale (SMS; Tanay & Bernstein, 2013). The Experiences Questionnaire (Fresco et al., 2007), ranked 7th in Park et al. (2013), was not included in Van Dam et al. (2018). The original article by Fresco et al. (2007) that developed EQ has been cited 443 times in the last 11 years; meanwhile, SMS (Tanay & Bernstein, 2013) has been cited 91 times in five years. Van Dam et al. (2018) found that the problematic definitions mainly originated from vague sematic interpretations of mindfulness. They argued that sematic ambiguity has consequences in experimental research on mindfulness. They proposed a two-feature multi-trait mindfulness structure (see Table 2 on p. 41) including the Primary Features (Arousal, Effort and five attention-related traits) and 2) Secondary

Features (Emotion and Affection, Reasoning, Expertise and Skill, Physical Activities, and Body Position).

The three most recent systematic reviews, although mentioning methodical issues (Van Dam et al., 2018), experimental methodologies (Mantzios & Giannou, 2018) and methodological rigor (Goldberg et al., 2017), have missed opportunities to discuss specific research designs and statistical modeling approaches. Therefore, in order to examine statistical conclusion validity, we synthesized the most recent literature to scrutinize the congruence between experimental designs and statistical approaches.

A SYNTHESIS OF MOST RECENT LITERATURE: RESEARCH DESIGN AND STATISTICAL MODELING

Literature Selection

Following Park et al. (2015), we employed the following search strategies for our most recent literature review. The databases ERIC, PsycINFO, Web of Science, and SCOPUS were used in the search process. The search key words were mindfulness index terms in combination with research design terms. Specifically, mindfulness index terms included: *contemplative meditation, mindful*, meditation, Vipassana, Zen meditation, insight meditation, Theravada, Buddhist meditation.* Research design terms included *experimental, quasi-experimental, correlational, causal-comparative, single subject/case, quantitative method, statistical modeling.* The search for research studies was limited to academic journal articles published between 2012 and 2018.

After the initial search, we had 1,016 records from the four above-mentioned databases. Due to duplications, 214 were excluded. Then we examined the title, key words, and abstract of the 802 articles. Four hundred and three articles, including editorial papers, book reviews, literature reviews, and irrelevant studies were detected and excluded. As the purpose of the literature research was to review the design and modeling trends of mindfulness and contemplative research, only quantitative empirical studies

were included by screening the full text. Articles selected were either studying the effectiveness of mindfulness intervention or mindfulness-related constructs. Finally, 321 articles were included for this review (see the flow chart in Figure 1).

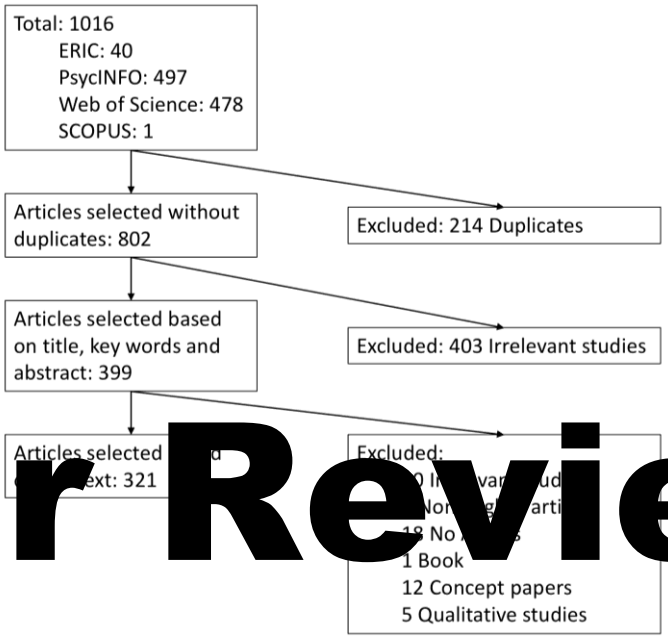


Figure 1. Literature search process.

Table 1. Number of selected articles in each year

Year	2012	2013	2014	2015	2016	2017-	Total
Frequency	29	37	44	59	75	77	321
Percent	9.00%	11.50%	13.70%	18.40%	23.40%	23.99%	100

Descriptive Results

The number of research papers on mindfulness has been growing since 2012. As Table 1 shows, the number of studies on mindfulness has increased with each passing year. It shows the increasing interest of researchers from

various fields, such as psychology, exercise science, medicine, and nursing training.

Study Design Trends in Mindfulness and Contemplative Research

To further examine the design and modeling trends in mindfulness and contemplative research, we coded the research design and statistical analysis of the 321 papers. The *research design* was operationally categorized as *true experimental design*, *quasi-experimental design*, *causal-comparative design*, *correlational design*, *and single subject/case design*. First, each study was screened to find out its own description of the study design. Second, the description of the study design was carefully examined and categorized into five major types. Some research articles contained multiple sub-studies; therefore, the number of studies in Table 2 was larger than the total number of articles.

Table 2. Number of each type of research design during 2012 - 2018

	True Experiment Design	Quasi Experiment Design	Causal Comparative Design	Correlational Design	Single Subject Design
2012	14	5	3	6	2
2013	24	8	1	4	-
2014	22	9	4	9	4
2015	29	9	4	11	7
2016	37	18	5	8	9
2017	36	28	5	4	6
Total	162	77	22	42	28

As shown in Table 2, 162 (48.94%) studies on mindfulness used true experiment design, with participants being randomly assigned to either a treatment group or a control group. Seventy-seven (23.25%) studies used quasi-experimental design, where a control group was provided to compare with the effectiveness of the treatment. In the last five years, *the percentage*

of quasi-experimental design studies showed a mild increasing tendency. Only five studies (17% of studies published in 2012) employed a quasi-experimental design, the number in 2017 was 28 (36% of studies published in 2017). The number of studies of correlational design in the selected articles was about 42 (12.69%), and fewer studies on mindfulness used causal comparative design (22, 6.65%) and single subject design (28, 8.46%).

The number of true-experimental design studies showed a steady increasing trend from 2012-2016; but it seemed to be saturated after 2016. The number of quasi-experimental design studies, although showing a slow increasing trend, were less than 10 in 2012-2015. From 2015-2017, the number of quasi-experimental studies showed a sharp increase. Without random assignment of participants, quasi-experimental studies need post hoc analytical techniques (e.g., propensity score matching in Wang, Houang, & Maier, 2018) to assure unbiased and accurate estimation of interventions in mindfulness and contemplation practices. *More rigorous design is needed to ensure causality inference and internal validity.*

Statistical Modeling Trends in Mindfulness and Contemplative Research

To draw a picture of the current trends in statistical analysis methods used in mindfulness and contemplative research, we first coded the analysis techniques used in the article, and then categorized them into different types. Various types of analysis have been used in the included mindfulness studies. Figure 2 shows the major statistical analyses used in these studies. The most frequently used analysis method was ANOVA. Chi-square and independent t-test were frequently used to examine the differences among treatment and control groups in experimental design studies. Paired t-test was frequently used in single subject studies. Due to the small sample size, some studies used nonparametric analysis, such as Mann-Whitney U test, and Wilcoxon signed-rank test.

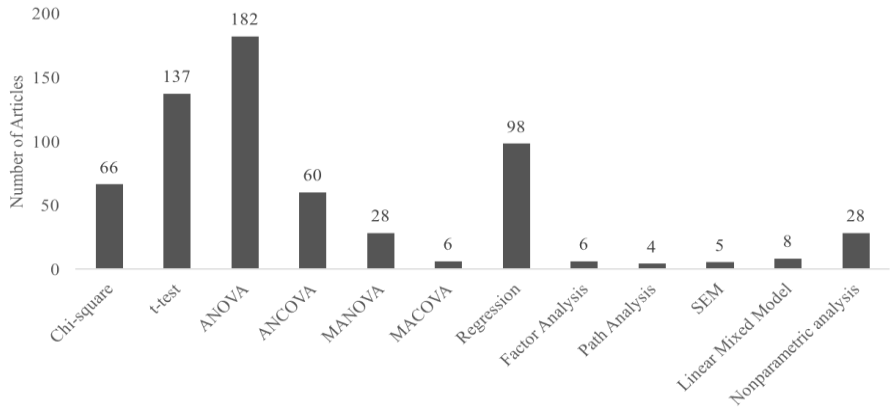


Figure 2. Statistical analysis used in the selected articles.

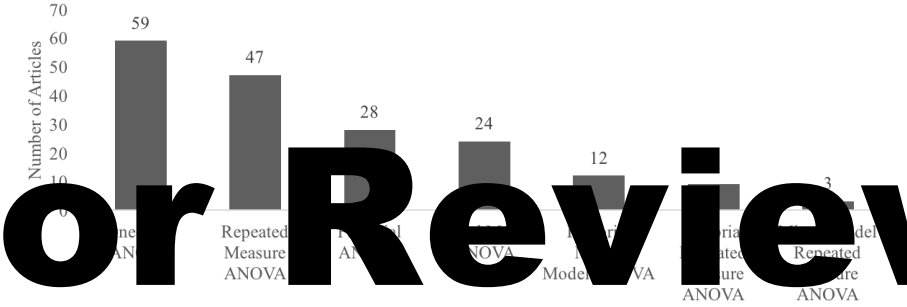


Figure 3. ANOVA used in the selected articles.

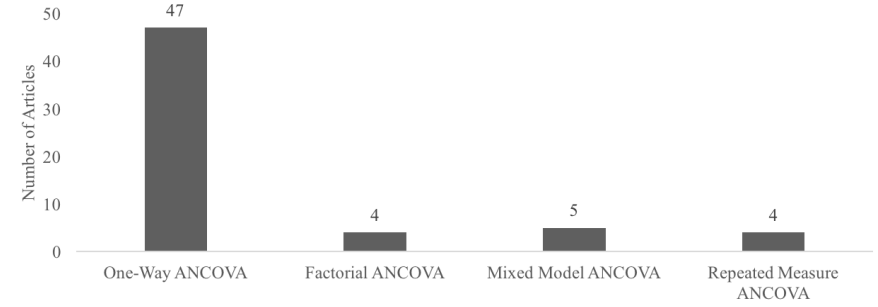


Figure 4. ANCOVA used in the selected articles.

As the complexity of each research design was diverse, the specific ANOVA used varied. Figure 3 presents the number of specific kinds of ANOVA used in these studies. As many studies employed pre-post and

follow-up test design, repeated measure ANOVA was frequently used in mindfulness related research.

ANCOVA was also a frequent choice. Figure 4 shows that several studies also used factorial ANCOVA, mixed model ANCOVA, and repeated measure ANCOVA in addition to one-way ANCOVA.

Regression analysis was another frequently used method. Among studies that used regression, most of the researchers used multiple regression. However, as Figure 5 showed, hierarchical linear modeling has been becoming more popular in mindfulness studies in recent years.

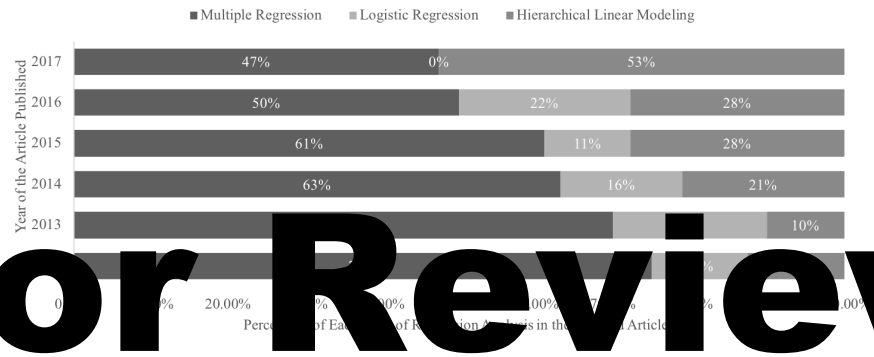


Figure 5. Percentage of each type of regression analysis used in the selected articles from 2012-2017.

In addition to the statistical analysis mentioned in Figure 1, there are other advanced analysis methods that have been applied in one or two selected articles, including cluster analysis, Bayesian estimation techniques, canonical correlation analysis, generalized estimating equations (GEE) model, indirect effect model, unconditional growth models, Cox proportional hazards regression model, multilevel zero-inflated Poisson regression, FMRIB's local analysis of mixed effects (FLAME)-1 algorithms, multilevel structural equation modeling (MSEM), linear change model, mixed-effects multi-level analyses for repeated measures, mediation and moderation analysis for repeated measures designs (MEMORE), propensity score matching approach, the SPSS expectation-maximization (EM) technique, Fisher's exact test, visual interpretation/inspection (e.g., the

percentage exceeding the mean method and trend analysis), Hurdle model[1], and Vuong test[2]. One study (Kee, Chatzisarantis, Kong, Chow, & Chen, 2012) mentioned using approximate entropy for time-series data. Following the neuro-phenomenological framework put forth by Varela and colleagues (Lutz & Thompson, 2003; Varela, 1996), case study design (Engström & Söderfeldt, 2010) was used to provide refined first-person descriptions of meditators' experiences (e.g., Berkovich-Ohana, Dor-Ziderman, Glicksohn, & Goldstein, 2013; Dor-Ziderman, Berkovich-Ohana, Glicksohn, & Goldstein, 2013). Given the complexity of the nature of meditation research, we believe that *the LVF modeling is needed to analyze complex mindfulness and contemplative data***.**

Summary

The most commonly used group-comparison analysis approaches (e.g., ANOVA) are well aligned with the majority use of the quasi-/experimental and causal comparative designs, which is supported by the practical and conclusion validity. However, most of the studies are based on the latent variable framework, in which a perfect-measure assumption has been hypothesized. The measurement errors have not been accounted for in the group comparison (Wang et al., 2018) and data analysis. Measurement error modeling and SEM have not been well adopted in contemplative studies. For example, only five studies used SEM between 2012 and 2018. Therefore, the LVF based design is needed.

Quasi-experimental design studies have been a trend in mindfulness and contemplative research. Because of the lack of randomization during participant assignment and group arrangement, an initial difference (Wang et al., 2018) between the treatment and control groups may bias the

[1] Hurdle Model is a modified count model with two parts, one is dealing with zero, and one is dealing with positive values. The model used for the two parts are not necessarily to be the same (Lecture 7: Count Data Models, n.d. https://www.bauer.uh.edu/rsusmel/phd/ec1-22.pdf).

[2] Vuong test is a model selection test; the null hypothesis is that the two models fit the data equally well.

intervention effect of the mindfulness and contemplation practice. Traditional ANCOVA is still appropriate to analyze contemplative data. Newly developed bias-reduction methods (e.g., propensity score matching and analysis in Wang et al., 2018) should be introduced and implemented to help contemplation researchers draw causal inferences in quasi-experimental and observational studies.

Principal component analysis has been used to decompose multivariate EEG data into meaningful components. However, the common factor model based latent mean comparison has not been introduced or used in mindfulness and contemplation analysis. We discuss this further in the next section.

Time-series data (see Kee et al., 2012), specifically, mindful and contemplative data, have been developed recently in the SEM literature, but due to its complexity, it will take time to apply in contemplative practice and research.

EXPLORATORY/MACRO-LONGITUDINAL MIXED EXPLORATIONS IN CONTEMPLATIVE RESEARCH

Based on the characteristics of participants, Barbezat and Bush (2014, chapter 2) reviewed contemplative research between 1998 and 2011, i.e., from the earliest (Shapiro et al., 1998) to the latest (Van Dam, Sheppard, Forsyth, & Earleywine, 2011). They classified contemplative studies into two types: one using long-term practitioners (e.g., monks), and the other using students and teachers in educational settings. In the first type, participants generally had more than a thousand hours of long-term contemplative experiences and they were *randomly* assigned into various types of *experimental* stimuli. Their physiological measures were recorded in specific mindful stages and contemplative states. These studies were conducted in strictly controlled lab conditions to record scientific neuropsychological measures, whose purpose is to assure internal validity. Strong causal inferences can be drawn between the manipulated stimuli (or

mindful stages) and psychophysiological outcomes. However, an obvious critique of such an experimental design is the lack of external validity because master-level practitioners are not randomly selected; and the findings cannot be representatively generalized into a layperson population.

Using quasi-experimental design groups, participants selected from natural school settings could be observed and studied in mindfulness conditions and contemplative practices. Unlike the short-time experimental lab sessions in the first type of study, the second type of mindful and contemplative research generally lasted for days, weeks and months, in which pre- and post-measures were collected and compared. In such longitudinal studies, the comparison between two time-points can show changes in the following five categories: 1) increased concentration and attention; 2) increased mental health and psychological well-being; 3) increased connection, generosity, and loving kindness; 4) deepened understanding of the course material; and 5) increased creativity and insight (Barbezat & Bush, 2014, p. 33).

Beyond Micro Research: The Whole-Student Perspective

Contemplative research in school settings focuses on the whole-student, not limited to performance in the classroom, but including their attention and functions needed to perform and finish class activities. The whole-student perspective is realized by connecting outside-classroom contemplative practices and inside-classroom learning activities. It reveals strong evidence of external validity to help researchers, scholars and educators to understand layperson growth and development by: 1) revealing realistic and more complex pictures of how mindfulness and contemplation are involved through multiple functions of cognitive and social activities in natural settings; 2) deepening our understanding of inter-variable relationships of different confounding measures, specifically to distinguish mediation and moderation in the chain effect; 3) implementing advanced latent variable models including factor analysis and/or SEM to deal with measurement error (see more detail in the later subsection *Quantifying the Intervention Effect*

in Mindfulness/ Contemplative Research) to accurately estimate the total (i.e., the sum of direct and indirect routes) effect of a critical common cause. Roeser and Eccles (2015) further extended the whole-student model and proposed a model to understand whole-life mindfulness growth and contemplation development.

Explicit-Macro Research: The Whole-Life Development Perspective

Contemplative research on the child/adolescent population is under-developed; specifically, there is a lack of studies using a developmental life-span perspective (Roeser & Zelazo, 2012). In a special issue of *Developmental Psychology*, Roeser and Eccles (2015) portrayed life-long development with mindfulness and compassion (see Van Dam et al., 2011). They theorized the naturalistic development of contemplative practices (including mindfulness and compassion), which would fill the gap and enrich our understanding of growth and the operation of mindfulness and compassion. First, they used the term "contemplative science" outlining contemplative practices as a two-component construct (including mindfulness and compassion). They hypothesized that the early-age initial state of mindfulness can be socialized and trained during development to be extended and internalized into the trait of mindfulness (See Figure 1 in Roeser & Eccles, 2015). They defined and operationalized contemplative practices in the context of data analysis, that is, individual level versus inter-individual level. An individual continuum and normative trajectory could be examined through discrete mindfulness development stages across the entire life. Between-individual variations/differences may be attributed to nurturing practices of parents, guardians, teachers, and community leaders.

Necessity of the Implicit-Micro Model

Both the whole-student perspective (Barbezat & Bush, 2014) and whole-life perspective (Roeser & Eccles, 2015), as macro-level models, can reveal

individual's daily, weekly, yearly or life-long contemplation changes and mindfulness development. However, the field also needs an LVF based implicit-micro model to account for measurement error across both nature and nurture growth and development. For example, the mindfulness construct's reliability and validity can be examined through the multitrait-multimethod (MTMM; Campbell & Fiske, 1959) approach across multiple-time-multiple-level settings. The construct can be operationalized through measures collected from the human brain and mind (e.g., EEG), behaviors, and social interactions using experimental, quasi-experimental, observational, and naturalistic culture-rich designs. The multitrait-multi-method data (e.g., correlations) can be used in statistical analyses including ANOVA, EFA (exploratory factor analysis), and CFA (confirmatory factor analysis; Kenny & Kashy, 1992). The following subsection will discuss the trends of implicit-micro level EEG data collection and introspective analyses displayed in Figure 6 (for more on introspection, see p. 32 in Barbezat & Bush, 2014).

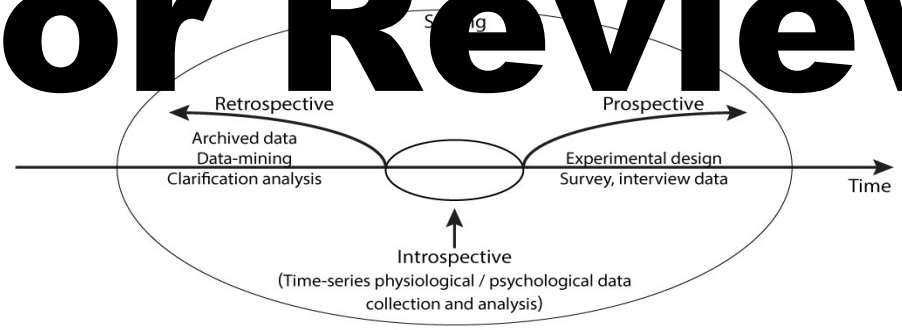


Figure 6. Introspective analysis in the timeline of contemplative research.

Introspective Modeling on EEG Data

An EEG introspectively records the brain's electrical activities (Nunez, 1981; Thakor, 1999) and provides temporal resolution and dynamics of the activities (Gevins et al., 1994). A review and the historical development of the use of EEG can be found in Teplan (2002). EEG signals usually are

measured by means of electrodes, which are placed on the scalp or directly on the cortex (Blinowska & Durka, 2006). Foreman, Thorngate, Burr, and Thomas (2011) presented a systematic exploration of factors influencing the accuracy of EEG measurement, especially skin preparation procedures and skin condition after electrode placement. Liao, Wang, Chen, Chang, and Lin (2011) developed a novel dry EEG sensor (without using the wet contact-based electrodes) to monitor EEG states, which fits especially well for brain-computer interface (BCI; Rao & Scherer, 2010) based contemplation applications and mindfulness practices. They argued that:

> In terms of the convenience of the EEG signal measurement process, [the traditional] procedures usually create trouble for users, especially in daily life applications for long-term monitoring. … [the proposed new] technique complements other existing EEG measurement approaches for the investigation of human EEG states involving neuronal activation and the behavioral responses to daily life applications (p. 5831).

EEG has worked with different fields and populations, including medical diagnosis and neurobiological research (Thatcher, 1991), depression (Hosseinifard et al., 2016), infants and young children (Forman et al., 2011; McEvoy, Hasenstab, Senturk, Sanders, & Jeste, 2015), gender differences in adolescents and individuals with special needs (Chai, Naik, Ling, & Nguyen, 2017; Kauhanen et al., 2006). Specifically, EEG data can be used in retrospective classification analysis (Popescu, Fazli, Badower, Blankertz, & Muller, 2007), specifically involving people with disabilities. For example, computational BCI uses the artificial neural network (ANN) to identify the EEG components and measures to classify and distinguish healthy individuals and individuals with tetraplegia (Chai et al., 2017). The EEG data can be collected from various BCI procedures including mental tasks, steady state visual evoked potential (SSVEP) based BCI, and eyes closed detection tasks. The classification accuracy can be estimated and compared through multiple classification methods such as ANN and LDA (linear discriminant analysis). Regarding the classification analysis using contemplative EEG data, please refer to Lin et al.'s chapter of this book.

Rhythm Decomposition of EEG in Physiological/Contemplative Conditions

EEG rhythm can be decomposed into different waves in terms of the frequency to indicate brain activities, physiological states, and contemplative conditions. For example, Delta waves originate in infants and sleeping adults. Theta waves are normally present in children and sleeping adults. Alpha waves form in the occipital brain region, while Beta waves appear with low amplitude during low attention states (Sanei & Chambers, 2007). Vaid, Singh, and Kaur (2015) summarized the rhythm, frequency range, amplitude, and physiological conditions as shown in Table 3.

Table 3. EEG rhythm, frequency range and physiological/contemplative conditions

Rhythm Power	Frequency Range (Hz)	Amplitude (uv)	Physiological Conditions
Delta	Less than 4	High amplitude (75–200)	Deep sleep
Theta	4-7	Very high	Emotional stress, sleep disorders
Alpha	8-13	30-50	Relaxed, awareness
Beta	13-30	5-30	Active thinking, active attention, high alertness
Gamma	30 and above	Below 5	Mechanism of consciousness, Fruition state in meditation[a]

Note: This table was based on Vaid et al. (2015). [a]Berkovich-Ohana (2017). The frequency ranges in McEvoy et al. (2015) are: Theta (4–7Hz), Alpha (8–12 Hz), Beta (13–30 Hz), and Gamma (35–45 Hz). Gamma (30–80 Hz)→Beta-1 (12–20 Hz), i.e., Gamma oscillations followed by Beta-1 oscillations, can be evoked by novel stimuli (Haenschel, Baldeweg, Croft, Whittington, & Gruzelier, 2000).

Makeig, Bell, Jung, and Sejnowski (1996) used independent component analysis (ICA) on EEG data and found that "the dominant Theta wave (near 7 Hz) spread across many EEG channels. Alpha activity (near 10 Hz) not obvious in the EEG data is uncovered in … the session [that] contains Alpha bursts interspersed with quiescent periods" (p. 148). Interplay of EEG waves (Gamma→Beta-1) reflects the biologically interactive functions and mechanism of the central nervous system (Haenschel et al., 2000). Gamma-to-Beta-1 transition in EEG data indicates a response to novel stimuli.

Interventions, such as mindfulness training and contemplative practices, can be treated as novel stimuli. An application is to detect the intervention effects indicated by the EEG data, specifically, the Gamma-to-Beta-1 transition. The correlation of Gamma and Beta-1 activities reveals a time-series effect across the sequence of stimuli. For example, Haenschel et al. (2000) found that the correlation between Gamma and Beta-1 was significant at the evoking stimulant but non-significant for the subsequent stimuli. Also, the induced Gamma-Beta-1 correlations are significant for the first and subsequent stimuli; and the magnitude is stronger (r = .95) for the late subsequent stimuli 2-8. This time-series effect indicates the response to the novel stimuli and later encoding and processing of the novel stimuli (p. 7648). Berkovich-Ohana (2017) focused on the functional connectivity or synchronization in the so-called "meditation-induced altered states" (Engström & Söderfeldt 2010; Lehmann et al., 2001). Berkovich-Ohana (2017) found that "that long-range global Gamma synchronization may offer an underlying mechanism for un-learning of habitual conditioning and mental patterns, possibly underpinning the neural correlates of the Buddhist experience of liberation" (p. 1). Berkovich-Ohana (2017) then analyzed the pinpointed the EEG measures (e.g., global long-range Gamma) synchronization in the "mindful meditation stage of Fruition" (p. 92) to understand "habitual conditioning and mental patterns, mechanism, which explains an alternation in habitual consciousness takes place, towards the [contemplative/mindful] aim of liberation from conceptual thought and mental conditioning" (p. 103).

Examining EEG Rhythm Differences through Statistical Modeling

Before we discuss the latent variable based methods to analyze EEG data, we will briefly introduce the Quantitative Electroencephalography (QEEG; McEvoy et al., 2015) approach. QEEG uses "specifically, resting state power, as a biomarker of typical and atypical development" and it "holds promise as a tool to better define more *subtle differences between*

individuals and subgroups within clinical populations, where behavioral measures may not be able to capture subtleties in clinical heterogeneity" (p. 104). The QEEG uses a two-way (4 Bands × 2 Power Types) linear mixed model (LMM) to account for within-individual correlations in the repeated EEG measures, but also the individual-specific heterogeneity for unequal numbers of repetitions. For example, the LMM was able to reveal the most significant differences in mean band power of the *Gamma* band for electromyogram (EMG) artifacts and the *Theta band* for ocular artifacts (p. 111). Although it is not an LVF based method, the QEEG, as an introspective examination, aligns well with the whole-student perspective across the whole-life to reveal "typical and atypical" development "across study [contextual] sites and clinical populations" (p. 112).

The LVF based methods allow researchers to collect construct/factor data and to analyze intensive time-series biomarker measures (Asparouhov, Hamaker, & Muthén, 2018) through SEM to understand the millisecond-level neuro-functions during mindfulness and contemplation practices.

FOUR CHALLENGES IN LVF BASED DESIGN AND DATA ANALYSIS

Since 2012, there have been an increasing number of articles using LVF and SEM in mindfulness research. How to use mindfulness (e.g., as a common cause or independent variable, or a mediation or moderation covariate) has become critical in mindfulness research study design, analytical frameworks, research hypotheses, and advanced statistical modeling. For example, Kabat-Zinn (1990) studied the mediating effect of mindfulness through mental training on mood and behavior. Kang and Gretzel (2012) used SEM and found that mindfulness was "an important [mediating] construct affecting the quality of experiences" and could "lead to enhanced tourist experiences and environmental stewardship" (p. 440). In their analytical framework of the mindfulness mechanism (Shapiro, Carlson, Astin, & Freedman, 2006), D. B. Brown, Bravo, Roos, and Pearson (2015) hypothesized mindfulness as a common cause (independent variable), "to be

related to the construct of perceiving or decentering, defined as a shift in perspective associated with decreased attachment to one's thoughts and emotions" (p. 1021). It was measured through the Mindfulness Attention Awareness Scale (MAAS), which includes 15 six-point Likert items. Because the MAAS has good internal consistency and criterion validity (K. W. Brown & Ryan, 2003), Fischer, Smout, and Delfabbro (2016) used the average rating across items as a measure of inattentiveness to understand the relationship between psychological flexibility, early maladaptive schemas, perceived parenting and psychopathology. However, in their analytical research model, the mindful inattentiveness score was treated as an item of the construct of psychological flexibility. Klainin-Yobas et al. (2016) used unidimensional mindfulness (one-factor instrument; MAAS; K. W. Brown & Ryan, 2003) as a predictor to understand positive and negative psychological well-being. In their study, mindfulness, as a five-attribute construct, was operationalized as the way one non-judgmentally focuses on current experience (Kabat-Zinn, 1990).

Because IVF and SEM involve both observed indicators and latent constructs, this complex interrelationships may highlight some of the challenges of examining mindfulness and contemplative practices. For example, the first two challenges involve the quantification of contemplative intervention effects and multiple-group experimental design, and the third challenge, sample size determination in the SEM for data collection. They echo the three issues discussed in Goldberg et al. (2017): 1) using more rigorous design by including control groups, 2) increasing sample size in mindfulness studies, and 3) calculating the intent-to-treat (ITT) effect.

Challenge 1: Quantifying the Intervention Effect in Mindfulness/ Contemplative Research

Quantifying Intervention Effects: Observed or Latent Mean Difference?

The manifest variables (i.e., indictor items in an instrument, y_1, y_2, …, y_p) are considered measurements (for multidimensional measures of

mindfulness, see D. B. Brown et al., 2015) for latent mindfulness (as a latent trait); and the intervention or treatment is considered to change the level of that latent trait. Should we use the *difference of latent means* of the treatment and control groups to represent the intervention effect?

Actually, the latent mean difference can theoretically represent the intervention effect, but in practice it may not be the best way in experimental/quasi-experimental design studies to calculate the effect using observed data. Using the difference of latent means can theoretically and conceptually represent the intervention effect, but it still requires observed data to reveal and calculate the effect. If one theoretically hypothesized the intervention effect based on latent mean difference, then an important follow-up question would be: How can the latent intervention effect be measured and indicated in mindful and contemplative practice?

Answering this question will require the framework of the latent variable, which will be indicated/measured by multiple manifest (observed) indicators, namely y_1, y_2, … y_k as measurements, so that latent difference due to the mindfulness treatment can be revealed by the observable changes of each of these indicators. And the observed mean of the observed changes will be the estimator of the latent *difference*. Using the observed indicators, we could calculate the implicit and unknown hypothesized latent intervention effect. However, a challenging issue is that the observed indicators suffer different levels of measurement error.

Measurement that is error-free cannot be achieved at all in behavioral studies. Take the latent construct of *stress* as an example. It can be operationalized and measured but not limited in five different ways: 1) observed rating of stress; 2) number of stressful events (summed composite score); 3) self-reported level on multiple stress-items (e.g., Perceived Stress Scale; Cohen, Kamarck, & Mermelstein, 1983) 4) daily hassles (for a summed composite score); and/or 5) galvanic skin responses (physiological measures). New conceptualized/operationalized measures of stress can be developed in the future. These measures, old or new, are subject to error across social/behavioral studies. The latent measurement error-free intervention effect exists in an ideal situation; but in reality and practice, measurement error must be accounted for. Let us use a primary framework

to explain it. Suppose we have the two groups' mindfulness measurement models: $Y_i = Truth_i + e_i$, for i being treatment (1) or control (0) and *Truth* representing the latent mindfulness variable. If there is *no* measurement error, $Y_i = Truth_i$ for treatment ($i = 1$) and control group ($i = 0$). Thus, if there is no measurement error, using the difference of latent means is *the* way to represent the treatment effect. But the ideal of error-free measurement cannot be achieved in behavioral research in practice. Because of measurement error, the unbiasedness becomes critical in estimating the latent mindfulness difference between the two groups.

Calculate Intervention Effect on Mindfulness

In the next few paragraphs, we further explain why including the intercept in a latent variable based measurement framework is necessary in behavioral research practices, and how the intercept-difference sufficiently reveals the unbiased (latent) intervention effect.

Psychometric Model: Classical Test Theory (CTT; Novick, 1966)

The CTT indicates that an observed score Y is a sum of two unobserved parts: true score (T) and measurement error (E). That is, $Y = T + E$. Then the total variance of Y will be $\boldsymbol{Var}(Y) = \boldsymbol{Var}(T) + \boldsymbol{Var}(E)$. Using this decomposition, psychometricians define the reliability as the ratio of $\boldsymbol{Var}(T)$ and $\boldsymbol{Var}(Y)$. This fundamental framework has been used by researchers to calculate the reliability (e.g., Cronbach alpha) in mindfulness and contemplative practices (see the reported reliability values of mindfulness instruments in Park et al., 2013).

If we put CTT in the treatment-control situation in contemplative and mindfulness research, then we have: $Y_0 = T_0 + E_0$, for the control group; $Y_1 = T_1 + E_1$, for the treatment group. E_0 and E_1 are normally distributed with a mean of 0. So, because of $\boldsymbol{E}(E_0) = \boldsymbol{E}(E_1) = 0$, the treatment effect can be estimated as $\boldsymbol{E}(Y_1 - Y_0) = \boldsymbol{E}(T_1 - T_0)$.

Why Should an Intercept be Included in the Framework?

Suppose, $T_1 - T_0 = delta_1$, then we can re-write: $Y_1 = [delta_1 + T_0] + E_1$. This implies that if the same person (with latent score of T_0) had been

assigned into the treatment group, he/she would have achieved an extra intervention effect of $delta_1$ that much. Now, $delta_1$ mathematically represents the intercept in the measurement equation of Y_1! Also, we can rewrite: $Y_0 = [delta_0 + T_0] + E_0$, with $delta_0 = 0$. This means that a person with latent score of T_0 has an intercept of 0. In other words, in the control situation, she/he gains a zero intervention-effect on T_0.

Mathematically, then, $\boldsymbol{E}(Y_1 - Y_0) = \boldsymbol{E}\{[delta_1 + T_0] - [delta_0 + T_0]\} = \boldsymbol{E}(T_1 - T_0) = \boldsymbol{E}(delta_1 - delta_0) = \boldsymbol{E}(delta_1 – 0) = delta_1$. So, including an intercept makes sense in reality and practice, specifically in a treatment-control experiment to represent the intervention effect.

Including an Intercept Helps to Achieve an Unbiased Intervention Effect

Behavioral scientists and developmental psychologists may argue that $delta_0$ cannot be 0, because she/he (with a latent score of T_0) can gain some effect by taking the test/survey/instrument or just going-through the process in the control situation. That is, $delta_0$ possibly a very small value should take into account, the intervention effect [illegible] accurate and pure.

Let us summarize what we have explained in a treatment-control situation to demonstrate how to achieve a pure estimation of the intervention effect. For an individual (with a latent trait of T), if she/he is randomly assigned to the control situation, then it follows the measurement equation: $Y_0 = [d_0 + T] + E_0$; otherwise treatment, $Y_1 = [d_1 + T] + E_1$. Here, d_0 is partially from T_0 (= $d_0 + T$) defined above, which captures the change when the latent score T goes through the measurement process in control. Similarly, intercept d_1 is a meaningful part of T_1 (= $d_1 + T$), and d_1 captures the change if the latent score T is counterfactually measured under the treatment condition. Mathematically, $\boldsymbol{E}(Y_1 - Y_0) = \boldsymbol{E}\{[d_1 + T] - [d_0 + T]\} = \boldsymbol{E}(T_1 - T_0) = \boldsymbol{E}(d_1 - d_0) = d_1 – d_0 =$ delta. So, $d_1 - d_0$ reveals the pure intervention effect. This implies that the treatment group not only gains the effect of the measuring process, but also gains an extra pure effect (delta) due to the intervention. Re-parameterizing the latent variable and decomposing it into meaningful parts (e.g., intercept and slope) has been practiced in the

psychometric field and behavioral research. For example, the item response theory (IRT) specifies the interaction between item-related parameters (item difficulty and item discrimination) and person-related ability. In latent growth modeling, the intercept-slope model (see p. 194, Raykov & Marcoulides, 2006) has been developed to capture the development of initial place (intercept) and development rate (slope). So, including such a meaningful parameter as *intercept* will help contemplative researchers to achieve their research goals (e.g., for group comparisons, see pages 366-367 in Bollen, 1989).

Introducing a Slope Parameter is also Necessary in the Framework

Further, more complicated equations can be written in the latent variable based measurement framework mentioned above. That is, for an individual (with latent mindfulness factor *eta*), if she/he is randomly assigned into control, then $Y_0 = [d_0 + b_0*eta] + E_0$; otherwise treatment, $Y_1 = [d_1 + b_1*eta] + E_1$. That is, two factor loading parameters b_0 and b_1 can be introduced in the equations. If the factorial measurement invariance holds ($b_0 = b_1$), then the estimation of intervention effects will focus on the group differences in factor intercepts for the factorial variables (e.g., *X* or *Y*) and latent variables. This has been well developed under the topic of *SEM with mean structure*. Please see the model specifications and parameter settings on page 297 of Jöreskog and Sörbom (1996) and pages 48-49 in T. A. Brown (2014). Following a similar fashion and logic, covariate *X* (e.g., demographic variables) can be included in the latent variable based framework to explain *X*'s impact on the intervention effect when randomization is not available in mindfulness research and contemplative practices across school settings (e.g., see more detail in Wang et al., 2018).

Challenge 2: Latent Framework Based Experimental Design

Solomon Four-Group Design (SFGD) in the Latent Framework

In the SFGD, participants are randomly assigned to one of four different groups (Figure 7). For example, Intervention I can be a particular

mindfulness or contemplative method. The dependent variable is assessed on M's, administered as a pre-test (Time 0, before I) and post-test (Time 1, after I). The SFGD calculates the pure intervention effect (i.e., the ITT in Goldberg et al., 2017) by subtracting the interaction between the pre-test effect and the treatment effect.

Experimental group ONE:	R	M	I	M
Control group ONE:	R	M		M
Experimental group TWO:	R		I	M
Control group TWO:	R			M

Figure 7. The Solomon four-group design: R represents randomization, I intervention, and M assessment.

Quantifying and Calculating Latent Growth

As a gold standard, random assignment is necessary to estimate the intervention effect in SFGD because of measurement error. Wang et al. (2018) showed how the intervention effect can be estimated through the latent variable framework based SFGD. Due to the random assignment of treatment and control, participants at the pre-test time point have an equal chance of being assigned to either the treatment or the control group. The measurement model at Time 0 holds equivalently in the four groups. It is called the *pre-equivalence of groups* (PEoG) assumption. Given the PEoG assumption, the *latent growth* derived from Group 2 is equivalent to that from Group 1 (Wang et al., 2018).

Revisiting the Latent Mean Comparison

Using *the difference of latent means* requires the assumption of measurement invariance, without which the latent mean comparison would be meaningless (Jiang, Mai, & Yuan, 2017; Van De Schoot, Schmidt, De Beuckelaer, Lek, & Zondervan-Zwijnenburg, 2015). Because of randomization (indicted as R in Figure 7 above), the control and treatment groups are counterfactually exchangeable before the mindfulness

intervention is used and these groups satisfy the measurement invariance. That is, treatment and control groups have no latent mean difference (i.e., the pre-equivalence situation) before the intervention is administered. In other words, the groups are comparable and counterfactually exchangeable due to randomization. Measurement invariance is very hard to achieve (Van De Schoot et al., 2015), specifically in behavioral mindfulness research and quasi-experimental contemplative practice when randomization is not possible. Thus, using latent means for comparison is impossible.

Challenge 3: Sample Size Determination in SEM-Based Mindfulness Research

Sample size determination is critical and difficult in latent variable based analyses including SEM (MacCallum, Browne, & Sugawara, 1996; Muthén & Muthén, 2002; Satorra & Saris, 1985; Wolf, Harrington, Clark, & Miller, 2013). The traditional rule-of-thumb approach only specifies the absolute number or range of the required sample size, proportionally to the length (the total number of items) of the instrument or the complexity (e.g., the number of parameters). For example, the sample size should be at least 100 (Boomsma, 1982; 1985; Gorsuch, 1983) or 200 (Guilford, 1954) or a more desirable number of 250 (Cattell, 1978). Comrey and Lee (1992) defined a sequence of rules: 100 = poor, 200 = fair, 300 = good, 500 = very good, and 1000 and above = excellent. There are at least 5-10 observations per estimated parameter (Bentler & Chou, 1987), or 3-10 cases per variable (MacCallum, Widaman, Zhang, & Hong, 1999; Nunnally, 1967).

Sample size determination has a close relationships with the following factors (Wolf et al., 2013): 1) data collection plan and design (multiple-group design or growth modeling), 2) model complexity; 3) measurement and variable types (continuous vs. discrete measures); 4) similarity of measures (e.g., using a mixture of inverse-coding and non-inverse coding); 5) correlation among variables; 6) reliably of measures; 7) missing data; 8) construct validity and factor determinacy; 9) normality of variables; 10) estimation methods. For example, Klainin-Yobas et al. (2016) used power

analysis (MacCallum et al., 1996) to calculate an accurate sample size for their SEM. Klainin-Yobas et al. (2016) used the following parameters for calculation: 1) a preferred power value of 0.80; 2) type I error (alpha) of 0.05; 3) a goodness-of-model-fit (i.e., root mean square error of approximation; RMSEA) value of 0.05; and 4) the degrees of freedom (*df*) of proposed model (MacCallum et al., 1996). The degrees of freedom (*df*) is calculated as the difference between the total number of data points (i.e., the variances and covariances of observed questionnaire variables) and the number of parameters. Klainin-Yobas et al. (2016) included 52 questionnaire variables (i.e., 15 items of Mindfulness, 10 items of Self-Efficacy, 12 items of Support and 15 items of Well-Being) in the proposed model with a total of 116 parameters (e.g., factor loadings and regression coefficients). The value of *df* (1262) is calculated as [52 (52 + 1)/2 = 1378] minus 116. The calculated *df*, along with power, alpha and RMSEA, determined a minimum sample size of 132. This procedure can help researchers to determine and justify the sample size when SEM is used in mindfulness and contemplative research.

Challenge 4: Principal Component Model or Common Factor Model

Cole, Maxwell, Arvey, and Salas (1993) describe two systems: 1) emergent variable systems (EVS) and latent variable systems (LVS). For the EVS, meaningful group differences can be examined in terms of a linear composite of the variables. For example, group comparisons in the EVS using MANOVA can be conducted by comparing multiple *components* across intervention-control groups. In the LVS, a construct (or factor/latent variable) is hypothesized to causally impact on the observed variables. A multiple group SEM or multiple indicators multiple causes (MIMIC; Bollen, 1989; Jöreskog & Goldberger, 1975) model can be used to examine intervention-control group difference and to estimate the intervention effect. The traditional component analysis is aligned well with the EVS; and common factor model with the LVS. Similarly, Bollen (1989) defined the

cause indictor and the *effect indicator*. That is, the questionnaire variables in the EVS or the component analysis are the cause indicators. Similarly, the questionnaire variables in the LVS or the common factor analysis are the effect indicators. The cause indicators lead to the component or the linear composite; but the effect indicators are outcomes or effects of the latent factor. The non-observed factors (F_1 and F_2) have a causal influence on the observed questionnaire variables ($X_1 \ldots X_6$) in the common factor model (right panel in Figure 8). In addition, each measurement error (e.g., e_1) accounts for the left-over impacts of the latent factors on an observed variable (i.e., X_1). But the latent causal relationship is reversed in (principal) component analysis (left panel in Figure 8). In other words, each observed variable is a linear combination of latent variables (factors) in common factor analysis (Figure 8). However, each principal component (PC_1 or PC_2) is a weighted linear combination of the observed variables (Figure 8). The principal components account for the total variance (i.e., the sum of common variance and error variance); the common factor analysis accounts for the common variance (i.e., error free part of the total variance). Principal component analysis is sensitive to sample size, data quality (e.g., measurement error), and data structure (Baker et al., 2010). Theoretical framework (construct-indictor relationship). Because common factor analysis *partials out* the measurement error variance, it is more likely to produce accurate and clear factor structure than principal component analysis in situations where sample size is comparatively small, and/or data quality is low (Velicer & Jackson, 1990; Widaman, 1993).

From Component Analysis to Factor Analysis: ICA on EEG Data

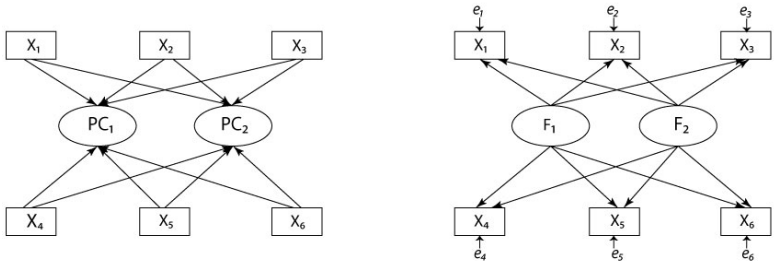
The EEG can be treated as "the output of a number of statistically independent but spatially fixed potential-generating systems that may either be spatially restricted or widely distributed" (Makeig et al., 1996, p. 146). However, Makeig et al. (1996) argued that the assumption "that the EEG is a linear mixture of exactly *N* sources, is questionable, since we do not know the effective number of statistically independent brain signals contributing to the EEG recorded from the scalp" (p. 147). Van Dam et al. (2018) pointed

out "there are clear mental processes and brain mechanisms that might facilitate insight and adaptive personal change" (p. 40). They implied the use of a proper analytical/statistical common factor model.

These *potential-generating systems* are aligned with the common factors including line and muscle noise, and/or eye movements. Event-related potentials (ERPS) may respond to "undetected and detected" noise. However, after weighted mathematical matrix training, the independent component analysis (ICA) filters noise and ERP data become more meaningful (see Figure 1 on p. 149 in Makeig et al., 1996). ICA, by nature, is a common factor analysis. That is, the "weighted matrix training" can be referred to as the *determination of common factors*. And the noise, i.e., measurement error, can be filtered, so the processed EEG data can carry more meaningful What or Where information. Makeig et al. (1996, p. 148, p. 151) claimed:

> An important problem in human electrophysiology is to determine a means of objectively identifying overlapping event-related potential subcomponents. [The … the experiment matrix] … could be low (lower dimensional or distributed) dynamics … and may represent a solution to the longstanding problem of objectively dividing evoked responses into neurobiologically meaningful, temporally overlapping subcomponents. …. By incorporating higher-order statistical information [i.e., the common factors], ICA avoids the non-uniqueness associated with decorrelating decompositions. The algorithm also appears to be useful for decomposing evoked response data into spatially distinct subcomponents, while measures of nonstationarity in the ICA source solution may be useful for observing brain state changes.

Thus, ICA-based decompositions (i.e., ERPS) can help to indicate the detected (Hit) and undetected (Lapse) patterns and signals/tasks/targets. This may help researchers to integrate intervention stimuli into contemplative research and mindfulness practices.



$PC_1 = a_{11}X_1 + a_{12}X_2 + ... + a_{1p}X_p$
$PC_2 = a_{21}X_1 + a_{22}X_2 + ... + a_{2p}X_p$
.
.
$PC_m = a_{m1}X_1 + a_{m2}X_2 + ... + a_{mp}X_p$

$X_1 = \lambda_{11}F_1 + \lambda_{12}F_2 + ... + \lambda_{1m}F_m + e_1$
$X_2 = \lambda_{21}F_1 + \lambda_{22}F_2 + ... + \lambda_{2m}F_m + e_2$
.
.
$X_p = \lambda_{p1}F_1 + \lambda_{p2}F_2 + ... + \lambda_{pm}F_m + e_p$

m: the number of components/factors; *p*: The number of variables observed and $m < p$.

Figure 8. Component analysis vs. common factor analysis: Graphical demonstration based on six-indicator model with general mathematical denotation.

LOOKING FORWARD: ACTUALITY OF LATENT VARIABLE MODELING ON TIME-SERIES MINDFULNESS DATA

Shibuya, Harada, and Kuniyoshi (2009) defined the causal effect in time-series data, i.e., "if the past information of one process *X* improves the predictability of another process *Y*, *X* is said to have a causal influence on *Y*" (p. 787). Simon (1953, p. 65) proposed "an asymmetrical relationship among the behavior of experimenters, equation coefficients and values of variables." Researchers in a lab or Mother Nature in daily settings can change the values of the "coefficient matrix of the linear structure." In other words, experimental or naturalistic impacts can be reflected by the regression coefficients of the SEM. Thus, the causal effect of the interventions can be operationalized, estimated and calculated through the simultaneous structural equations in LVF based design and modeling**.** Recently, Mplus has developed a SEM-based time-series data analysis (Dynamic Structural Equation Modeling; Asparouhov et al., 2018) to conduct factor analysis on single subject individual data ($n = 1$) and also can

run multiple subject data to detect micro-factor level relationships and inter-individual introspective differences. Due to the complexity of modeling, professional training and workshops may be needed for contemplative researchers to gradually introduce modeling approaches into the field.

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Chapter 4

LEARNING TO MODEL A MEDITATION BRAIN STATE USING EEG DATA

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ABSTRACT

Contemplative practices aim to improve a person's quality of life by adjusting their internal state. There are various methods that help achieve

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the goal of contemplative practices. While these methods have been proven effective, they affect different people in different ways and have different effects. It is necessary to develop a way to objectively measure the effect of contemplative practices and from there develop some regulations that can guide the practices. In this study, we used machine-learning methods to classify brain states using electroencephalogram (EEG) data. The experimental results have shown the feasibility of distinguishing different brain states using properly tuned machine-learning algorithms. In particular, there is potential for building brain state models for calibrating the routine of meditation. Through these studies, we believe we will be able to promote contemplative practices and help them benefit human life in contemporary society.

Keywords: contemplative practices, brain state modeling, data analysis, machine learning.

INTRODUCTION

Contemplative practices have drawn increased attention in recent years. People found that the contemplative quality of life [about particular training procedures (Oh, Butow, Mullan, & Clarke, 2008). Borrowed from traditional practices like meditation, yoga, Taichi, and Qigong, contemplative practices emphasize people's internal states and enhance functionality in intelligence, memorization, reaction, and the ability to stay healthy. In recent years, contemplative practices have been cultivated in various areas, including healthcare, sports, recreation, education, and social justice.

One example of a non-religious organization in the US that promotes contemplative practices is AMRA (American Mindfulness Research Association: https://goamra.org/), whose mission is to support empirical and conceptual efforts to: (1) establish an evidence base for the process, practice, and construct of mindfulness; (2) promote best evidence-based standards for the use of mindfulness research and its applications; and (3) facilitate discovery and professional development through grant giving.

Another example is 1440 Multiversity (https://1440.org/), a facility designed for people to "explore new approaches to how you live, love, and

work. At 1440, there is something for everyone. From meditation to writing to dance to psychology to team-building, our faculty teach valuable life skills through experiential immersion." CMind (The Center for Contemplative Mind in Society) holds an annual Association for the Contemplative Mind in Higher Education (ACMHE) conference, which presents (on their web site):

> cutting edge ways contemplative approaches to inquiry and learning can further justice and compassion on college and university campuses and beyond … Participants will explore how diverse contemplative pedagogies and practices can support transformations on multiple levels – self, classroom, organization, community – and invite creative, unconventional approaches to how we imagine and seek to address the many challenges of the 21st century.

While contemplative practices have shown advantages in enhancing effectiveness in various actual activities, there is no sufficient [illegible] methods to regulate those practices; therefore the [illegible] the practices mainly rely on self-guiding [illegible] subjective. Needless to say, there is a difference between self-report data and some way of measuring the physiological effects of contemplative practices on the brain. With the availability of a physiological measurement, there might be a way to objectively reflect the progress of the practitioner's practices.

With the advancement of human-centered computing technologies, we are able to analyze physiological data to distinguish different mind-body states with properly built models. This opens a pathway for us to establish a calibrating system to regulate contemplative practices. We have studied electroencephalogram (EEG) data collected in different brain states and obtained positive results indicating the possibility of building such a system.

In this paper, we present the case studies we have performed using EEG data downloaded from Physionet.org and EEG data we collected manually from selected subjects. Firstly, we studied the EEG data downloaded from Physionet.org that were collected from people in various brain states that are related to sleep disorders. We found that, with proper feature extraction, we were able to distinguish a normal state from states of sleep disorder.

Secondly, we collected EEG data from an experienced meditator and found that prominent differences can be detected from EEG data collected while the person was in a meditating state versus other states. Although our work is preliminary and more systematic study is necessary to verify our findings, the results indicate that our goal of building a calibrating system for contemplative practices is achievable.

BACKGROUND

Advancements in brain imaging and other techniques overturned an earlier belief that connections among brain nerve cells are fixed early in life and do not change in adulthood (Hölzel, Carmody, & Vangel, 2011). In the 18th century, scientist Luigi Galvani discovered electrical activity in living organisms (Kropotov, 2009). Thereafter, electrophysiologist Hans Berger recorded electrical act[illegible]m the human brain. T[illegible] term electro-[illegible]log[illegible] or EE[illegible]as [illegible]ned [illegible]e t[illegible]vo[illegible]e [illegible]cill[illegible]due [illegible] fl[illegible]in[illegible]e neurons [illegible]he [illegible]ma[illegible]rain, this [illegible]eco[illegible] a[illegible] invasiv[illegible] clinical and research technique that is frequently used to record brain activity.

How are EEG signals related to mental states? This is a question that has been studied for decades and scientists have found some general rules as depicted in Table 1, which lists five major EEG waves and the corresponding mental states. For example, Alpha waves are related to disengagement; Beta waves are associated with consciousness (Larsen, 2011); Theta waves are seen in motionless but alert states (Sławińska & Kasicki, 1998); Delta waves indicate sleep, and Gamma waves represent a mechanism of consciousness and fruition state in meditation (Berkovich-Ohana, 2017). The findings in these studies have been applied in areas including human-computer interaction, emotional intelligence, affective computing, and human-centered computing. As an example in the area of brain-computer interface (BCI), Yang, Song, and Xu (2010) used harmonic wavelet transform and bispectrum to extract features from EEG signals to classify left and right hand motor imagery. They reached 90% recognition accuracy in their

experiments. In the area of spectrum analysis of brain waves, Zhuang, Zhao, and Tang (2009) found a positive correlation between upper Alpha wave generation and memory formation in response to a specific music stimulus.

With the advancement in data mining, people are interested in finding features in EEG data that can help interpret and analyze the data in developing a wide range of applications in healthcare and biomedical research. Yuvaraj et al. (2014) used machine-learning algorithms to discover links between emotional states of patients and their brain activity. In this research, EEG data were collected during various emotional states from 40 Parkinson disease patients as well as healthy subjects. This research concluded that in determining emotional states, the higher frequency bands such as Alpha, Beta and Gamma played a more important role than lower frequency bands such as Delta and Theta. Another study led by Direito and his group resulted in a model that identifies the different states of the epileptic brain using topographic mapping relative to Delta, Theta, Alpha, Beta and Gamma frequency (Direito et al., 2012). The accuracy in predicting abnormal versus normal brain states using their method achieved 89%. These studies have found that the nature of the relationship of data variables associated with the modeling solution and among the influencing factors that affect the variability in the analysis and the prediction of the model. This underscores the complexity of applying mathematical models to brain activities.

On the other hand, researchers have been trying to find measurable brain effects of contemplative practices for decades. The trend in this type of research generally is moving from proving the effect of contemplative practices by using statistical models towards finding micromodels that can help interpret the effectiveness of contemplative practices. These models try to catch features in physiological signals during contemplative practices. For example, some studies examine pseudo-scientific models (e.g., those based on Eastern philosophy in history) to interpret the differences between the minds of those practicing meditation and those who do not (Lin, 2010). A more commonly adopted method in recent studies is statistics. A 20-week self-healing contemplative practice program concluded that contemplative practices are effective in reducing distress and disability (Loizzo et al.,

2010). A long-term project (5-20 years) performed by Habermann et al. (2009) investigated the effects of contemplative practices on the subjects' health. Lengacher et al. (2009) performed a 6-week mindfulness-based stress reduction program, which demonstrated significant improvements in psychological status and quality of life compared with usual care. Oh et al. (2008) used EEG technology to study the impact of Qigong on the quality of life of cancer patients and observed that the group of Qigong practitioners demonstrated better life quality (measured by psychological metrics) than the control group. Researchers at the University of Wisconsin facilitated a short program in mindfulness meditation and observed its effects on brain and immune function. They concluded that meditation may change brain and immune function in positive ways (Davidson et al., 2003).

Table 1. Brainwave frequencies

Brainwave Type	**Frequency Range**	**Mental States and Conditions**
Delta	0.1 Hz to 4 Hz	Deep, dreamless sleep, non-REM sleep, unconscious
Theta	4 Hz to 7 Hz	Intuitive, creative, recall, fantasy, imaginary, dream
Alpha	8 Hz to 12 Hz	Relaxed, but not drowsy, tranquil, conscious
Low Beta	12 Hz to 15 Hz	Relaxed yet focused, integrated
Midrange Beta	16 Hz to 20 Hz	Thinking, aware of self and surroundings
High Beta	21 Hz to 30 Hz	Alertness, agitation
Gamma	31 Hz to 40 Hz	Conscious perception

To work towards a model that can explain the differences between the mindset during contemplative practice and other states, machine-learning methods can be used to classify EEG data between different brain states. This study may have to consider feature extractions from raw EEG data. The work is further complicated by the fact that the human brain is composed of many interrelated but also anatomically separable areas, and different areas exhibit different features while the brain stays in the same state (Hfffdfffdlzel et al., 2007). Moreover, sometimes the EEG record also changes spontaneously (Fox & Raichle, 2007). We hope that statistical

classification methods can overcome the difficulties in analyzing EEG data. Fortunately, many modern machine-learning algorithms have successfully extracted features hidden in the EEG data collected from brains in different states and built useful brain state models.

Machine-learning algorithms include supervised machine-learning algorithms, such as tree bagging, boost (Sun, Zhang, & Zhang, 2007), random forest (Fraiwan, Lweesy, Khasawneh, Wenz, & Dickhaus, 2012), and support vector machine (SVM) (Guler & Beyli, 2007), as well as unsupervised machine-learning algorithms, such as k-means, and hierarchy clustering. Different algorithms exhibit different characteristics because they use different bases for classification, e.g., some are based on a decision tree algorithm while others are based on the measurement of distance between nodes. Regarding the features that help distinguish data from different states, entropy is one of the commonly used tools. Song and Lio (2010) showed that sample entropy, a method that aims to measure the uncertainty inside a sequence of data, helped analyze brain activities using EEG data.

Before investigating the effect of deep learning algorithms within EEG data, I would like to briefly introduce meditation, its principles and methodology, for it lays the foundation of contemplative practices. Meditation is a method adopted by *Chan* (in Chinese or *Zen* in Japanese and *Dhyana* in Sanskrit). As an essential part of Chan practice, meditation is the primary way to achieve a Chan state, although meditation itself is not the goal of Chan. Chan requires that practitioners be aware of their thoughts at every moment, and the purpose of this awareness is to refrain from following (and thus not be controlled by) your stream of thoughts and therefore avoid entering any emotional state. Bodhidharma is the first patriarch of Chan Buddhism in China. The primary teaching of Bodhidharma Chan is meditation with no objects, anchors, or pursuance. The meditator strives to stay away from the stream of thoughts, allowing them to rise and pass without interference. If the practitioner can maintain such a state continually, he/she will experience the emptiness of the dharma (all the forms of existence) and acquire prajna (practical wisdom). Meditation starts with sitting meditation as illustrated in Figure 1. Sitting meditation is the most

important part of Chan practice since it is the most effective way to regulate one's mind. There are various methods to regulate one's mind, e.g., focusing on counting or watching the breath, fixing attention on the body's energy center below the navel, imagining the image of a Buddha or a scene, repeating a mantra, or using a mixture of the aforementioned methods.

Why is the Chan principle important to contemplative practices? As a Chinese saying goes: Illness comes from the mind. The cause of illness is obsessions (desires) in the mind, which cause greed, anger, and ignorance, which further cause physical anomalies (Lin, 2013). People's perceptions lead to the conceptualizations of "good" and "bad," and they begin to judge between themselves and others and to pursue wisdom so that they can judge more "correctly." The Chan principle is to let go of recognition and distinction, and from there avoiding desires, judging, and all entailed sentiments. Buddhism classifies volatile sentiments such as lust, anger, and obsessing as "coarse vexations" and subtle mind activities such as perception, distinction, and thinking as "fine vexations." Chan practitioners should annihilate vexations in stages. The procedure is summarized into three steps: [illegible]ming (from [illegible]ning [illegible] (the ability to [illegible] and [illegible] (wisdom to get insight). These steps are correlated to each other and therefore have to be practiced concurrently.

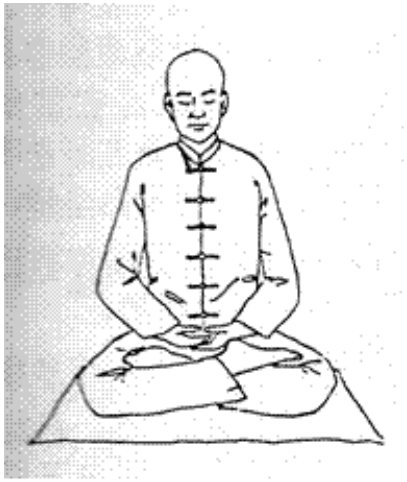


Figure 1. Meditation in lotus position.

What is the manifestation of the ultimate meditative state? The four Dhyanas (catvari-dhyanani) theory clearly depicts the procedure of meditation in a series of four stages, viz., the first Dhyana through the fourth Dhyana (http://www.bhaisajyaguru.com/buddhist-ayurveda-encylopedia/four_dhyanas_sz-chan_sz-jing-chu_catvari-dhyanani_jhana.htm), Each stage has a specific state of mind, a realm of sensory perspectives, possible interaction with spiritual beings, and methods to avoid deviations from the right path. During the Sui Dynasty of China, Patriarch Zhi Kai (智凯, AC 523-597), the first patriarch of the Tiantai School (one of the eight primary Buddhism schools), specified the detailed methods of Dharma practice for each Dhyana stage (Ma, 1995) and his methods have been used as the primary method and/or guidance for meditation ever since.

Detailed descriptions of the four Dhyanas are:

- In the First Dhyana, the Ground of Bliss Born of Separation, one's pulse stops, but does not mean one is dead. This brings a pa[illegible]r happi[illegible]s th[illegible]s u[illegible] to[illegible] t[illegible] wo[illegible]
- The Second Dhyana is called the Ground of Bliss Born of Samadhi (proper concentration and proper reception). In the Second Dhyana, one's breath stops. There is no detectible breathing in and out, but at that time, an inner breathing takes over.
- The Third Dhyana is the Ground of the Wonderful Happiness of Being Apart from Bliss. One renounces the *dhyana*-bliss as food and the happiness of the Dharma that occurs in initial samadhi. One goes beyond that kind of happiness and reaches a sense of wonderful joy. It is something that one has never known before, that is inexpressible in its subtlety, and that is inconceivable.
- The Fourth Dhyana is called the Ground of the Clear Purity of Casting Away Thought. In the Third Dhyana thoughts were stopped—held at bay—but they still had not been renounced altogether. In the heavens of the Fourth Dhyana, not only are thoughts stopped, they are done away with completely. There basically are no more cognitive considerations. This state is extremely pure, subtly wonderful, and particularly blissful.

It is easily seen that each Dhyana has specific bodily manifestations. For example, one's pulse stops in the first Dhyana and the breath stops in the second Dhyana, and one can anchor his thoughts in the third Dhyana and totally stop thoughts in the fourth Dhyana. With the advancement of modern technology, we can go well beyond these obvious bodily manifestations and give more detailed accounts of bodily manifestations in terms of modern medical terminologies, such as those used in electrocardiogram, electroencephalogram, and magnetic resonance imaging (MRI). A word of caution, though: Although we clearly define the four stages separately, in practice, one may experience one or more of the stages briefly but may not be able to retain that state deliberately without long-term training.

This is to say that the four Dhyanas represent a very high achievement level in meditation practice and may not be easily achieved for the majority of meditators. Therefore, it would be more meaningful to talk about the measurement of meditation among common meditators using comprehensive physiological and psychological metrics.

Since a contemplative practitioner should demonstrate good behavioral self-control, the effectiveness of intervention practices may be evaluated by assessing mental health indicators, including lust, anger, fear, self-control, balance in personality, etc. There are psychological indicators such as the Functional Assessment of Cancer Therapy-General (FACT-G) (Cella, Tulsky, & Gray, 1993), which consists of four subscales assessing physical well-being, social well-being, emotional well-being, and functional well-being. Another metric is the Profile of Mood States, which measures mood (McNair, Lorr, & Droppleman, 1992). In Mruk & Hartzell (2003), the therapeutic value of meditation is analyzed, and six Zen principles of psychotherapeutic value are presented: acceptance (suffering), fearlessness (courage), truth (enlightenment), compassion (toward self and others), attachment (desire), impermanence (letting go). Other work that analyzes Zen with the phenomenology of traditional psychotherapy can be found in the biological approach, learning theory, the cognitive approach, the psychodynamic perspective, and the humanistic approach.

Now we discuss mind wave analysis and how to make meditation states tangible. We begin with a case study analyzing the brain waves of people

with sleep disorders, and then move into the modeling of meditation using EEG data.

ARE SLEEP DISORDERS DETECTIBLE WITH EEG?

Sleep is a very important function for good health. However, according to the National Institute of Neurological Disorders and Stroke, about 40 million people in the United States suffer from chronic long-term sleep disorders each year and an additional 20 million people experience occasional sleep problems (Stanley & Swierzewski, 2016). Interestingly, there are more than 70 different sleep disorders, which are generally classified into one of three categories: lack of sleep (e.g., insomnia), disturbed sleep (e.g., obstructive sleep apnea, bruxism—clenching or grinding teeth during sleep), and excessive sleep (e.g., narcolepsy). Thus, identifying patterns in b[illegible]ls, based on electrical a[illegible]ity in the brain, i[illegible]t in o[illegible]ti[illegible]di[illegible]os[illegible]ti[illegible]sle[illegible]ord[illegible]

Specifically, it is important to be able to predict if a person is normal (does not have a sleep disorder), or if a person has insomnia, bruxism, or narcolepsy. Proper diagnosis will allow participants to start the correct treatment to combat their disorder.

In order to predict whether a participant is normal or abnormal (i.e., having insomnia or sleep disordered breathing), we downloaded normal, insomnia, and sleep disordered breathing files from the online database at the Physionet.org web site. To predict insomnia versus sleep disordered breathing, we used the same approach.

The following is the summary of the data we used:

- Collection of 108 polysomnographic recordings
- Data included at least 3 EEG channels (F3 or F4, C3 or C4 and O1 or O2)
- 16 Healthy Participants with no neurological disorder
- 92 pathological recordings

- 40 recordings of patients diagnosed with Nocturnal frontal lobe epilepsy, 22 affected by Rem behavior disorder, 10 with Periodic leg movements, 9 insomnia, 5 narcolepsy, 4 affected by Sleep-disordered breathing and 2 by bruxism
- Ages 14 to 82
- 66 males and 42 females

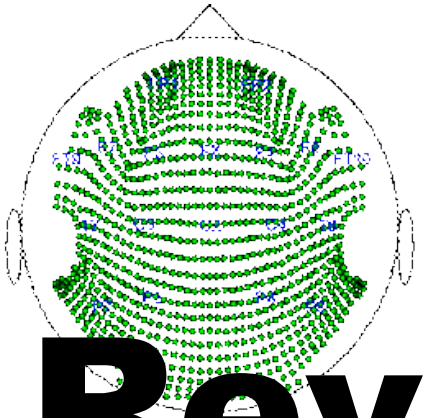


Figure 2. Electrode positions and labels.

We loaded the EEGKIT and EDF libraries and ran code to see where the electrode positions reside on a participant. The electrode positions are shown in Figure 2.

In order to predict whether or not a participant is normal versus having insomnia or sleep disordered breathing, we loaded the (nsi.csv) file in R and used a Naïve Bayes Algorithm. We then trained and tested the classification model to make the prediction. Figure 3 is a snapshot of the dataset we have assembled for machine learning.

We partitioned the dataset into train and test datasets. All columns are normalized into [0-1] range. We selectively discretized the data and/or extracted approximate entropy before the classification. Figure 4 shows the result by training the model with raw data (or without discretization).

The misclassification rates were 62.3% false positive and 10.7% false negative, respectively.

	A	B	C	D	E	F	G	H	I	J	K
1	Fp2_F4.da	Fp2_F4.t	F4_C4.dat	F4_C4.t	C4_P4.dat	C4_P4.t	P4_O2.dat	P4_O2.t	C4_A1.dat	C4_A1.t	Normal
2	-20.2237	0	69.97358	0	-57.1263	0	-8.56485	0	-25.4692	0	1
3	-14.0357	0.01	67.35085	0.01	-53.5405	0.01	-0.47127	0.01	12.13012	0.01	1
4	-3.81115	0.02	57.3517	0.02	-50.4465	0.02	-1.90558	0.02	18.09273	0.02	1
5	8.564848	0.03	61.88	0.03	-48.3156	0.03	-3.81115	0.03	-12.1301	0.03	1
6	-20.2237	0.04	64.974	0.04	-45.9387	0.04	2.848119	0.04	-10.2245	0.04	1
7	-25.2233	0.05	61.40873	0.05	-49.504	0.05	-0.47127	0.05	4.282424	0.05	1
8	-2.62273	0.06	61.40873	0.06	-49.9753	0.06	0	0.06	13.8103	0.06	1
9	-4.7537	0.07	59.97442	0.07	-50.4465	0.07	10.22454	0.07	-5.47085	0.07	1
10	-12.6219	0.08	56.63454	0.08	-48.5615	0.08	7.376424	0.08	18.80988	0.08	1
11	-16.1872	0.09	59.97442	0.09	-48.5615	0.09	-2.37685	0.09	11.65885	0.09	1
12	3.811152	0.1	60.93746	0.1	-51.1637	0.1	-4.7537	0.1	-26.9035	0.1	1
13	2.848119	0.11	55.692	0.11	-47.1272	0.11	-2.15146	0.11	-4.99958	0.11	1
14	-7.6223	0.12	59.72854	0.12	-45.2216	0.12	-0.71715	0.12	-10.7163	0.12	1
15	-9.52788	0.13	59.50315	0.13	-47.5984	0.13	-0.24588	0.13	4.528305	0.13	1
16	-16.4125	0.14	55.692	0.14	-45.9387	0.14	3.339881	0.14	12.13012	0.14	1
17	0.245881	0.15	57.1263	0.15	-45.6928	0.15	1.188424	0.15	-10.9417	0.15	1

Figure 3. Dataset for normal, insomnia & sleep-disordered breathing, sample size: 6000 rows, number of variables: 11.


```
Total Observations in Table:  2000

             | actual
   predicted |        1 | Row Total |
-------------|----------|-----------|
             |       99 |           |
             |          |           |
             |          |           |
-------------|----------|-----------|
           1 |       25 |           |
             |       77 |           |
             |    0.623 |     0.893 |
-------------|----------|-----------|
Column Total |     1324 |       676 |
             |    0.662 |     0.338 |
-------------|----------|-----------|
```

Dataset: nsi.csv
Normal: 0
Insom: 1
Train: 400
Test: 2
Non-cat
Disc-cat

Figure 4. Classification of normal, insomnia & sleep-disordered breathing without discretization or feature extraction.

```
             | actual
   predicted |         0 |         1 | Row Total |
-------------|-----------|-----------|-----------|
           0 |       575 |       102 |       677 |
             |     0.849 |     0.151 |     0.677 |
             |     0.877 |     0.297 |           |
-------------|-----------|-----------|-----------|
           1 |        81 |       242 |       323 |
             |     0.251 |     0.749 |     0.323 |
             |     0.123 |     0.703 |           |
-------------|-----------|-----------|-----------|
Column Total |       656 |       344 |      1000 |
             |     0.656 |     0.344 |           |
-------------|-----------|-----------|-----------|
```

Figure 5. Classification of normal, insomnia & sleep-disordered breathing with 10 bins discretization but no feature extraction.

Total Observations in Table: 36

	actual		
predicted	0	1	Row Total
0	24	0	24
	1.000	0.000	0.667
	0.923	0.000	
1	2	10	12
	0.167	0.833	0.333
	0.077	1.000	
Column Total	26	10	36
	0.722	0.278	

Figure 6. Classification of normal, insomnia & sleep-disordered breathing with 10 bins discretization and feature extraction.

Figure 5 shows the result by training the model with 10 bins discretization, i.e., discretizing the data into integers in range [0-9].

The misclassification rates were 12.3% false positive and 29.7% false negative, respectively.

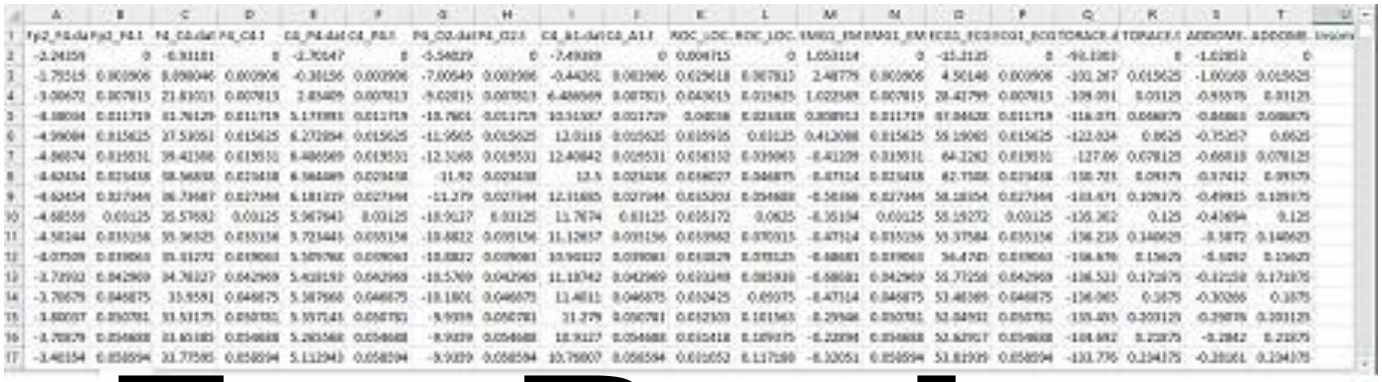
Figure 5 shows the result by training the model with 10 bins discretization and feature extraction for feature extraction, we computed approximate entropy for a sequence of 128 rows (referred to as "window size"), sliding the window 32 rows for the successive entropy value.

The misclassification rates were 7.7% false positive and 0% false negative, respectively.

In order to predict insomnia versus sleep disordered breathing, we loaded the (istest.csv, shown in Figure 7) file in R and used a Naïve Bayes Algorithm. We then trained and tested the classification model to make the prediction.

Again, we partitioned the dataset into train and test datasets. All columns were normalized into [0-1] range and discretized into the 0 or 1 values. We compared the results with or without feature extraction using the approximate entropy. Figure 8 shows the result by training the model without feature extraction.

The misclassification rates were 8.6% false positive and 3.2% false negative, respectively.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	Fp2_Fz-Cz	Fp2_F4.1	F4_Cz-Cz	F8_C4.1	C3_P4-Cz	C4_P8.1	P8_Cz-Cz	P4_O2.1	C4_p1-Cz	C3_O1.1	ROC_LOC-	ROC_LOC.	EMG1_EM	EMG1_EM	ECG1_ECG	ECG1_ECG	TORACE-A	TORACE-I	ΔDEOXYE.	ΔDEOXYE.	Index
2	-2.24159	0	-0.91181	0	-1.70147	0	-5.54029	0	-7.49389	0	0.004715	0	1.053114	0	-15.2135	0	-90.1383	0	-1.02853	0	
3	-1.75515	0.801906	8.098046	0.002906	-0.30156	0.002906	-7.00549	0.002906	-0.44261	0.002906	0.029618	0.007813	2.48779	0.002906	4.50146	0.002906	-101.267	0.015625	-1.00268	0.015625	
4	-3.00672	0.807815	21.83013	0.007813	2.85405	0.007813	-5.02815	0.007813	6.486569	0.007813	0.043613	0.015625	1.022589	0.007815	28.41799	0.007813	-109.091	0.03125	-0.95576	0.03125	
5	-6.18004	0.011719	61.76129	0.011719	5.171893	0.011719	-15.7601	0.011719	10.51507	0.011719	0.08038	0.023438	0.808913	0.011719	67.04628	0.011719	-116.071	0.046875	-0.86863	0.046875	
6	-4.99084	0.015625	27.53051	0.015625	6.272894	0.015625	-11.9905	0.015625	12.0118	0.015625	0.015915	0.01125	0.412088	0.015625	59.19065	0.015625	-122.024	0.0625	-0.75257	0.0625	
7	-4.86074	0.019531	39.41368	0.019531	6.486569	0.019531	-12.5068	0.019531	12.40842	0.019531	0.016132	0.009963	-0.41209	0.019531	64.2282	0.019531	-127.06	0.078125	-0.66818	0.078125	
8	-4.62454	0.023438	58.56938	0.023438	6.584889	0.023438	-11.92	0.023438	12.5	0.023438	0.016027	0.046875	-0.87514	0.023438	82.7588	0.023438	-130.721	0.09375	-0.57412	0.09375	
9	-4.62454	0.027344	86.73687	0.027344	6.181229	0.027344	-11.279	0.027344	12.11885	0.027344	0.015201	0.054688	-0.56166	0.027344	58.18354	0.027344	-103.671	0.109375	-0.49915	0.109375	
10	-4.68559	0.01125	35.57682	0.01125	5.967843	0.01125	-10.9127	0.01125	11.7674	0.01125	0.015172	0.0625	-0.35194	0.01125	58.19272	0.01125	-105.302	0.125	-0.41694	0.125	
11	-4.58244	0.035156	55.36325	0.035156	5.723443	0.035156	-10.6812	0.035156	11.12657	0.035156	0.015982	0.070313	-0.47514	0.035156	55.37584	0.035156	-106.235	0.140625	-0.3872	0.140625	
12	-4.07509	0.039063	55.31271	0.039063	5.589768	0.039063	-10.8812	0.039063	10.90312	0.039063	0.018829	0.078125	-0.68681	0.039063	56.4783	0.039063	-108.676	0.15625	-0.3892	0.15625	
13	-3.73932	0.042969	34.76127	0.042969	5.410153	0.042969	-10.5769	0.042969	11.18742	0.042969	0.013249	0.085938	-0.68681	0.042969	55.77258	0.042969	-108.521	0.171875	-0.32258	0.171875	
14	-3.70679	0.046875	33.9591	0.046875	5.387966	0.046875	-10.1801	0.046875	11.4011	0.046875	0.012425	0.05075	-0.47514	0.046875	53.46369	0.046875	-106.065	0.1875	-0.30266	0.1875	
15	-3.80037	0.050781	33.53175	0.050781	5.337141	0.050781	-9.9939	0.050781	11.279	0.050781	0.012303	0.101563	-0.29568	0.050781	52.84931	0.050781	-105.495	0.203125	-0.29878	0.203125	
16	-3.70879	0.054688	33.85183	0.054688	5.265568	0.054688	-9.9939	0.054688	10.9127	0.054688	0.015418	0.109375	-0.22094	0.054688	52.62917	0.054688	-104.692	0.21875	-0.2842	0.21875	
17	-3.46154	0.058594	33.77585	0.058594	5.112943	0.058594	-9.9939	0.058594	10.76807	0.058594	0.011652	0.117188	-0.32051	0.058594	53.81939	0.058594	-103.776	0.234375	-0.28161	0.234375	

Figure 7. Da[illegible] of insc[illegible]al sl[illegible] sordered [illegible] Sam[illegible] Siz[illegible]40[illegible]ow[illegible]ur o[illegible]ria[illegible]s: [illegible]

Total Observations in Table: 1500

	actual		
predicted	0	1	Row Total
0	709	23	732
	0.969	0.031	0.488
	0.914	0.032	
1	67	701	768
	0.087	0.913	0.512
	0.086	0.968	
Column Total	776	724	1500
	0.517	0.483	

Figure 8. Classification of insomnia versus sleep-disordered breathing with discretization but not feature extraction.

Total Observations in Table: 23

	actual		
predicted	0	1	Row Total
0	13	0	13
	1.000	0.000	0.5
	1.000	0.000	
		1	
	1.00	1.000	0.4
	1.00	1.000	
Column Total	13	10	23
	0.565	0.435	

Figure 9. Classification of insomnia versus sleep-disordered breathing with 10 bins discretization and feature extraction.

Figure 9 shows the result by training the model with feature extraction. The entropy was calculated in the same way as in the previous experiment.

The misclassification rates were 0% false positive and 0% false negative, respectively.

Based on the results of the above experiments, we can see that it is feasible to detect normal brain state versus abnormal states, and further detect insomnia versus sleep-disordered breathing state. The key is to view the EEG recording data as time sequences and properly extract features that can reflect the changes in the brain waves over time.

IS IT PLAUSIBLE TO CALIBRATE MEDITATION?

We collected EEG data from different brain states, including meditation. We used both experienced meditators as well as subjects with no meditation training. Data were collected using NeuroSky headsets and Emotiv headsets. An Emotiv headset has 14 channels while a NeuroSky headset has only one channel. The data collected should be representative in terms of the diversity in types of subjects and the instrumentation. Nineteen student volunteers were involved in the data collection using NeuroSky headsets, and five were involved in the data collection using Emotiv headsets. The NeuroSky data were collected from five different brain states while the Emotiv data were from three different brain states. We classified the data using algorithms including tree bagging, random forest, k-nearest neighbors, boost, and support vector machine.

We experimented with different methods to distinguish a meditation state from other states in different contexts. Firstly, we used pooled subjects with different brain states. By pooled subjects, we mean that data collected from the same subjects can be in the training data set, the testing data set and the validation data set. We put all the data together regardless of when and from whom they were collected, and then we trained our models and did the classification.

Firstly, we classified the NeuroSky data from 19 subjects. Some data were collected based on contrasting two different brain states; others were collected based on contrasting three different brain states. The NeuroSky headset has only one channel. However, the raw E data are filtered into 11 variables: attention, blink strength, meditation, Alpha low (8-9Hz), Alpha high (10-12Hz), Beta low (13-17Hz), Beta high (18-30Hz), Gamma low (31-40Hz), Gamma mid (41-50Hz), Delta (1-3Hz), and Theta (4-7Hz). Data were split into three datasets, viz., validation set, training set, and testing set. The validation set was a small set that was used to tune parameters in the model so as to achieve the smallest misclassification rate. Once the classification was complete, that group of parameters was set as the default parameters for our models in the experiments that followed. After tuning the parameters, the model was trained by the training dataset, and then used to

classify the testing dataset to see how classification results differ from the true classes.

In order to maximize the performance of each model, the corresponding parameters must be set properly, i.e., the shrinkage in every step, the interaction depth, and the number of trees in boost; the number of trees in tree bagging; the number of neighbors used to determine the neighborhood in k-nearest neighbor; the number of trees and the number of variables used in every decision tree in random forest; the coefficients in the kernel functions and the restrictions on boundary in SVM, etc. We tested the linear, polynomial, sigmoid, and radial kernels. Figure 10 shows the detailed results including the confusion matrices, parameters, and misclassification rates. We found that kernel functions had little impact on the misclassification rates of SVM, but choosing good restriction conditions for the boundary could greatly improve the classification result. We used radial kernel for SVM. It turned out that all classifiers had very low misclassification rates (< 0.042). Thus, we concluded that pooled subjects models have very good classification performance.

With the success of the classifiers using pooled subjects above, we used data from different subjects for training and testing. We also used the previous models with established parameters, but we got dramatically worse results. Figure 11 shows the results when we used data collected from six subjects to train the models and the data from the other six subjects to test the models. The misclassification rates were as high as 52.9%.

We tried to use a majority vote algorithm to decrease the misclassification rates. Figure 12 shows the voting results among tree bagging, boost, and SVM algorithms. The majority vote algorithm assigns an entry of test data to the classification made by the majority of the three algorithms. The confusion matrix in Figure 12 shows that the misclassification rate decreased to 36.7%. It is better than the result before voting but not significantly.

It is worth noting that most of the mistakes were made when classifying a subject in a meditation state, as there is only a 35% correct classification of the test data from meditation. It is reasonable since all the subjects were

not highly experienced at meditating. This indicates the difficulty in modeling the meditation state.

Parameter: tree number=5000; shrinkage=0.0019; interaction depth=5;				
Misclassification Rate = 0.001423				
Boost		Predicted States		
		watch video	meditation	reading
True	watch video	530698	633	253
	meditation	542	493966	99
	reading	368	228	465026

Parameter: tree number=5000;				
Misclassification Rate = 6.837×10^{-5}				
Tree Bagging		Predicted States		
		watch video	meditation	reading
True	watch video	494604	3	0
	meditation	0	465562	60
	reading	11	28	531545

Parameter: tree nu[illegible]; number of variables=3				
Misclassification R[illegible]				
[illegible] Forest		[illegible]		
		[illegible]		
True	[illegible]tch video	[illegible]		28
	meditation	0	494607	0
	reading	60	0	465562

Parameter: k=4				
Misclassification Rate = 8.647×10^{-5}				
K-nearest Neighbor		Predicted States		
		watch video	meditation	reading
True	watch video	531516	0	68
	meditation	61	494546	0
	reading	0	0	465622

Parameter: radial core, $\gamma = 1$, cost $= 20$, $\epsilon = 0.1$;				
Misclassification Rate = 0.042				
Support Vector Machine		Predicted States		
		watch video	meditation	reading
True	watch video	133613	3882	1249
	meditation	1258	136200	1372
	reading	1506	2517	21208

Figure 10. Classification for pooled subjects with 3 different brain states.

Misclassification Rate = 0.529
Correct Rate for True Brain State is Watch Video = 0.534
Correct Rate for True Brain State is Meditation = 0.357
Correct Rate for True Brain State is Reading = 0.901

Tree Bagging		Predicted States		
		watch video	meditation	reading
True	watch video	613	213	322
	meditation	587	382	100
	reading	230	154	426

Misclassification Rate = 0.350
Correct Rate for True Brain State is Watch Video = 0.708
Correct Rate for True Brain State is Meditation = 0.357
Correct Rate for True Brain State is Reading = 0.949

Boost		Predicted States		
		watch video	meditation	reading
True	watch video	813	335	0
	meditation	34	382	635
	reading	0	42	778

Misclassification Rate = 0.372
Correct Rate for [illegible] State is Watch Video = 0.68[illegible]
[illegible]

Support Vector [illegible]		Predicted States		
		watch video	meditation	reading
True	watch video	789	338	68
	meditation	56	379	634
	reading	2	79	739

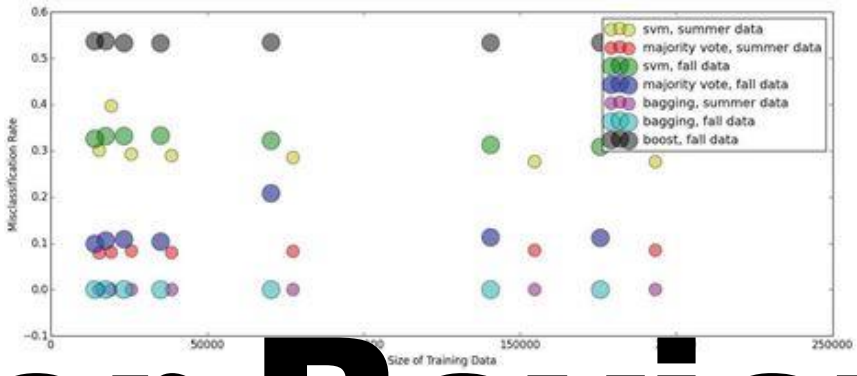
Figure 11. Tree bagging classification for different subjects.

Misclassification Rate = 0.367
Correct Rate for True Brain State is Watch Video = 0.687
Correct Rate for True Brain State is Meditation = 0.333
Correct Rate for True Brain State is Reading = 0.946

Confusion Matrix		Predicted States		
		watch video	meditation	reading
True	watch video	789	308	51
	meditation	56	356	657
	reading	2	42	776

Figure 12. Majority vote classification for different subjects.

In the following, we discuss how the training dataset size and the number of observations affected the performance of the classifier. Firstly, we observed that the misclassification rates decreased when the training dataset sizes increased. As shown in Figure 13, in general, when the data size increased five times, the misclassification rate decreased 3%. Figure 13 shows the results with pooled subjects using various classifiers.



ure Misclassification diff ng ta e.

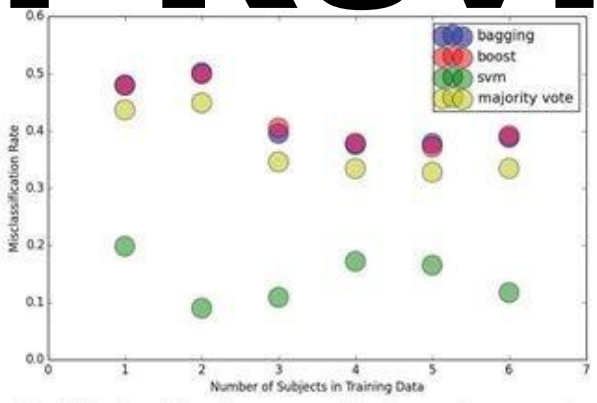


Figure 14. Misclassification rate with increasing number of subjects.

In light of the results with pooled subjects, we moved on to test the results by adding data from different subjects incrementally. Figure 14 shows the results of the experiment. While different models change their

performance differently when the number of subjects increased, they generally got lower misclassification rates. The SVM gave the best performance in this experiment. The most significant decrease was given by the majority vote, which lowered its misclassification rate by 23%.

In the following, we demonstrate how the use of feature extraction improved the performance of the classifiers. We used data collected from Emotiv headsets as well as NeuroSky headsets. As mentioned, the NeuroSky headset collects only one channel of raw data. The Emotiv headset, however, collects 14 channels of data. In our experiments, we used the data from seven well-contacted channels from the Emotiv headsets. We calculated one sample entropy value from the brain wave data collected in one minute, and then used sample entropy to do classification using tree bagging, boost, SVM, and the Gaussian Mixture models.

Before calculating sample entropy, we normalized data in each variable. 0-1 normalization is defined as follows:

$$Normalized(e_i) = (e_i - Emin) / (Emax - Emin)$$

where Emin was the minimum value of the variable and Emax the maximum value.

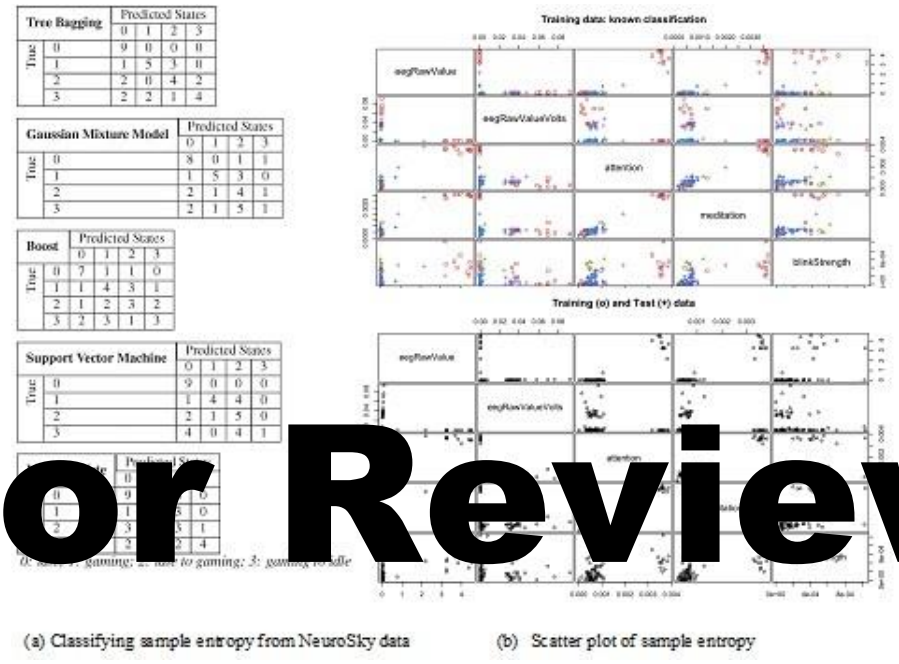
Emotiv data were collected from five different subjects. There were three different brain states in the collected data: talking, meditating, and idle, which were labeled as 1, 0, -1, respectively. The Emotiv headsets' sampling rate was 128 times per second. Therefore, every entry of sample entropy was based on 7680 (=128*60) consecutive data entries read every minute.

NeuroSky data were collected from five different subjects. There were four different brain states from which data were collected: idle, gaming, from idle to gaming, and from gaming to idle. These four states were labeled as 0, 1, 2, and 3, respectively. The NeuroSky headset's sampling rate was 512 times per second. Therefore, every entry of sample entropy was based on 30720 (=512*60) consecutive data entries read every minute.

We then split data into training and testing datasets. We used the training dataset to train models, and then plugged in the testing dataset to see what the prediction results were. The confusion matrices for the data collected

from the NeuroSky headset are in Figure 15. The misclassification rates were between 52% and 40%.

On the other hand, the confusion matrices for the data collected from the Emotiv headset are in Figure 16. All the misclassification rates were zero.



Tree Bagging		Predicted States			
		0	1	2	3
True	0	9	0	0	0
	1	1	5	3	0
	2	2	0	4	2
	3	2	2	1	4

Gaussian Mixture Model		Predicted States			
		0	1	2	3
True	0	8	0	1	1
	1	1	5	3	0
	2	2	1	4	1
	3	2	1	5	1

Boost		Predicted States			
		0	1	2	3
True	0	7	1	1	0
	1	1	4	3	1
	2	1	2	3	2
	3	2	3	1	3

Support Vector Machine		Predicted States			
		0	1	2	3
True	0	9	0	0	0
	1	1	4	4	0
	2	2	1	5	0
	3	4	0	4	1

		0			
	0	9			0
	1	1		5	0
	2	3		5	1
	3	2		2	4

0: idle; 1: gaming; 2: idle to gaming; 3: gaming to idle

(a) Classifying sample entropy from NeuroSky data (b) Scatter plot of sample entropy

Figure 15. Confusion matrices of data collected from NeuroSky headset.

We can observe the overlapping between different classes of data collected in Figure 15(b) and 16(b) and see that the classes from NeuroSky data overlap far more than the classes from Emotiv data. A reasonable interpretation is that the quality of Emotiv data is higher than that of NeuroSky data, given that the number of channels of the Emotiv data is 14 while that of NeuroSky data is one. Another factor is from the sensing technique used in the Emotiv headset and the NeuroSky headset. The NeuroSky headset uses a dry sensor to ensure easy use, while the Emotiv headset uses saline saturated pads to enhance the electrical conductivity of the sensors.

However, a bigger factor that makes the difference between the performance of the NeuroSky data and Emotiv data may be the sources of data. NeuroSky data were collected from student volunteers. As mentioned, the "meditation" state in which the data were collected may not be a true meditation state, if compared to the states that an experienced meditator achieves when performing the same activity. On the other hand, the Emotiv data included meditation data collected from experienced meditators. This underscores the importance of the depth of meditation the subjects can achieve in the study of meditation measurement.

In order to have a thorough picture of the features of the data, we further performed hierarchical clustering on sample entropies. Figure 17 displays the hierarchical clustering results presented in dendrograms. It is clear that the sample entropy calculated from data collected using Emotiv headsets is far more separable with respect to the different brain states than those using NeuroSky headsets.

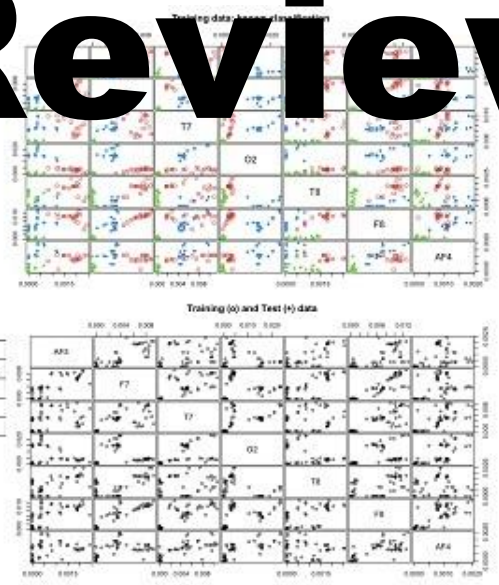
		Predicted States		
		idle	meditation	talking
True	idle	5	0	0
	meditation	5	0	0
	talking	0	0	5

Gaussian Mixture		Predicted States		
		idle	meditation	talking
True	idle	5	0	0
	meditation	0	5	0
	talking	0	0	5

Boost		Predicted States		
		idle	meditation	talking
True	idle	5	0	0
	meditation	0	5	0
	talking	0	0	5

Support Vector Machine		Predicted States		
		idle	meditation	talking
True	idle	5	0	0
	meditation	0	5	0
	talking	0	0	5

Majority Vote		Predicted States		
		idle	meditation	talking
True	idle	5	0	0
	meditation	0	5	0
	talking	0	0	5



(a) Classifying sample entropy from Emotiv data (b) Scatter plot of sample entropy

Figure 16. Confusion matrices of data collected from Emotiv headset.

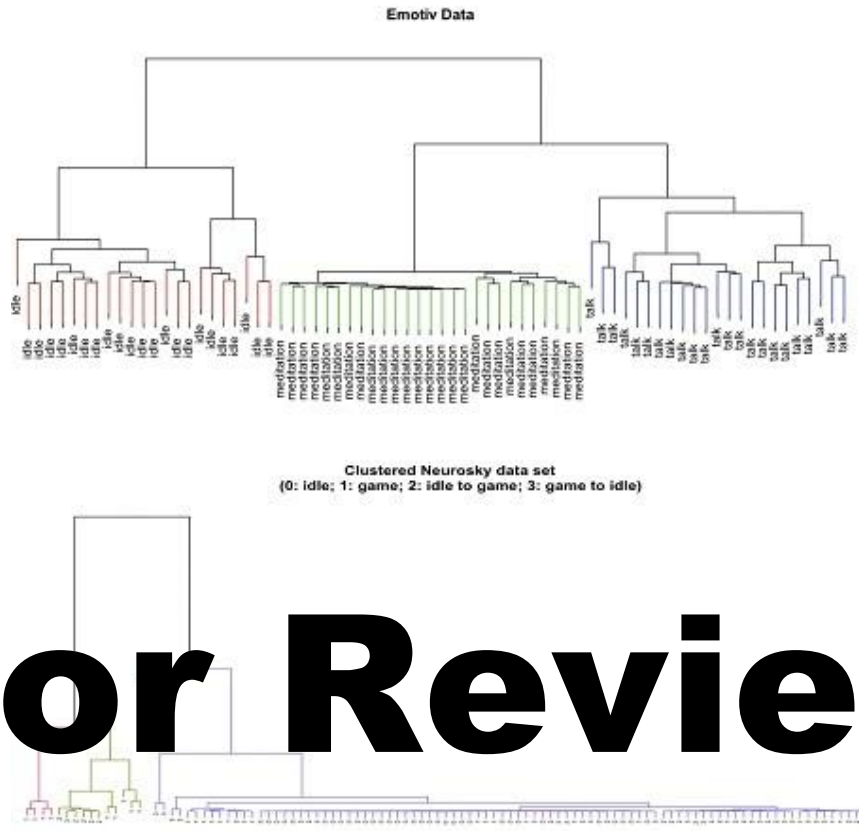


Figure 17. Hierarchical clustering for sample entropy.

DISCUSSION

The experimental study presented in this paper indicates the feasibility of developing calibrating methods for meditation. It is notable that modeling a meditation state using EEG data is a difficult task due to the following factors:

1. The quality of EEG data is susceptible to outside noises, such as gyro signals and the electrical disturbances of the instrument itself.

2. Certain states, such as meditation, are not fully defined or fully reachable, especially by inexperienced practitioners.
3. The study of extracting features for identifying certain brain states is still in a premature stage.

The experimental results we have obtained should be considered promising and finer study should lead to precise brain state models that can be used as guiding references in meditation and Chan practice. According to the progression model, such brain state models should consist of a series of models that cascade along the meditation stages. Building these models may require assistance from other physiological data, such as ECG, EMG, breath rate, and body temperature.

CONCLUSION

re very of ate ice as t ci e th the v e in mo ciety with the ance en in moder experimental technologies, the effects of meditation have become measurable. In this paper, we present a series of experimental studies that aim to build a brain state model for meditation using EEG data. Our experiments show that for different data sets, different models have different performances. Majority vote, which combines all the results together, is generally stable. We also found that with increasing number of subjects and increasing training data size, misclassification rates decrease.

Data analysis involving time series data such as EEG data calls for feature extraction methods that capture the right features reflecting the progressive streaming of the readings of EEG data. We tried to use entropy to identify the uncertainty patterns resulting from the different brain states. The performance of the classifiers is dramatically enhanced by using entropy. This is confirmed in both the study of classifying the EEG data from sleep-disorder states, and the study of classifying the EEG data from meditation states.

In summary, our results are promising and serve as a basis for further exploration of this topic.

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The student researchers working on the Brain Waves Analysis project at the University of H[illegible]owntown Grid Comp[illegible]ng Lab have c[illegible]te[illegible]e work[illegible]so[illegible]in[illegible]er[illegible]

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Chapter 5

MEASURING THE NEURAL CORRELATES OF MINDFULNESS WITH FUNCTIONAL NEAR-INFRARED SPECTROSCOPY

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ABSTRACT

Although a good deal of research has explored clinical intervention studies to evaluate the efficacy of mindfulness-based interventions, little is known about how mindfulness manifests itself in the mind and body of practitioners. In particular, real-time, objective measurements of state mindfulness would be a valuable tool for researchers to learn more about

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the mechanisms of mindfulness. In this chapter, we describe prior theoretical definitions of mindfulness, and we demonstrate the utility of the non-invasive, lightweight, and highly practical functional near-infrared spectroscopy (fNIRS) device for measuring the neural correlates of state mindfulness in the brain in ecologically valid environments.

Keywords: functional near-infrared spectroscopy, mindfulness, meditation, brain measurement, brain-computer interfaces

INTRODUCTION

Rigorous research has demonstrated that meditation and mindfulness-based practices can improve psychological and physical well-being through cognitive, behavioral, and neurological changes that reduce the physiological stress response and reshape the neural landscape. With respect to effects of meditation, an emerging literature argues that training the ability to regulate attention can improve well-being and cognitive function as well as [illegible] psychiatric disorders [illegible], [illegible] Hasenkamp, [illegible] Lang, [illegible], & Barbaro, 2012). Similarly, practice has been shown to reduce schizophrenia (Chien & Thompson, 2014), depression (Teasdale et al., 2000), anxiety (Grossman, Niemann, Schmidt, & Walach, 2004), ADHD (Smalley et al., 2009), post-traumatic stress (Possemato et al., 2016), as well as improve emotional regulation (Lutz et al., 2014), memory (Davidson et al., 2003; Grossman, Ludger, Schmidt, & Walach, 2004; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010), self-regulation (Tang et al., 2014), and self-awareness (Holzel et al., 2011). Mindfulness-based stress reduction (MBSR) and mindfulness-meditation have also been shown to improve a number of chronic health problems such as asthma, diabetes, high blood pressure, chronic pain and underlying neural dysregulation that affects the hypothalamic pituitary axis and cortisol output (Bergen-Cico, Possemato, & Pigeon, 2014; Davidson et al., 2003; Grossman et al., 2004; Loucks, Britton, Howe, Eaton, & Buka, 2015; Parswani, Mahendra, & Iyengar, 2013; Paul-Labrador et al., 2006). Beyond the context of meditation, the cultivation of mindfulness can be seen more generally as a compassionate open attitude

with which to face situations that involves a focus on the current experience (Bishop et al., 2004).

As outlined above, a good deal of research has explored clinical intervention studies to evaluate the efficacy of mindfulness-based interventions. We have seen repeatedly that mindfulness results in a number of positive outcomes. Although much is known about *why* we should engage in mindfulness, far less is known about *what* mindfulness is and *how* mindfulness actually works (Bishop et al., 2004; Shapiro, Carlson, Astin, & Freedman, 2006). Kabat-Zinn operationalized mindfulness as non-judgmentally paying attention, on purpose, in the present moment (Kabat-Zinn, 2003). This was further expanded upon by Bishop et al. (2004) and Shapiro et al. (2006), and ultimately helped to strengthen and inform many investigations into mindfulness in the past decade. This includes the creation of several survey instruments that have been used to measure both trait (Baer et al., 2008; Medvedev, Krageloh, Narayanan, & Siegert, 2017) and state (Galia & Bernstein, 2017) facets of mindfulness. However, mindfulness is a complex construct that is difficult to measure (Grossman, 2008), and self-report surveys are known to have various problems and limitations including changing experiences through the task, the idea of applying a mindfulness session to measure how mindful you are is counter to the practice of mindfulness. To compensate for the shortcomings of survey measures, researchers have made progress in objectively measuring the neural correlates of mindfulness in real-time using EEG and functional magnetic resonance imaging (fMRI; Boccia, Piccardi, & Guariglia, 2015; Lutz et al., 2014; Posner & Tang, 2013), but both devices have limitations with regard to their efficacy for measuring mindfulness. EEG takes a long time to set-up, has a noisy signal, and has low spatial resolution, making it difficult to measure specific regions of the brain recruited during mindfulness (Parasuraman & Rizzo, 2008). Although fMRI provides high quality spatial information about the functional human brain (Dimoka, 2012; Lutz et al., 2014), the device is limited for mindfulness-based research as participants are constrained inside a loud magnet with their movements heavily restricted, which can seriously inhibit one's ability to reach a mindful state while in the magnet.

In this chapter we build on the definition of mindfulness from Kabat-Zinn (2003) and expanded upon by Bishop (Bishop et al., 2004), and then Shapiro (Shapiro et al., 2006), and we demonstrate the utility of the non-invasive, lightweight, and highly practical functional near-infrared spectroscopy (fNIRS) device for measuring the neural correlates of state mindfulness in the brain. As detailed below, the fNIRS device provides researchers with a tool to complement and build upon prior fMRI research, by allowing for similar spatially accurate measurements of blood flow in the brain in more comfortable, quiet, and less restrictive settings (Chance, Zhuang, Chu, Alter, & Lipton, 1993; Hirshfield et al., 2011; Izzetoglu, Bunce, Onaral, Pourrezaei, & Chance, 2004; Solovey, Afergan, Peck, Hincks, & Jacob, 2015; Solovey et al., 2009). An example of an 8-channel fNIRS device is shown in Figure 1.

Figure 1. The ISS Oxyplex is an 8-channel non-invasive fNIRS device.

The rest of this chapter proceeds as follows: First, we describe Bishop and Shapiro's prior theoretical model on the construct of mindfulness, and

we note elements of the model that can be measured using cognitive and physiological sensors. We then describe the fNIRS device in detail and we highlight prior fNIRS research (both our own and from other researchers in the field) that dovetails with the model of mindfulness. Lastly, we describe a research agenda for future studies using fNIRS to directly measure and help empirically validate models of mindfulness.

AN OPERATIONAL MODEL OF MINDFULNESS

In order to define and measure mindfulness, it is important to distinguish between one's general tendency to be mindful (a trait) and an individual's degree of mindfulness at any particular point in time (a state; Medvedev et al., 2017). Our focus in this chapter is on measuring the state of mindfulness, but we do touch briefly upon trait measures of mindfulness as well. We adopt Kabat-Zinn's definition of mindfulness as "paying attention in a particular manner, on purpose, in the present moment, and non-judgmentally" (Kabat-Zinn, 2003), which we use to outline the theoretical definition of mindfulness proposed by Bishop (Bishop et al., 2004), and added to by Shapiro (Shapiro et al., 2006), whereby experiencing the state of mindfulness arises through the simultaneous cultivation of the three axioms of 1) attitude, 2) intention, and 3) attention. Attitude refers to the personal qualities that one brings to the process of attention, as one can approach attention with a cold, critical quality, or with an affectionate, compassionate, and curious quality (Shapiro et al., 2006). Intention includes the "on purpose" element in Kabat-Zinn's definition. Intention involves having a personal vision, which is often dynamic and evolving, that includes a self-understanding of why one is practicing mindfulness. Attention includes "paying attention" to the moment-by-moment experience of mindfulness, and it is an essential element of mindfulness. Figure 2 provides our adaptation of Shapiro's model of mindfulness.

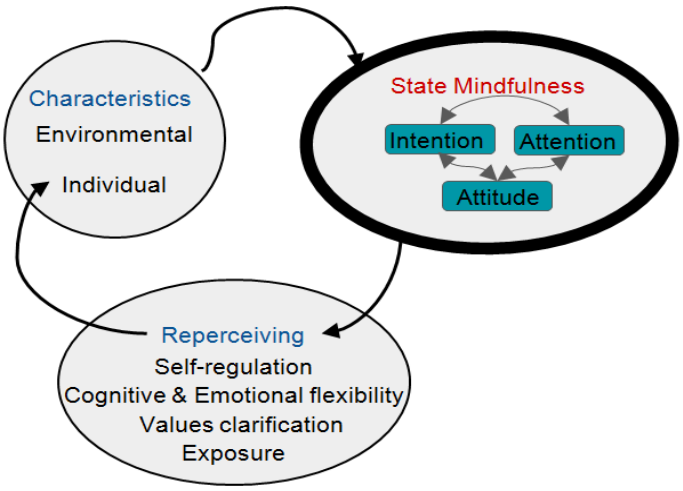

Figure 2. A model of state mindfulness (Shapiro et al., 2006), with environmental and individual characteristics added.

Shapiro calls the result of the mindfulness process "reperceiving," which is a gradual shift in perspective that results from mindfulness. Reperceiving helps foster the positive outcomes produced by mindfulness and includes self-regulation, cognitive and emotional flexibility, values clarification, and exposure (Shapiro et al., 2006). Self-regulation refers to one's ability to self-regulate their emotional and behavioral states. Related to self-regulation, cognitive and emotional flexibility refers to one's ability to have flexibility when responding to one's environment, rather than following more rigid patterns of reactivity, where the environment has more control over the individual than the individual has over his or her environment. Values clarification refers to one's ability to re-evaluate what one values, rather than allowing one's culture and society to define those values for us. Exposure refers to one's ability over time to experience even very strong (often negative) emotions with greater objectivity and less reactivity (Shapiro et al., 2006). For example, repeated exposure to an event that produces high levels of anxiety can result in less feelings of anxiety and less relying on avoidance behaviors when encountering environmental scenarios that traditionally cause significant emotional reactions.

We have also added two moderating factors onto Shapiro's model of mindfulness, which involve individual trait characteristics and environmental characteristics, as both are likely to affect mindfulness (Medvedev et al., 2017). A person's ability to be mindful could be greatly affected by environmental characteristics (i.e., environments that are loud and uncomfortable could inhibit one's ability to be mindful). Also, trait characteristics such as age, gender, and one's general ability to be mindful are individual characteristics that may play a role one's experience of state mindfulness. Figure 2 provides our adaptation of Shapiro's model of mindfulness with these additional trait and environmental considerations added.

THE UTILITY OF FNIRS FOR MEASURING MINDFULNESS

Now that we have [illegible]ical model in which to [illegible]und meditation [illegible]ndfu[illegible] researc[illegible] w[illegible]esc[illegible]as[illegible]cts[illegible] t[illegible]mo[illegible]t a[illegible]ely [illegible]be[illegible]easurable [illegible]h n[illegible]inv[illegible]ve fNIRS [illegible]nolo[illegible]. I[illegible]is sectio[illegible] we first provide an overview of the fNIRS device, and then we outline the neural and physiological correlates of mindfulness that are measurable with fNIRS.

Recent advancements in biotechnology have resulted in development of the lightweight, portable, non-invasive fNIRS brain measurement device, which is well positioned to measure the neural correlates of mindfulness without interfering with the process of meditation via clunky and uncomfortable sensors. We posit that fNIRS can be used to empirically validate theoretical models of mindfulness and to enable the real-time measurement of the construct. The fNIRS is a relatively new device that can provide spatially accurate brain activity information like the fMRI (about 1cm lower than that achieved by fMRI; Gratton & Fabiani, 2009; Medvedev, 2013), but it can do so in ecologically valid experimental environments. The fNIRS holds great potential for non-invasive brain measurement in naturalistic settings due to its practical nature, ease of set-up, robustness to motion artifacts, and high spatial resolution (Chance et al., 1993; Hirshfield

et al., 2011; Izzetoglu et al., 2004). The basis of fNIRS is the use of near-infrared light, which can penetrate through scalp and skull to reach the cortex. Optical fibers are placed on the surface of the head for illumination while detection fibers measure light, which reflects back (Figure 3).

Particularly, concentration changes in oxy- and deoxy- hemoglobin can be distinguished (Chance et al., 1993). The fNIRS has higher spatial resolution than EEG, making it possible to localize specific functional brain regions of activation, as could be done with the constrictive fMRI device (Parasuraman & Rizzo, 2008). However, a significant limitation of both fNIRS and EEG is that, unlike fMRI, they are unable to measure deep brain structures like the amygdala, which is particularly important in measurement of raw emotions. Fortunately, the outer region of the brain is also filled with rich information relating to attention and emotion regulation. Since the fNIRS was only recently introduced (in the mid-1990s) there has been a dramatic increase in fNIRS research for brain measurement in recent years with the number of fNIRS-related publications doubling every 3.5 years over the last two years (B[illegible], E[illegible]ll, F[illegible]i & T[illegible]ga, 2014). For [illegible]view of the history of fNIRS, see [illegible] & C[illegible] (2[illegible]2) and [illegible]as[illegible], 14). The large increase in research is b[illegible] compounded by advancements in fNIRS technology. For example, research on the Fast Optical Signal (FOS) has found that it is possible for frequency-domain fNIRS devices to measure the miniscule changes in membrane potentials caused by neural activity, which could provide fNIRS with the fast temporal resolution of EEG (Gratton & Fabiani, 2009), which measures the electrical potentials caused by neurons firing in the brain with millisecond level precision. Additionally, several companies have recently introduced wireless fNIRS devices, making the device even better suited for use in ecologically valid settings (Ferrari & Quaresima, 2012). As the fNIRS research community continues to improve the device and its accompanying analysis techniques, we expect the highly practical tool to become increasingly useful in research labs and beyond for measuring neural correlates of mindfulness.

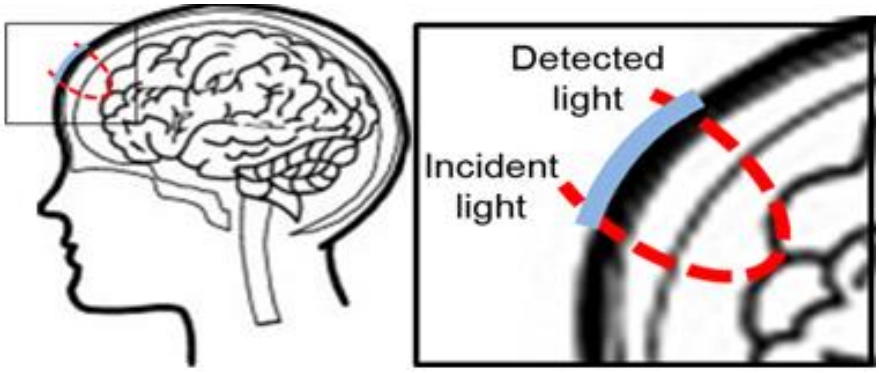

Figure 3. Light in the near infrared range is pulsed into the brain cortex and the reflected light is determined by means of optical detectors.

State Mindfulness: Measuring Mindfulness with fNIRS

The goal of this chapter is to demonstrate the utility of fNIRS for objectively measuring the state of mindfulness as it relates to mindfulness. As illustrated in figure 1, state mindfulness is considered to be different (i.e., level of expertise in mindfulness, gender, longitudinal exposition) and environmental characteristics (i.e., quiet versus noisy environment, surrounded by others or alone). Once an individual is experiencing mindfulness, the three axioms of attitude, intention, and attention are all intertwined, contributing to one's changing psychological state during mindfulness (for example, states such as curiosity, empathy, joy, love, and self-perception are among the complex states found throughout mindfulness research). These psychological states are likely to be very complex, but we can gain a better understanding by breaking them down into their *neural correlates.* The neuroscience literature has linked many cognitive processes to specific brain areas, which are called neural correlates (Camerer, Lowenstein, & Prelec, 2004; Crockett, Clark, Tabibnia, Lieberman, & Robbins, 2008; Dimoka, 2012). While it is often assumed that there is a simple one-to-one mapping between processes and brain areas, in reality it is more complex with a many-to-many mapping between brain activations and human processes (Poldrack,

2006). Thus, a complex psychological construct would typically map onto and activate multiple brain regions.

In this section, we look at these intertwined elements of attitude, intention, and attention, and we describe research that has been conducted using fNIRS to measure neural correlates of these three elements.

Attitude, Intention and fNIRS

The attitude that one brings to mindfulness and the intention that one has for a given mindfulness session are interwoven and overlapping constructs. As Shapiro noted, intention involves having a personal vision, which is often dynamic and evolving, that includes a self-understanding of why one is practicing mindfulness. Obviously, one's attitude during mindfulness cannot be fully disentangled from his or her intentions during that session. In this section, we describe fNIRS studies that have measured various elements of attitude and intent as they relate to the practice of mindfulness.

The term attitude is used by Shapiro to refer to the emotional qualities that one brings to the practice. Attention refers to mindfulness as a practice with attention with a curious quality, with an accurate, compassionate and curious quality. This usage is in line with the large amount of prior research on the construct of attitudes, which has played an important role in social psychology for decades (Crano & Prislin, 2008). There are various psychological factors involved in attitude formation, and there are overlapping theoretical models that have been proposed to define attitude. Most models agree that cognition and affect are two central components of attitudes (Crano & Prislin, 2008). The cognitive basis for an attitude has been defined as beliefs, judgments and thoughts one has while the affective basis for an attitude involves emotions (McGuire, 1969) and these two components interact to directly affect one's information processing in different ways. fNIRS has been successfully used to measure people's emotional state using a range of experimental paradigms (Bandara, Velipisalar, Bratt, & Hirshfield, 2018; Doi, Nishitani, & Shinohara, 2013). A frequently used metric for quantifying emotions is by mapping them to points in a two-dimensional space of affective valence and arousal. Valence

represents overall pleasantness of an emotional experience and arousal represents the intensity level of an emotion, ranging from calm to excited. In particular, recent work in our lab demonstrated the capability of classifying and distinguishing between affective states on the valence and arousal dimensions using a 52-channel fNIRS device. Our results showed that the dorsolateral prefrontal cortex (DLPFC) was recruited during changes in emotional valence and arousal. This is in line with prior research on the brain, which has found the DLPFC to be activated during emotion regulation (Bandara et al., 2018). This can be particularly useful in mindfulness training for individuals who aim to self-regulate negative emotions such as stress or fear. In another fNIRS experiment we found DLPFC activation accompanied by activation in Broca's region while participants experienced highly stressful stimuli (Hirshfield et al., 2014). Activation in Broca's area has been tied to highly stressful and fearful scenarios such as those experienced by individuals with post-traumatic stress disorder (PTSD; Hull, 2002). We posit that measuring the DLPFC and Broca's area during mindfulness sessions can shed light on the emotional component of one's experience of mindfulness. Moreover, when we consider both the attitude and intention that one brings to a mindfulness session, we open the door to measuring a range of psychological states that one may experience during mindfulness. These states could involve elements of curiosity, self-reflection, or feelings of love and empathy, to name a few. For example, Leung and colleagues found that expert meditators that engaged in the loving-kindness Theravada tradition had more gray matter volume in their right angular gyrus than novice meditators. Since the right angular gyrus is related to cognitive empathy, the authors suggest that the loving-kindness meditation caused this increase in gray matter (Leung et al., 2013). See Appendix B in Dimoka (2012) for a review of fMRI studies looking at the neural correlates for several of these complex psychological states. Many of these complex psychological states will engage brain regions in participants' Theory of Mind (ToM) brain regions. ToM is a research paradigm concerned with understanding how individuals attribute beliefs, desires, and intentions to themselves and to others. The brain regions most typically implicated in ToM reasoning

include regions in the medial prefrontal cortex (MPFC), anterior cingulate cortex (ACC), and the bilateral temporoparietal junction (TPJ; Mahya, Mosesa, & Pfeifera, 2014). fNIRS has been used to measure ToM brain regions (Bowman, 2015; Hirshfield, Bobko, Barelka, & Sommer, 2018).

Attention and fNIRS

Attention is a complex construct, involved in how we attend to and actively process specific information in our environment in the presence of external stimuli. Goal-driven attention is referred to as top-down or *endogenous attention*, whereas stimulus-driven attention is referred to as bottom-up or *exogenous attention*, being driven by external events in the environment (Jonides, 1981; Posner, Snyder, & Davidson, 1980). Allocating attention over short time periods can be referred to as *phasic orienting*, while maintaining attention over longer time periods is referred to as sustained attention, or *vigilance* (MacLean et al., 2009). One initial goal of mindfulness training is to increase one's ability to control his or her attention over [illegible] (increased endogenous attention) and studies have shown that mindfulness does indeed increase sustained attention [illegible] (Jha, Krompinger, & Baime, 2007; Tang, Hölzel, & Posner, 2015). With increased expertise, mindfulness has been shown to increase one's ability to maximize both endogenous and exogenous attention. For example, a novice meditator may focus sustained endogenous attention on his or her breath, whereas an expert meditator is able to focus attention more broadly, with his or her attention receptive to the whole field of awareness, remaining in an "open state so that it can be directed to currently experienced sensations, thoughts, emotions, and memories" (Jha et al., 2007). *The Task-Positive Network* (TPN) is a network of brain regions found to be active during endogenous attention-demanding tasks, and the *Default Mode Network* (DMN) is a network of interconnected regions shown to be active when a person is not focused on the outside world and the brain is at wakeful rest. The DMN is shown to be active when one's mind is wandering, which very often involves thinking about oneself or others, which is associated with a large 'Theory of Mind' body of literature (Schilbach et al., 2006). As mentioned above, ToM is concerned with the way that people think about

other people's mental states (e.g., their thoughts, feelings, and intentions). Activation of the TPN inhibits the DMN and vice versa.

During TPN states, we have increased conscious attention towards the external environment through our five senses, towards our internal bodily states, and to the willful execution of physical and mental action. However, the type of stimulus will impact the relationship between TPN and DMN activation and in disease states like PTSD, there is often dysregulation in the coupling between TPN and DMN activation. Mindfulness-based practices will also change the relationship between TPN and DMN activation; and should regulate the coupling between the two for people with PTSD following sustained and regular practice. It is also noteworthy that during mindfulness-based practices there are changes in the activation of TPN and DMN. For example during mindfulness-based meditation the TPN should be activated while the DMN would be deactivated; however, during the body scan there may be fluctuation between the TPN and DMN (R. Lee, 2015; Lin et al., 2017).

The fNIRS device holds great potential for the measurement of the ... states described above. For example, the use of fNIRS to measure activation in the TPN, particularly the LPFC which is responsible for attentional direction, decision-making, working memory and cognitive control, should provide objective measures of neural changes from mindfulness-based meditation and contemplative practices. Mindfulness-based practice improves working memory, attentional direction, emotional regulation, and executive function (EF). The TPN is engaged when we are in the present moment. Therefore, LPFC activity should increase in response to mindfulness practices. fNIRS can evaluate the association between the PFC activation and EF (Moriguchi & Hiraki, 2013) as well as emotion processing (Doi et al., 2013). These are viable measures of cognitive processes for working memory and attention (Snyder, 2013) which are often impacted by stress, trauma, and depression. Cognitive and emotional responses measured using fNIRS and galvanic skin response (GSR) sensors found fNIRS and GSR can be used to measure changes in cognitive and emotional responses associated with EF, working memory and conflict monitoring. In one experiment, we used the 8-channel ISS Oxyplex (Figure

2) to measure the level of workload on a myriad of executive functions while participants worked with simplistic tasks such as the *n-back task* (a simple working memory task from the cognitive psychology literature used to engage specific brain regions; it involves remembering a sequence of numbers), along with more complex tasks that involved searching the internet for specific trivia content and working with a driving simulator (Hirshfield et al., 2011). Research has found that depressed individuals have hypoactivation of the DLPFC (an area strongly tied to emotion), and the measurement of activity in this region using fNIRS could be used to explore cognitive processes that might represent changes in depression and depressive relapse. Furthermore, although much of the DMN is located deep within the brain where the fNIRS cannot measure, cortical regions of the ToM network have been measured with fNIRS (Durantin, Dehais, & Delorme, 2015), and in scenarios when the mind-wandering is in the context of social cognition (thinking of oneself and others), the fNIRS is well positioned to measure ToM brain regions such as the temporoparietal junction and the medial prefrontal cortex (Bowman, 2015).

PROPOSING A 3-DIMENSIONAL APPROACH TO MEASURE MINDFULNESS WITH FNIRS

In Hincks et al. (2017), we argued for the importance of describing psychological states through the lens of neuroscience when building brain-computer interface (BCI) applications. BCI applications are an umbrella term for applications that involve measurement of the human brain and adaptations in response those measurements. Unless there is a strong coupling between the psychological state under investigation and the underlying activity of the brain as portrayed by the physiological sensor, then system adaptations will behave randomly, and our brain measurement is unlikely to be effective. The purpose of this section is to understand aspects of mindfulness in terms of three ‘dimensions’, where a dimension refers to a construct that we are trying to measure that is not directly

observable. For example, the construct of intelligence and motivation are used to explain phenomena in psychology, but neither is directly observable. Rather, we find ways to operationalize those constructs and measure their correlates. We also propose ways to detect mindfulness using physiological sensors (with a focus on fNIRS in particular). The three dimensions are:

1) Entropy (Random vs Stable)
2) Attentional Direction (Top-down vs Bottom-up)
3) Predominant network (TPN vs DMN)

We believe that although these three dimensions are not directly measurable (i.e., there is not one specific area in the brain that fires when one has high vs. low 'entropy'), that we can indeed identify measurable neural correlates that relate to each of the dimensions above. For a state to be detectable on the basis of physiological sensors, the two poles of the dimension (e.g., random vs. stable) should differ as much as possible in terms of global energy consumption. Alternatively, the differential energy consumption between the states should be spatially localized at a probe so that spatially well-resolved changes in metabolic activity indicate the state on the basis of probe location. Finally, for the state to be useful in BCI, the dimension should suggest information about the user that a User Interface designer can understand and map onto system adaptations.

The ability to measure the neural correlates of each of the three dimensions listed above depends in part on a Bayesian conceptualization of mind and brain (Friston, 2010). The Bayesian Brain Hypothesis postulates that a fundamental goal of the brain is to efficiently predict and suppress external sensory signals using existing internal representations, and to continuously update these models to minimize future error (Friston, 2010). The brain can be regarded as a hierarchical prediction and error correction machine (Clark, 2013), in which data flows bidirectionally, with prediction flowing from the top-down and the residual difference between the prediction and data (error), modifying the internal bookkeeping used to make those predictions from the bottom-up. Computation in the brain (and energy consumption) should therefore be maximized when input from the

environment has enough predictable data to warrant interest from some top-down network, but offers enough new information so that those networks reorganize themselves into machinery that better understands reality in the future. When the input is novel relative to the brain and interesting, more prediction error flows up the Bayesian hierarchy, thus stimulating a cascade of data to flow up the information processing hierarchy (Carhart-Harris et al., 2014).

This condition of engaged surprise is known as *entropy* in cognitive neuroscience, and we believe it is the first and most obvious attribute to describe any cognitive state, especially in the context of physiological sensors. Extreme entropy states include the continuous experience of being an infant (since infants lack the explanatory tools to suppress external stimuli), schizophrenic psychosis (which may be seen as impoverished top-down reality testing), psychedelic states (which interact with neuroreceptors in hierarchically central filters in the DMN) and creativity (where existing models undergo reorganization by original material) (Carhart-Harris et al., 2014). As [illegible] scuss the basic phenom[illegible] int[illegible] e[illegible] enc[illegible] ve[illegible] ad[illegible] e[illegible] o[illegible] eir own t[illegible] s t[illegible] ss[illegible] [illegible] ation[illegible] p be[illegible] een[illegible] y, its realization on neural substrate as increased and random computation, and the phenomenological richness of conscious life.

The criteria listed above for properly measuring the neural correlates of mental states suggests that *Entropy* (Random vs. Stable) is plausibly detectable because it is a barometer for the amount of computation and energy consumption in the brain. With the same criteria, the *Predominant Network (*TPN vs. DMN) dimension could be detected in practice in the event that these networks are spatially distributed; indeed, most regions in the brain appear to have a bias in one direction or the other (Glasser, Coalson, & Robinson, 2016). It is worth noting how these two dimensions relate to each other. The brain's capacity to model and react to some exogenous signal likely determines whether the brain will enter a TPN state. The entropic framework thus predicts that when the informational bandwidth established between the brain and environment is low, the user will retreat into a more endogenous (DMN) mode of being.

In Hincks et al. (2017), we found support for the hypothesis that both fNIRS and EEG measure user entropy and the predominant network of the brain. In that study, the classification accuracy of a machine learning algorithm calibrated to detect differences between task-positive and resting states on the basis of fNIRS and EEG data decayed significantly in the second session of the experiment as compared to the first session, whereas the same measure remained consistent when the machine learning algorithm classified differences between two conditions of the task. This finding supports the hypothesis that fNIRS and EEG are highly sensitive to the amount of entropy in the user's brain since the task (which amounts to new inputs to the user and novel demands for output) produces a mental state that is differentiable from the resting state in the first session, but when the user's expectations and capabilities are better calibrated in the second session of the experiment, the user's state ceases to be as differentiable from the resting state, which, as described above, is the default state visited by the brain when the informational bandwidth between task and user is too low.

In this [illegible] architecture, a third dimension (Attentional Directedness) may describe the relative distribution of [illegible] networks [illegible] the top-down and the [illegible] bottom-up. A mixture of top-down and bottom-up processing is likely required for the signal to absorb human attention. But it may nonetheless be possible to meaningfully separate states that are more bottom-up from those that are top-down. This third dimension–whether the state of the user's brain is set from the top-down using neural resources that (depending on how free will is conceived) generate or are generated by user agency versus the state being determined by a bottom-up source from the environment or a spontaneous endogenous process outside of user control—is closely related to the concept of mindfulness. In fact, one might recursively define mindfulness as top-down processing that only occurs in brains that have properly encoded some concept of mindfulness.

Cognitive neuroscience in general is difficult because it relies on the capacity to experimentally induce and track the states that a given subject is visiting. Dimensions like Entropy and Predominant Network can be probabilistically induced by manipulating the information burden of the

environment. But it seems harder to manipulate the extent to which a subject is willfully exerting top-down mindfulness processes without simultaneously manipulating their degree of entropy and predominant network. For this reason, we recommend considering experimental methodologies that may seem pseudoscientific to conventionally trained scientists in order to parse subject mindfulness. Specifically, the subject under investigation could contribute information to the experiment regarding their moment-to-moment experience, which informs how concurrent brain imaging data should be labeled.

In Hincks, Afergan, & Jacob (2016), we explored an alternative approach to interpreting ongoing fNIRS data. In that study, the author performed a total of fourteen 4-backs and 0-backs. In an n-back, participants repeat the number heard n iterations ago. The author reports that his solution to solving the 4-back entailed sub-vocally rehearsing a 4-item mental buffer, continuously shuffling the order of elements as a new item was heard. The author had practiced n-backs before, and had set n to be so difficult that he would not be able to solve it unless his attention was exclusively executive. He describes strategy. [illegible] free- [illegible] approaches [illegible] the session, his mental state was therefore high entropy (since he had practiced the task), task-positive (as it required instantiating an input-output loop with the environment), and top-down (since the strategy required willful control of mental state). In the session reported in the paper, the author reports successfully implementing the mental strategy in all but one case when mind wandering prevented task focus. His introspected state therefore shifted to a high entropy, bottom-up DMN mode. As is evident from the figure in the paper, the fNIRS data pertaining to 4-backs and 0-backs are clearly different in all but the trial in which the author reported distraction.

FUTURE WORK

In this chapter we built on the definition of mindfulness from Kabat-Zinn (2003) and expanded upon by Bishop (2004), and then Shapiro et al. (2006), and we demonstrated the utility of the non-invasive, lightweight, and

highly practical functional near-infrared spectroscopy (fNIRS) device for measuring the neural correlates of state mindfulness in the brain. Future research is needed to determine whether engagement in mindfulness-based practices is associated with a greater shift towards activation in the TPN and thus away from the DMN. People with higher levels of trait mindfulness should have significantly more TPN activation than people with low levels of trait mindfulness. Future research should evaluate the convergence of fNIRS measures of the TPN's prefrontal cortex and EF engagement in conjunction with self-report cognitive measures for EF and attention. Using fNIRS to measure elements of mindfulness in real time also opens the door to adaptive systems, whereby a mindfulness-based training program may adapt its feedback in real-time based on the individual's current psychophysiological measures of attitude, intention, or attention. Real time measurement places more technical constraints on the problem. The constraint is typically not in computer performance, but rather in needing to make a decision based on a single trial or even during a single trial using streaming data before all the data has been received. We have paired fNIRS data with machine learning techniques to classify in real time mental states ranging from mental workload (Ayaz, Onaral, et al., 2012), to emotional states (Bandara et al., 2018), to types of multitasking (Solovey et al., 2012), and the prospect of transitioning this machine learning work to the mindfulness domain is promising.

Building on the premise of real-time systems, one area that we consider to be particularly promising is using virtual reality (VR) to create highly controlled, immersive environments to facilitate mindfulness practice. Virtual Reality is a "presence inducing media" (Riva et al., 2015). There are multiple related definitions of presence (K. Lee, 2004), but the simplest way to think about the concept is a sense of being there, where "there" is the virtual environment. That idealized virtual environment can be used to both isolate novice practitioners from overly stimulating environments (Kosunen, Salminen, Järvelä, Ruonala, & Ravaja, 2016) as well as create an idealized environment that elicits its own positive emotional experience. The idea of a special place for contemplative practices is not new; often people have a room or vacation spot or type of environment they seek out for a sense of

peace; natural environments often induce a sense of peace even before the meditation begins (Lymeus, Lundgren, & Hartig, 2017).

When we couple well-designed, replicable, and easily accessible environments with a physiological measurement system like an EEG or fNIRS, we can create adaptive environments that guide users towards some idealized state. Whether we measure the emotional or cognitive state, we can create environments that change according to the condition of the user. These adaptations can be aural or visual; either way, they are intended to help guide the focus of the practitioner back to the practice of meditation. These environments are very helpful for novices, basically serving as a set of training wheels. However, research has found that experienced practitioners benefit as well (Kosunen et al., 2016). In the future, we expect to see more brain-computer interface systems designed to facilitate certain aspects of meditation, helping more people initiate and sustain engagement in the practice of mindfulness meditation.

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Chapter 6

MINDFULNESS AND CONTEMPLATIVE PRACTICES FOR DIVERSE CULTURES

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ABSTRACT

Mindfulness-based practices can benefit people physically and psychologically; and they may be particularly beneficial for vulnerable populations who face socio-economic challenges and lack access to quality healthcare. Societies are increasingly multicultural with rich blended spiritual and cultural histories that can serve as either bridges or barriers to mindfulness-based practices. The challenge is to find the salient and common cross-cultural teachings and attitudinal foundations that can support the cultivation of mindfulness-based practices for people across all socio-economic strata that embrace diverse cultural experiences.

Keywords: African American, Buddhism, Christianity, Judaism, Muslim, Native American, mindfulness, stress, refugee, diversity, health

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INTRODUCTION

The attentional balance, equanimity, and stillness of the mind shapes how we experience the world, our lives, and the lives of others (Wallace, 2005; 2006). Attentional balance is the ability to sustain a voluntary flow of attention with ease, focus, and clarity. Combined, these are mindful characteristics that are associated with psychological well-being. More importantly, these characteristics have been shown to be cultivated through personal contemplative practices and through conscious efforts to engage in mindful and compassionate interactions with others. However, our attentional balance can be easily disrupted and can deteriorate in response to environmental, cultural and social stressors and experiences that are toxic, chaotic and traumatic. When mental clarity is lost, the mind is easily distracted ruminating on what happened to you in the past or what you expect to happen in the future, and the perceived implications of those thoughts and actions.

Mindfulness-based practices including, Mindfulness-Based Stress Reduction (MBSR), mindfulness meditation, transcendental meditation (TM), and yoga are associated with improvements in psychological and physical health and well-being across diverse age groups (Razza, Bergen-Cico, & Raymond, 2015) and cultures (Cook-Cottone, 2015; Proulx, Croff, et al. 2017). For example, mindfulness-based interventions are associated with reductions in stress (Kabat-Zinn, 2009), anxiety (Bergen-Cico & Cheon, 2013), depression, posttraumatic stress (Possemato et al., 2016) and substance use (Zgierska et al., 2009); improved physical measures of body mass index, waist circumference, blood sugar (Parswani, Sharma, & Iyengar, 2013; Paul-Labrador et al., 2006; Raja-Khan et al., 2017), and cholesterol (Loucks, Britton, Howe, Eaton, & Buka, 2015); and reduction of the physiological stress response as evidenced by changes in cortisol output (Bergen-Cico, Possemato, & Pigeon, 2014). Psychological and physiological stressors; encompassing acute stress, chronic stress, toxic stress, and traumatic stress, not only negatively impact physical and mental health they also reduce educational attainment, economic stability and community safety (Shonkoff et al., 2013; Thompson, Johnson-Jennings, &

Nitzarim, 2013; U.S. Department of Education, 2008). These previous points are salient to underserved populations, particularly in the United States, where unequal social, cultural, and historical burdens are associated with health disparities across the life course (see, Dannefer, 2003; Goins, John, Hennessy, Denny, & Buchwald, 2006). Indeed, limited research has indicated that interventions that reduce stress among diverse populations, like Native Americans, appear to have long-term positive effects on health and income disparities in some minority communities (Le & Gobert, 2015). However, the most compelling data from the growing field of mindfulness in minority communities are those which show that underserved populations and ethnic minorities respond well to mindfulness programs that take into account cultural and historical values as well as coping approaches that have been cultivated within those communities (Proulx, Croff, et al., 2017; Spears et al., 2017).

Mindfulness-based programs have grown exponentially with the validation of scientific evidence and further supported by the direct beneficial experiences of practitioners and participants. Across the globe these practices are integrated to help [illegible] are widely [illegible] in mainstream medical centers and mental health clinics. People of many ages and all walks of life are engaging in yoga and mindfulness-based programs for prevention and recovery of physical and mental health problems (Cook-Cottone, 2015; Kabat-Zinn, 2009). Although mindfulness, meditation and contemplative practices are thousands of years old, the adaptation, acceptance and integration of these practices is an emerging phenomenon that is not accessible to many segments of the population, which could benefit from these practices and skills. In some ways, these practices with ancient roots remain seemingly inaccessible to many people from underserved communities because they do not see themselves, their culture, or their language in the ways that mindfulness-based programs may be presented. Yet if we take the time to examine a broad range of cultural traditions we can find philosophical, spiritual and physical practices that are similar in their cultivation of self-regulation, compassion, awareness, and knowledge of self. Learning about the ways in which these practices and

attitudinal foundations relate to, and reinforce, mindfulness-based practices can expand the reach of these lifesaving and life enhancing practices.

Buddhism is grounded in the belief that that the best way you can help others is to work on yourself and that such work is never truly finished. Similarly, an understanding of mindfulness in diverse cultures begins with the self-awareness of the researcher or clinician who is developing or delivering mindfulness programs in minority communities (Proulx, Croff, et al., 2017). This self-awareness (e.g., stereotypes, discrimination, bias) are considered foundational to psychological and health-related care (Neville, Worthington, & Spanierman, 2001; Sue & Sue, 2003). Further, an unwillingness to turn inward to explore these potential barriers to effective mindfulness interventions may perpetuate oppression against racial and ethnic minorities (Proulx, Croff et al., 2017). On the other hand, Proulx (2010) noted that culturally appropriate approaches to healing increase the likelihood that the transaction between researcher/clinician and the patient from an underserved population is a fruitful and healthy one (Swinomish Tribal Mental Health Project, 1991; Witko, 2004). Further, the extent to which individuals read mind[illegible] interventions can be confusing when [illegible] of known cultural issues [illegible] community of interest will predict the extent to which communities will accept the intervention (Conte, Schure, & Goins, 2016; Simonds, Wallerstein, Duran, & Villegas, 2013; Witko, 2004).

To maximize accessibility and effectiveness of mindfulness-based practices, the field is encouraged to identify contemplative and cultural practices in diverse communities that can mirror and enhance mindfulness-based practices rather than replace cultural practices (Proulx, 2010). However, the first step is to recognize two things: many minority populations in the United States share much in common, but there is a great deal of diversity within these populations. For instance, Indigenous, First Nations and Native American cultures across North, Central and South America are not monolithic; they are diverse in traditions and practices. While each community is unique, there are also similar strengths in Native contemplative practices and traditions that mirror many of the empirically accepted mindfulness practices (Proulx, 2010; Proulx, Croff, et al., 2017).

The goal then for the researcher, clinician and mindfulness facilitator is to develop a method for understanding the inter-individual variation within larger contexts of shared history and culture. For example, preliminary data from a study by Proulx and colleagues (2017) shows that traditional Native dance may be an accepted adaptation of mindful movement as promoted by MBSR and yoga, tai chi, etc. Thus, Native traditional dancing may be an approach to mindful movement that is applicable across tribal nations. However, the *type* of dance may be unique to each community. Therefore, a creative and respectful discussion of how these transitions can be made will be helpful in understanding the contemplative needs of each community, but recognizing what is shared across Native communities and what is unique to those communities.

INTEGRATING DIVERSE CULTURAL RESOURCES INTO MINDF[illegible] PRACTICE AND TEACHING

Mindfulness-based [illegible]gra[illegible]sh[illegible]d be deli[illegible]d in [illegible]tu[illegible]y relevan[illegible] formats that are in line with economic realities of the communities and geographic regions being served. As noted mindfulness-based practices can benefit people physically and psychologically; and they may be particularly beneficial for vulnerable populations who face unique economic, ethnic, racial and religious challenges. Society is increasingly multicultural with diverse blending of rich spiritual and cultural histories that can serve as bridges to mindfulness-based practices, or become barriers when we overlook the commonalities in these human experiences. An example of how cultural diversity can serve as a doorway or bridge to mindfulness-based practices is through the integration of poetry, readings, and terminology from a variety of cultures to demonstrate the commonalities of humanity. The MBSR curriculum encourages the use of poetry and culturally relevant readings to foster inquiry and reflection that support self-discovery and introspective learning rather than didactic teaching with directives. We encourage MBSR teachers to explore and find salient and common cross-

cultural teachings and attitudinal foundations that can support the cultivation of mindfulness-based practices for all people.

Examples of Integrating Native American Narratives in Mindfulness and Contemplative Teachings

Mindfulness teachings and Indigenous or Native American (NA) teachings aim to cultivate deep insight into the nature of our existence, compassion, interdependence, impermanence, and a deep level of connection to the world. These practices are also grounded in inner knowing/self-awareness and the importance of personal peace that comes from understanding our connection with the universe and all other beings (Hausman, 2001; Hölzel et al., 2011; Kabat-Zinn, 2009; Pember, 2012). Similarly, Buddhist and Native teachings both emphasize how a person's physical presence and e[illegible] state influence, and are influenced by, the [illegible]rou[illegible]m (Va[illegible]ine, 2017).

Following are quo[illegible] na[illegible]ives fro[illegible]ige[illegible]us and Nativ[illegible] cultures across North America that illustrate parallel teachings and attitudinal foundations to those found in mindfulness-based practices and teachings. These narratives speak to the importance of the capacity to be introspective and self-aware which is a primary aim of mindfulness practice. It is also noteworthy that the Western Indigenous and Native teachings are similar to the reflective mirrored jewels described in the Hindu metaphor of Indra's net that is often referenced in MBSR teachings. Indra's net is a vast and infinite web of multidimensional interconnectedness with mirrored jewels at each intersecting point reflecting the light of one another to illustrate that nothing is isolated and everything (every quantum particle) is related and connected to everything else (every other quantum particle).

The following Ute prayer reinforces many of the attitudinal foundations of mindfulness, which are *acceptance*, *beginner's mind*, *letting go*, *non-judging*, *non-striving*, *patience*, and *trust* (Kabat-Zinn, 2009). This Ute prayer illustrates how paying attention to the natural environment can teach us about suffering, humility, caring, courage, limits, freedom, acceptance,

impermanence/renewal, kindness and quiet stillness. This a wonderful example of Native American culture showing us how nature, including the example set by nature, gives us everything we need to live peacefully and harmoniously

> "Earth teach me *quiet* - as the grasses are still with new light.
> Earth teach me *suffering* - as old stones suffer with memory.
> Earth teach me *humility* - as blossoms are humble with beginning.
> Earth teach me *caring* - as mothers nurture their young.
> Earth teach me *courag*e - as the tree that stands alone.
> Earth teach me *limitation* - as the ant that crawls on the ground.
> Earth teach me *freedom* - as the eagle that soars in the sky.
> Earth teach me *acceptance* - as the leaves that die each fall.
> Earth teach me *renewal* - as the seed that rises in the spring.
> Earth teach me to *forget myself* - as melted snow forgets its life.
> Earth teach me to remember *kindness* - as dry fields weep with rain."

The following quote from Black Elk, a spiritual leader from the Oglala Sioux tribe, illustrates the interdependency and reciprocity of the ... relationship. The insight and wisdom being conveyed here by Black Elk shows us that we must *deepen the peace within* and know our true selves, first and foremost, before we can achieve interpersonal and intercultural peace and understanding. This is the root of Buddhism and the aims of contemplative and mindfulness-based practices.

> "The second peace is that which is made between two individuals, and the third is that which is made between two nations.
>
> But above all you should understand that there can never be peace between nations until there is known that true peace.
>
> Which, as I have often said, is within the souls of men."

Presented here is a Lakota prayer, which also reinforces the attitudinal foundations of mindfulness by illustrating the importance of *trust* and inner knowing/self-awareness, cultivated through awareness of how these facets are experienced in our bodies.

> "Wakan Tanka (the Great Spirit), teach me how to *trust* My heart, My mind, My intuition, My *inner knowing*, The *senses of my body*, The blessings of my spirit. Teach me to *trust* these things So that I may enter my sacred space and love beyond my fear, and thus *walk in balance* with the passing of each glorious sun."

This statement by Chief Seattle is a beautiful allegory to the Hindu teaching of the Indra's net that is often integrated into MBSR programs to illustrate the interconnectedness of all living things, and the ways in which the wellbeing of each person reflects upon one another. "*Humankind has not woven the web of life. We are but one thread within it. Whatever we do to the web, we do to ourselves. All things are bound together. All things connect*." Similarly, the Lakota teaching of Wakan Tanka, refers to the interconnectedness of everyone and everything. "*And when they realize that at the center of the universe dwells Wakan-Tanka. And that this center is really everywhere, it is within each of us. This is the real peace, and the others are but reflections of it.*" The terminology and concept of Wakan-Tanka is presented here to illustrate integration of Native American philosophy and teachings about cultivating awareness and to illustrate cultural boundaries in teachings into Native and non-Native communities.

MINDFUL PRACTICE

Here we present some examples of how Native American traditions and terminology can establish the framework for engaging in mindfulness-based meditation and walking meditation, beginning with physically positioning oneself for sitting meditation, awareness of breath exercises and mindful walking.

Learn to Be Still

The technical practice of meditation is both a physical and psychological exercise in learning to be still, non-striving and non-doing – being rather

than doing. The benefits of being still, clearing the mind and waiting for the answers to surface through the clarity are evident in the following quote from Ponca Chief White Eagle "When you are in doubt, *be still, and wait*; When doubt no longer exists for you, then go forward with courage. So long as mists envelop you, be still; Be still until the sunlight pours through and dispels the mists, as it surely will. Then act with courage."

Sitting Meditation - Touching the Earth

Sitting meditation does not encompass sitting on lofty couches, but traditionally takes place sitting on the ground with a modest zafu or cushion. Similarly, there are good reasons that mindful walking is best practiced barefoot, or as close to the ground as practical, because of the benefits and importance of making contact with the ground, with our feet, in order to cultivate present moment awareness.

The following narrative attributed to Chief Luther Standing Bear describes the benefits of physically engaging with the earth during contemplative practices such as sitting and walking meditation.

> "The old people came literally to love the soil, and they sat or reclined on the ground with a feeling of being close to a mothering power… That is why the old Indian still sits upon the earth instead of propping himself up and away from its life-giving forces. For him, to sit or lie upon the ground is to be able to think more deeply and to feel more keenly. He can see more clearly into the mysteries of life and come closer in kinship to other lives about him."

Awareness of Breath

There is a Native American reference to *the Sacred Space*, which is *the space between the in-breath and out-breath.* Paying attention to the space between the in-breath and the out-breath, or inhalation and exhalation, is a meditation technique that has been practiced for thousands of years and is

the foundation of mindfulness meditation and mindfulness-based practice. Awareness of breath meditation is central to mindfulness-based meditation, which includes the cultivation of awareness of the sensations and flow of inhalation and exhalation of each breath including holding the breath in the space between the in-breath and the out-breath (Kabat-Zinn, 2009).

RELIGION AND SPIRITUAL BRIDGES TO MINDFUL PRACTICE

The previous section presented several examples of Indigenous and Native American spiritual teachings that reinforce the attitudinal foundations and practices of mindfulness-based stress reduction. In the following section, we examine religious teachings and practices that parallel mindfulness teachings and practices. Identifying similarities between mindfulness-based pra[illegible]d terminology with the teachings and [illegible]s [illegible]verse sp[illegible]nd [illegible]ur[illegible]co[illegible]mu[illegible]ies [illegible]an[illegible]nal[illegible]t[illegible]ser[illegible]ili[illegible]and acces[illegible]lity [illegible]f t[illegible]e progra[illegible]r di[illegible]se [illegible]pulations. Spirituality and religious affiliation are also cultural factors to consider and can provide a bridge to mindfulness-based meditation and contemplative practices. It is important to note that Buddhism is considered a science and a psychology as well as a religion; and that mindfulness-based meditation and teachings are secular although grounded in Buddhist teachings. Here we will explore some commonalities between mindfulness-based practices and religious teachings. At their core, the contemplative practices of Judaism, Christianity and Islam are about mindfulness, as are Buddhism and Hinduism. There are recurrent themes and common attitudinal foundations across these spiritual teachings and practices that support mindfulness-based practices, each of which aim to foster self-awareness, self-regulation, moderation, truth, and compassion (Dahlsgaard, Peterson, & Seligman, 2005).

There are teachings and terminology in Arabic and Muslim cultures that are salient to mindfulness-based practice and meditation. For example, the

word *sabr* in Arabic means patient, calm, non-judgmental, acceptance of what is occurring in the present moment. Thus, the term sabr captures the attitudinal foundations of mindfulness practice. Meditation and the Islamic faith are also compatible. Islamic teachings call upon Muslims (and all people) to be mindful of what you like and what you dislike. Islam teaches that what you like may in fact be harmful to you, and what you dislike may in fact be good for you. Similarly, mindfulness teaches people to observe their cravings, desires and aversions to people and things, noting that craving and desire can be problematic and aversion/disliking should be viewed with caution. Moreover, the Qua'ran teaches about the importance of patience, compassion, equanimity and non-reactivity, which are embodied in mindfulness teachings. There are also similarities that can be drawn between meditation and *salat*, or Muslim prayer. The intention one brings to salat is important just as it is with mindful meditation. In the Muslim faith, the purpose of engaging in salat, the Islamic practice of praying five specific times per day, is to foster equanimity of mind, body and soul, captured by the Arabic term *khushu*. Arab and Muslim participants may be assured the similarities between Islamic teachings and practice and mindfulness practices, which are to foster equanimity, patience, calm as well as non-judgmental acceptance through practices, which bridge mind and body.

Similar to Buddhist inspired mindfulness teachings, the South American Indigenous Inka (Inca) cultures have a philosophical and spiritual belief that everything consists of living energy called *Sami*. The Inka have ceremonial practices for working with energy on a regular basis called *saminchakuy* and *saywachaku*y. These exercises are designed to cleanse, strengthen, and connect people more deeply with the world and can be integrated with body scan, yoga and mindful eating practices. These practices are for cleansing and energizing body energy (*poq'po*) to support the capacity for *ayni* or sacred reciprocity with all creation. The practice of saminchakuy is designed to release stuck or heavy energy to return to the sacred source of Mother Earth. Once the energetic body is cleansed, the practice of saywachakuy is believed to draw subtle energy from the earth, which can support

experiencing ourselves as living columns of energy with reciprocity between people, the earth and all living beings.

Although mindfulness-based stress reduction is secular, there are some similarities in contemplative practices and teachings with many of the world's religions. One such example is Christianity, which has been a common topic when considering adapting mindfulness programs to minority communities. A study by Proulx and colleagues (Proulx, Hebert, Croff, & Oken, 2017) found that many African American MBSR participants were firmly committed to the principles outlined in Christian text and wanted to find ways in which mindfulness practices related to their Christian identity before engaging in MBSR practice. Some participants needed to understand and hear how mindfulness fit with Biblical readings. Researchers found that for participants needing or seeking a Christian context for their mindfulness practice, there were parallels between Christian teachings about forgiving and praying for enemies and Buddhist practices of compassion meditation; and Christian scriptures about finding one's way after being lost and mindful [illegible] programs. Simi[illegible] stu[illegible] of African Americans and mindfuln[illegible] ve [illegible]ow this trend [illegible] a[illegible]view [illegible]d mini[illegible]ness [illegible]og[illegible] f[illegible] t[illegible] p[illegible]tive[illegible] Christian[illegible] and [illegible]blic[illegible] [illegible]nings[illegible] [illegible]e W[illegible]ds-[illegible]abé & Gaylord, 2014) and the concept that praying is a way to talk to God; whereas, silent meditation is a way of hearing God. Researchers recruiting for a study of mindfulness in African Americans had difficulty with recruitment until the church pastor allowed the researchers to hold the mindfulness classes in the church and allow a researcher to appeal to the congregation from the pulpit during a church service. This approach was effective in demonstrating support of the clergy and the church. Moreover, the sermons were about stress, which further helped encourage participation and the mindfulness programs for the study filled quickly. Similar themes emerged within Native American communities, with some variations based on tribal location. For example, some mid-Atlantic coastal tribes identify strongly as fundamental Christians and did not want to participate in a program that involved yoga or meditation. Other tribes in the southwest and northwest noted that Christianity was important to their community, but were open and willing to

share traditional values developed in their community and participate in mindfulness-based programs.

Research by Knabb (2012) has drawn practical parallels between centering prayer, a Christian meditation practice and that of mindfulness-based cognitive therapy (MBCT) for depression and depressive relapse. Identifying the convergence of intention and philosophical teachings across spiritual practices can provide participants with the permission, support, and framework to engage in mindfulness-based practices so that they may benefit from all that mindfulness-based practices have to offer. The overall point here is that religion and people's relationship to their religion should be taken into account and the approach to each community may be radically different. This main point illustrates the importance of *approaching each community with a beginner's mind and a sense of openness* and flexibility and an understanding that each community (even within demographics) is unique.

CONSIDERATIONS FOR MINDFULNESS AND CONTEMPLATIVE TEACHERS

Participants in most of the mindfulness studies in underserved populations that we have engaged with preferred a mindfulness class facilitator from the population they identify with, or person of a minority population who could relate to the experiences of their population and community. A common theme is that this would provide a safe and comfortable environment in which to share personally significant experiences and feelings. As one participant said, *"Especially for me when I think about it, I am so much around and entrenched with whites, for me these past few weeks has been a safe haven because it's a place I can share my heart without being judged."* Finding a facilitator of color may not be realistic, but that an effort should be made to find someone who can clearly relate to the people in the class. As one participant noted, the classes may not be as effective if the facilitator's "story" was not the same "story" as

their own. Participants across our studies of African Americans and Native Americans and mindfulness unanimously have commented that they felt most comfortable when they can express freely without fear of judgment. People have noted that a variety of ages, sexes, and races may be beneficial to the mindfulness experience as a group, but at first participants were concerned that this much diversity is a detractor. The mindfulness class offered many people a venue for discussing stressors and fears unique to minority communities in North America where the intervention is being implemented. This is one important aspect of the mindfulness class that arose: the deep suspicion of having the dominant culture become aware of the coping processes developed in American minority communities to address stress. Most of the communities we engaged with had histories of having those coping processes or spiritual foundations destroyed specifically to decimate and humiliate those populations. Therefore, many of the most intimate knowledges in these communities remain hidden from view and people in the American minority communities we worked with were firm th[illegible] f[illegible]ations f[illegible]heal[illegible] would remain hidden if the facilitator, [illegible]met[illegible]es other class p[illegible]cipants, [illegible]fro[illegible]th[illegible]san[illegible]co[illegible]s. [illegible]well[illegible]ained mind[illegible]ness [illegible]vil[illegible]vests [illegible]ostan[illegible]t tim[illegible]often money in their training and preparation, particularly if they hope to achieve a nationally or internationally recognized certification (e.g., Mindfulness Based Stress Reduction Teacher Certification through the University of Massachusetts Medical School's Center for Mindfulness in Medicine, Health Care and Society). The conditions and circumstances that enable a person to invest the time and resources needed to become an effective mindfulness teacher can, by their very nature, be a culturally divergent factor that has potential to create an unhealthy distance and cultural disconnect between teachers and participants. However, potential barriers between teachers and participants can be rectified through authentic practice with beginner's mind and diverse experiences with people such that the teacher remains vigilant of the common characteristics of the human experience and the true nature of suffering and joy that exists across cultures. From this perspective, cultural differences should not present barriers. Therefore, it is important to consider that mindfulness practices are taking place within

contexts of power and inequality that are part of the American narrative. Researchers and clinicians are encouraged to consider the relation to racial and interrelated forms of privilege more broadly when considering working with or learning from minority communities in the United States.

CONCLUSION

In this chapter, we have focused on the importance of being aware of cultural, spiritual and religious diversity and provided examples of how these may be integrated into mindfulness-based teaching in order to build bridges and open doors for participation in mindfulness-based practices. Much of what we have written about here is informed by research and practice in North America. However, as we have noted, the world is increasingly multi-cultural and our identities are decreasingly bound by geography. In addition to socio-economic disparities that exist within countries, there are 65.5 million forcibly displaced people worldwide (United Nations High Commissioner for Refugees, 2017) thus illustrating the shifting cultural context of community while underscoring the importance of providing access to mindfulness-based practices to support the mental health and well-being of people through the use of self-directed self-regulation skills that can be used anywhere. The need for mindfulness-based self-regulation practices cuts across geographic locations and economic strata. Refugees who are resettled in high income countries, like the U.S. and much of Europe, still have mental health challenges and vulnerabilities (Fazel, Reed, Panter-Brick, & Stein, 2012), and can benefit from mindfulness and contemplative practices. The integration of economic, social, cultural and spiritual factors into mindfulness and contemplative programs are important considerations for future research.

The range of needs, constraints, economic and cultural realities in different parts of the world require some flexibility in the standards and expectations for professional training of mindfulness practitioners. To that end, there are also time constraints, economic barriers and accessibility limitations and cultural realities among current and prospective "students"

that call for diversifying the ways in which mindfulness-based programs are delivered. Ultimately, mindfulness is a no cost self-directed practice that can be available to anyone, at any time, anywhere, because it becomes a trait, a way of being that is continuously refined through practice. The challenge is to make mindfulness-based practices as widely available as possible to benefit humanity without losing the integrity of the practice, which is fundamental to its effectiveness. This may in part be achieved through the identification of traditions and practices among cultures that can serve as a scaffolding or framework from which we can amplify the cognitive practices that cultivate present moment attunement, strengthen engagement of the prefrontal cortex, and reduce the physiological stress response.

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Chapter 7

THE PROMISE OF MINDFULNESS AS A PROPOSED INTERVENTION TO ALLEVIATE THE DELIMITING EFFECTS OF MATH ANXIETY

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ABSTRACT

This chapter is motivated by the challenge of supporting adolescents suffering with *math anxiety*—an adverse emotional response to thinking about or doing mathematics. We explore the promise of mindfulness in education, with specific attention to social emotional learning in mathematics. We focus on the issue of math anxiety and propose

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mindfulness practices as a supportive instructional intervention to help mitigate math anxiety and its delimiting effects. We close by proposing directions for future research and practice.

Keywords: mathematics education, math anxiety, social emotional learning, mindfulness practices

INTRODUCTION

Mathematics is a gatekeeper for students' success in school, and is central in college and career pathways in our technological society (Ashcraft & Krause, 2007). Yet a great failure of school mathematics is students' disaffection toward learning mathematics (Lewis, 2016). This is especially problematic in light of the urgent need to expand more equitable mathematics learning opportunities for *all* students that do not result in the fears and anxieties we regularly observe in schools and society alike (Gutiérrez, 2017). [illegible] of [illegible] mathematics learning [illegible] deficits in schooling.

Math anxiety is an adverse emotional response to thinking about or doing mathematics that can be debilitating. In this chapter we explore the promise of mindfulness in education, specifically in the context of addressing math anxiety with attention to social and emotional aspects of learning. We propose mindfulness practices as a supportive instructional intervention to help mitigate math anxiety and its delimiting effects. We discuss some issues concerning the use of mindfulness in mathematics education and close by proposing directions for future research and practice.

THE PROMISE OF MINDFULNESS IN EDUCATION

Mindfulness is defined as "a moment-to-moment awareness of one's experience without judgment," but the term *mindfulness* can be used to refer

to "a psychological state of awareness, a practice that promotes this awareness, a mode of processing information, and a characterological trait" (Davis & Hayes, 2011, p. 198). Being mindful disengages us from automatic thoughts and unproductive habitual patterns of behaviors. "Mindfulness is about realizing that we can't be anywhere else but here and now.… The content of now is their inner-experience" (Ergas, 2015, p. 217). The benefits of mindfulness are many and varied. Mindfulness has become a mainstream psychotherapy due to the success of mindfulness-based stress reduction (MBSR) programs. Mindfulness has found to be related to improvement in mental wellness, cognitive functioning, and emotional intelligence (Davis & Hayes, 2011). In terms of wellness, mindfulness has been reported to improve emotion regulation, reduce rumination, reduce psychological distress and anxiety, increase positive affect, and increases immune functioning (Davis & Hayes, 2011). In terms of task performance, mindfulness meditation practice can increase information processing speed (Moore & Malinowski, 2009), decrease task effort (Lutz et al., 2009), and decrease thoughts unrelated to the task at hand (Lutz et al., 2009).

In educational settings, mindfulness meditation may promote healthy emotion regulation, attention preparedness, sustained attention, processing information quickly and accurately (Shapiro, Brown, & Astin, 2011). In a meta-analysis on the effects of mindfulness-based programs in education, Zenner, Herrnleben-Kurz, and Walach (2014) found that mindfulness-based interventions in schools are linked to gains in student achievement and resiliency to stress. For example, Saltzman and Goldin (2011) adapted an 8-week MBSR course for adolescents, and found participants had statistically significant lower anxiety by the end of the course as compared to wait-list participants. A growing interest in mindfulness in education suggests a shift in expanding what it means to be educated. Proponents of mindfulness in education support the notion that there is a need to expand our value system to include non-cognitive dimensions of learning including social and emotional health and well being. We focus on the domain of mathematics education, and the issue of math anxiety in particular.

MATH ANXIETY: A SOCIAL-EMOTIONAL CHALLENGE IN MATHEMATICS EDUCATION

Social emotional learning in mathematics education is often investigated as an affective domain of learning (Middleton, Jansen, & Goldin, 2017), in which a great failure of mathematics education is students' disaffection toward learning mathematics (Lewis, 2016). Social and emotional learning in mathematics education is given relatively little attention compared to research on cognition (Lewis, 2016). Not only is there a dearth of research in mathematics education on emotion (Zan, Brown, Evans, & Hannula, 2006), but our understanding of emotion in mathematics education is largely undertheorized (Lewis, 2016).

This imbalance and gap in the literature is troubling given the demonstrated need for a broadened educational focus that prioritizes social and emotional development in addition to academic development (The Aspen Institute, 2017). Increasingly, the need to support an integrated growth in adolescent being, each as a whole-child dimensions emphasized (Diamond, 2010). Despite these aims, mathematics education we are faced with great challenges in supporting an imperative in educational research to address "a more clearly antioppressive and humane course for mathematics education: a mathematics education that does not result in the negative experiences, fears, anxieties, and disaffected mathematical identities that we continue to encounter in schools and society" (Aguirre et al., 2017, p. 125).

One of the biggest affective obstacles students face is math anxiety—a fear of doing mathematics (Ashcraft, 2002), or "irrational dread of mathematics that interferes with manipulating numbers and solving mathematical problems within a variety of everyday life and academic situations" (Buckley & Ribordy, 1982, p. 1). Math anxiety has crippling effects for students, as it is linked to students' lower math performance and avoidance of taking future courses in math (Ashcraft, 2002; Hembree, 1990). Indeed, "the higher one's math anxiety, the lower one's math learning, mastery, and motivation" (Ashcraft & Krause, 2007, p. 245). This

phenomenon is especially problematic in light of the urgent need to expand math learning opportunities for all students that are not rooted in fear (Aguirre et al., 2017). Given that mathematics is a gatekeeper for students' success in school, and is central in college and career pathways in our technological society (Ashcraft & Krause, 2007), understanding the mechanisms for how to alleviate math anxiety is greatly needed area of research and development.

Many studies of math anxiety rely on self-reported surveys using a Likert scale (see Table 1 for an abbreviated version of such a scale by Hopko, Mahadevan, Bare, & Hunt, 2003). These measures can show correlations; for example, increased math anxiety is correlated with decreased math problem solving (Hembree, 1990). However, surveys of math anxiety are not sensitive enough measures to understand *how* students' anxiety and mathematics problem solving are related, or how emotions of anxiety are experienced during problem solving (Middleton et al., 2017). That is, there are opportunities in the field to extend existing measures to examine qualitative investigations of math anxiety, and how math anxiety is linked to cognitive, emotional and physiological aspects of learning. Moreover, lowering math anxiety has been demonstrated to advance innovations and interventions to help mitigate math anxiety, explored next.

Table 1. Abbreviated math anxiety scale

On a scale of 1 (low anxiety) to 5 (high anxiety), rate the following:

1. Having to use the tables in the back of a math book.
2. Thinking about an upcoming math test 1 day before.
3. Watching a teacher work an algebraic equation on the blackboard.
4. Taking an examination in a math course.
5. Being given a homework assignment of many difficult problems that is due the next class meeting.
6. Listening to a lecture in math class.
7. Listening to another student explain a math formula.
8. Being given a "pop" quiz in math class.
9. Starting a new chapter in a math book.

Hopko et al., 2003, p. 180

MITIGATING MATH ANXIETY

In seeking to understand how to mitigate math anxiety, we summarize themes in the literature around two main theoretical orientations toward math anxiety. The first is a social orientation toward learning and influences on math anxiety. The second is a cognitive orientation toward learning and math anxiety. Both orientations contribute different yet related threads of how mindfulness practices might mitigate math anxiety, a hypothesis we formalize in the next section.

Social Orientations

In a recent research synthesis, Middleton et al., (2017) report the origins of mathematics anxiety are complex, and intertwined with a web of social, emotional, cultural, and [illegible] factors and experiences. For instance, [illegible] anxiety can be transferred from parents' [illegible] influenced by [illegible] emotional support by the teacher, such as overt modeling and pointing out mistakes, or covert scowls and frustration, or assuming an insensitive and uncaring attitude (Jackson & Leffingwell, 1999). Some assert that math anxiety is rooted in experiences that perpetuate fear of making mistakes, which can be cultivated by teachers and teaching in unsupportive classroom environments (see A. H. Brown & Uhde, 2006). Thus, some suggest students with math anxiety may be best supported in learning environments in which they feel safe (Simmons, 2017), without the pressure of performing math with no mistakes (Boaler, 2016).

In a recent advancement in understanding why students with math anxiety fail in mathematics, Heyd-Metzuyanim (2015) found that students' repeated participation in discourses of "not good at math" and related anxieties co-occur over time, and go hand in hand with poor performance. Heyd-Metzuyanim suggests teaching students to be aware of how negative feelings about math may be a result of influence from parents, media, and societal expectations that tend to prioritize correct performance. This empirical finding supports the notion that parents, teachers, and cultural

norms play a large role in students' learning of negative attitudes and fears of mathematics through social practices (see also Kutner, 1992). It also suggests the importance of awareness of inner dialogue or stories about not being good at math, a practice of mindful awareness.

Cognitive and Psychological Factors

Recent research from a cognitive orientation sheds light on other possible ways to mitigate math anxiety through awareness and breath—both bedrock components of mindfulness. First, Ashcraft and Kirk (2002) found that perseverating on unhelpful fears and negative thoughts induced by anxiety consumes limited cognitive resources, leading to decrements in math performance. An implication of that research, and congruent with neuroscience research by Lyons and Beilock (2011), is to support students in developing an *awar*[illegible] of their anxiety or perceived fears of doing m[illegible]ati[illegible] a mea[illegible] to r[illegible]uce [illegible] anx[illegible]ty. S[illegible]co[illegible], Kh[illegible] (20[illegible]) ugh[illegible] e[illegible]mine the ef[illegible]t o[illegible] *rea*[illegible]y [illegible]do[illegible]s' [illegible] a[illegible]y (sta[illegible] a[illegible]y clo[illegible]y linked t[illegible]ath [illegible]iet[illegible]) [illegible]ng (20[illegible]) ind[illegible]d a [illegible] of test anxiety by administering a 60-second timed test, then tested the effect of deep breathing for treatment group students compared to students who did not engage in deep breathing (control group). Khng found that for grade 5 students "taking deep breaths before a timed math test significantly reduced self-reported feelings of [test] anxiety and improved test performance" (p. 1).

To build on and extend these studies, there is potential to frame the teaching of practices of awareness and breathing from a mindfulness perspective, which may help to increase awareness of feelings of anxiety, and detachment from those feelings. Studying the role of deep breathing practices before and while doing mathematics may support understanding how such practices help mitigate math anxiety. There is an opportunity to develop theory to link possible effects of math mindfulness to instructional design principles, elaborating *how* mindfulness practices mitigate math anxiety.

WORKING HYPOTHESIS : MINDFULNESS CAN MITIGATE MATH ANXIETY

As reviewed above, the origins of math anxiety can be traced to social-emotional influences such as a lack of emotional support by teachers and/or parents (Heyd-Metzuyanim, 2015; Jackson & Leffingwell, 1999). In light of this, some suggest students may be best supported in learning environments where they feel safe (Simmons, 2017), without the pressure of performing math with no mistakes (Boaler, 2016; Turner et al., 2002). From a cognitive orientation, math anxiety is linked to a limited cognitive working load to engage in math problem solving when distracted by unhelpful fears and negative thoughts induced by anxiety (Ashcraft & Kirk, 2002; Maloney, Schaeffer, & Beilock, 2013). Perhaps the most compelling finding to reduce math anxiety is to support students in developing an awareness of their anxiety or perceived fears of doing mathematics (Lyons & Beilock, 2011). Self-awareness and focused breath-work are core practices of mindfulness that have been shown to [illegible] general [illegible] math-specific) [illegible] anxiety for adolescents (Chang, 2013; Saltzman & Goldin, 2008). In recent empirical research with college students, there is promise for incorporating focused breath work to reduce math anxiety (see for example Brunyé et al., 2013).

The link between focused-breath work and awareness of math anxiety may contribute to decreasing math anxiety. This issue is ripe for empirical investigation with adolescents in mathematics classroom settings, who face myriad pressures, especially with high-stakes testing. We hypothesize that mindfulness practices may serve as effective tools for supporting students' awareness of cognitive, emotional, and social forces linked to math anxiety in the context of math learning, such as distracting thoughts, states of anxiety, and patterns of discourse, respectively. We hypothesize that if students learn to apply mindfulness practices in math problem solving settings, they may learn to become more aware of their math anxiety—a mechanism for reducing it—and in turn, improve their math problem solving. We turn next to three issues related to mindfulness in mathematics education. The first deals with metacognition and mathematics problem

solving. The second deals with teachers' receptivity to mindfulness practices. The third deals with possible tensions that may arise while incorporating mindfulness practice in a mathematics learning environment.

Mindfulness and Metacognition in Math

In solving math problems, "doing whatever first comes to mind … or diving into the first approach that comes to mind" (Watson & Mason, 2007, p. 307) is commonly observed among students. It is theorized that mindfulness promotes metacognitive awareness (Davis & Hayes, 2011). Metacognitively aware learners are found to be more strategic in solving problems than those metacognitively less aware (see Schraw & Sperling-Dennison, 1994). Metacoginitve knowledge consists of (a) knowledge of self as a problem solver, (b) knowledge of tasks (how to meet demands under various conditions), and (c) strategies for accomplishing the task (Hacker, Dunlosky, & Graesser, 1998). Kluwe (1982) differentiates between two [illegible] metacogni[illegible] knowledge of [illegible]'s own thinking, and ([illegible]nitoring and regulati[illegible] of one's thinking (i.e., executive routines). Schraw and Sperling-Dennison (1994) developed the Metacognitive Awareness Inventory for assessing both aspects of metacognition. Mindfulness may be an antidote to impulsivity—"decreased sensitivity to negative consequences of behavior; rapid, unplanned reactions to stimuli before complete processing of information; and lack of regard for long-term consequences" (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001, p. 1784). "The cultivation of mindfulness precludes impulsive thought and behavior through the maintenance of attention on the present moment and the qualities of acceptance, openness, and curiosity" (Stratton, 2006, p. 52).

Preservice Math Teachers' Receptivity to Mindfulness

If more and more schools integrate mindfulness into their curriculum, then teachers need to be familiar with the practice of mindfulness. Being curious whether prospective teachers are receptive to the practice of

mindfulness, Lim led a classroom research study. Lim and Yeh (2017) conducted a study to investigate (1) prospective teachers' receptivity to mindfulness in a math course, and (2) the impact of watching a five-minute video in each class (eight informational videos on mindfulness, seven guided mindfulness meditation videos, and four videos on kindness) on their impulsiveness and mindfulness. Twenty participants in a geometry-measurement course for prospective teachers took a pre-post questionnaire consisting of two scales and an end-of-course online survey.

On the pre-post questionnaire, they reported less impulsive (p = .0001) on the *Barratt Impulsiveness Scale Version 11* which has 30 items such as "I do things without thinking." Interestingly, on the *Mindful Attention Awareness Scale* (K. W. Brown & Ryan, 2003) which has 15 items such as "I find it difficult to stay focused on what's happening in the present," students reported to be less mindful (p = .0002) probably because they were starting to notice their monkey minds. On the online survey, 90% agreed or strongly agreed with statements like "I am more likely to practice mindfulness now than before taking MATH 2304"; and "If I become [illegible] have my [illegible] 75% checked [illegible] class routine"; and 55% checked "I now believe this will be helpful in my life." This exploratory study suggests that introducing mindfulness via videos may help preservice math teachers to reduce their impulsivity, be aware of their mindfulness states, induce their interests in mindfulness, and potentially reduce their mathematical errors caused by impulsive disposition.

Tensions in Incorporating Mindfulness While Doing Math

Learning and doing mathematics evoke emotions, which may be pleasant or unpleasant. Pleasant ones are associated with accomplishments such as successfully discovering a viable strategy, solving a problem, resolving a cognitive conflict, confirming one's hunch, and understanding a challenging concept. Unpleasant emotions are associated with not knowing how to get started, repeated failures, feeling lost, and not seeing what seems

obvious to others. Pleasant experiences motivate math learning and reinforce students' confidence, whereas unpleasant experiences instill math anxiety and destroy students' confidence. On the one hand, we seek to optimize pleasant experiences and avoid unpleasant experiences. On the other hand, mindfulness practice requires us be aware and let go of our experiences, including pleasant ones. A tension may arise as to whether one should build on or let go of one's pleasant experiences while doing mathematics mindfully. We don't have a definite answer but we are inclined to think that holding on to pleasant experiences makes it difficult for our mind to let go of unpleasant experiences when they arise.

Mindfulness involves observing non-judgmentally whatever we are experiencing without classifying it as good or bad, and without striving to attain a different experience (Alidina, 2015). Solving a math problem, on the other hand, is a goal-oriented activity that involves making judgements as to whether we are on the right track or if our work is mathematically correct. Advanced mindfulness practitioners can work towards a goal objectively by accepting and letting go of outcomes and emotions. Beginners, on the other hand, may have difficulty engaging in judgmental and non-judgmental thinking while experiencing subjective emotional responses. Students who are experiencing math anxiety would find it challenging to let go of their anxiety especially when they are hoping to get rid of it.

On a final note, mindfulness practice may be easy for some people but difficult to practice for others. Depending on individuals' predispositions, mindfulness may takes years to cultivate for some of us. A tension may arise when a teacher is incorporating mindfulness while noticing her or his lack of mindfulness due to inadequate training or practice. How does one know when one is incorporating mindfulness appropriately? On what basis does one decide whether or not to incorporate mindfulness?

CONCLUSION AND FUTURE DIRECTIONS

From the above review, we suggest a few viable next steps for research on how mindfulness might mitigate math anxiety. First, the importance of

cultivating supportive learning environments that are safe for students to express vulnerabilities, mistakes, and uncertainties in learning mathematics is key to supporting growth (Boaler, 2016). Second, training students' attention and ability to cultivate an awareness of their feelings and states of anxiety before or during mathematics problem solving is essential (Lyons & Beilock, 2011). Interventions for mitigating math anxiety might be guided by objectives grounded in mindfulness practices. For example, an objective for students might be to develop and apply techniques of mindfulness to become more aware of math anxiety. Furthermore, once students are taught to notice math anxiety, they can learn to accept and let go of attachments to unhelpful fears that may delimit future educational opportunities.

Finally, very few studies on math anxiety measure students' anxiety during the moment of problem solving (Middleton et al., 2017; see Heyd-Metzuyanim, 2015 for an exception). Many measures of math anxiety are limited to self-reported survey instruments (Hopko et al., 2003) which may not be sensitive enough measures for observational studies and students' anxiety during in-the-moment mathematics problem solving. Such assessments for on standardized tests may suggest there is a gap for future studies that focus on how to observe or notice math anxiety during mathematics problem solving, and for testing the suggested mindfulness interventions to possibly alleviate the delimiting effects of math anxiety.

Fonger is currently conducting exploratory research on how to support college students suffering with math anxiety by teaching mindfulness during mathematics classes (Fonger calls this novel approach *mathematics mindfulness*). Early in the pilot research, one of Fonger's students remarked, "at the start of the semester it's overwhelming but after taking a deep breath, and focusing on one thing, I felt much less anxious" (personal communication, Sept. 27, 2017). This points to the power of opening up safe spaces for students to express frustrations and fears as a mechanism for overcoming such challenges. The promise of mindfulness in education, and mathematics education in particular is great. Yet two central questions remain: Can mindfulness mitigate math anxiety, and if so, how?

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Chapter 8

TRAIT MINDFULNESS AND PROBLEMATIC SMARTPHONE USE

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ABSTRACT

As seen in social science research and in popular media, we are growing increasingly aware of the problematic aspects of the demands of ubiquitous smartphones upon our attention, particularly from electronic human communication such as social media apps. Recent research suggests that mindfulness, the deliberate, non-judgmental paying of attention to present-moment phenomena, can be useful for the mitigation of a variety of problematic behaviors. The present survey research finds that mindfulness factors attention and awareness, describing, non-judging of inner experience, and acting with awareness all have statistically significant negative correlations with factors comprising problematic habitual use of smartphones (salience, reactibility, monitoring, preference for online social interaction, mood regulation, deficient self-regulation, and negative outcomes).

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Keywords: mindfulness, trait mindfulness, smartphone use, online vigilance.

INTRODUCTION

Smartphones have a ubiquitous presence in the lives of the inhabitants of industrialized countries (Pew Research Center, 2016) and, among other effects, have transformed social communication (Ling, 2012). While these devices offer great and flexible utility, scholars and researchers increasingly offer arguments and evidence for the non-productive aspects of smartphones, including interference, defined by Gazzaley and Rosen (2016) as the (unintentional) distractions and (intentional) interruptions that prevent us from concentrating on goals and tasks at hand, from conversation with friends and driving an automobile to writing a paper; and the compulsion to feel permanently online and permanently connected (Vorderer, Kroemer, & Schneider, 2016). The current research looks at the relationship between trait (dispositional) mindfulness, which involves the tendency to focus one's [illegible] attention [illegible] and [illegible] in the present moment, and attitudes, affect, and behavior related to problematic smartphone use.

PROBLEMATIC SMARTPHONE USE

Within only a decade, mobile communication technologies such as smartphones have facilitated a transformative increase in availability and diversification of mobile communication, including social networking applications such as Instagram, Facebook, Twitter, Snapchat, and Whats-App. Scholars are increasingly investigating the negative impact of portable, endless connectivity on human communication. Turkle (2011) summarizes what she sees as the problem in the title of her book *Alone Together*. Even when two or more people occupy the same physical space, they tend not to be present for one another, but direct their attention to the mediated social life that flows from their smartphones. More recently, Turkle (2015) argues that for purposes of social interaction we should put away our smartphones,

whose use have led to a diminution of essential aspects of human interaction such as empathy and compassion, and proactively embrace the millennia-old activity of face-to-face conversation.

Brewer (2016) addresses the motivation for our embrace of human communication via smartphone, which he frames in terms of the classical behaviorist mechanism of positive reinforcement: When we have the urge to post to social media (trigger), we do so (behavior), and get a bunch of "likes" or other approbation (reward). He cites research that seems to demonstrate that these social media rewards seem to be associated with activation of the nucleus accumbens, one of the brain regions "most consistently linked to the development of addictions" (Chapter 2, Section 2, para. 5).

Gazzaley and Rosen (2016) divide the problematic behaviors related to smartphone use into two types: Interruptions, in which we choose to divert our attention from our business at hand (including face-to-face interaction with another person), and distractions, in which we are unintentionally pulled away from it. Choosing to turn our attention from our conversation partner to check your Facebook news feed for "likes" to see if a recent post is an example of the former; noticing, and then ignoring, the ding that tells us that someone else is texting a new message is an example of the latter. Gazzaley and Rosen frame these phenomena as "ancient brains in a high-tech world" and as conflicts between our goals (which could include attentive in-person social interaction) and "a powerful barrier…the limits of our cognitive control" to resist the instantaneous rewards offered by mobile technologies, including smartphones (2016, Chapter 1, Section 3, para. 3).

Recently, Reinecke et al. (2016) have developed the theoretical concept of online vigilance, referring to "users' permanent awareness of the constant availability of online…communication as well as their motivational disposition [to access it] anywhere and anytime" (p. 1). Online vigilance, with three theorized factors—salience, reactibility, and monitoring—describes a condition which falls short of addiction but still may yield some of the problematic outcomes discussed above, and appears to be widespread. Other researchers describe more detrimental and problematic smartphone use in terms of involvement (Walsh, White, & Young, 2010), compulsive use (James & Drennan, 2005) and maladaptive use (Beranuy, Oberst,

Carbonell, & Chamarro, 2009), and addiction (Casale, Primi, & Fioravanti, 2016; Kwon, Kim, Cho, & Yang, 2013). Caplan (2010), in a theoretically-driven engagement with the topic, proposes four factors comprising this problematic behavior: preference for online social interaction; mood regulation; deficient self-regulation; and negative outcomes. The present study is interested in both the more widespread but less severe phenomenon of smartphone vigilance and the less prevalent but more detrimental smartphone-related behaviors, and so will use scales of both Reinecke et al. (2016) and Caplan (2010) modified to measure use of and attitudes toward smartphones.

MINDFULNESS

"The mindfulness revolution" (Pickert, 2014) has received much popular attention in recent years as a purported means to improve health and well-being on various [illegible] and published scientific research articles [illegible] mindfulness, [illegible] psychology and medicine has more than six-fold in [illegible] ding in 2[illegible] Van Dam et al., 2017). However, as with other media-hyped trends, there have been both exaggerated and uncritical claims of mindfulness as a panacea, and excoriation of it as another empty New Age fad (Johnson, 2014), and the vagueness of the term "mindfulness" only contributes to the difficulty.

Defining Mindfulness

A challenge in assessing and designing research on mindfulness is that "there is neither one universally accepted technical definition…nor any broad agreement about detailed aspects of the underlying concept to which it refers" (Van Dam et al., 2017, p. 3). Perhaps the most-cited definition is Kabat-Zinn's: "[Mindfulness means] paying attention in a particular way: on purpose, in the present moment, and nonjudgmentally" (2013, p. 13). Building on this definition, Bishop et al. (2004) describe mindfulness as a two-part process:

> The first component involves the self-regulation of attention so that it is maintained on immediate experience, thereby allowing for increased recognition of mental events in the present moment. The second component involves adopting a particular orientation toward [that experience]…that is characterized by curiosity, openness, and acceptance. (p. 232)

Thus, both Kabat-Zinn's (2013) and Bishop et al.'s (2004) definitions can be seen as having a *focus* component and a *quality* component (Rau & Williams, 2016). From the above definitions, and following Van Dam et al.'s (2017) recommendation to researchers to reduce construct ambiguity by specifically naming the aspects of mindfulness to be measured, this study will focus on and measure these two aspects of mindfulness: focus and quality. Arguably, the most theoretically informed and extensively validated self-report mindfulness scales (Vago, n.d.) are the one-factor Mindful Awareness and Attention Scale (Brown & Ryan, 2003), "perhaps the most widely-used unidimensional measure of mindfulness" (Rau & Williams, 2016, p. 34), and the Five Facet Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006), which the aforementioned factors are along with awareness, observing, describing, non-judging of inner experience, and non-reactivity to inner experience. We argue that the first three correspond to mindfulness' focus component noted above, while the last two correspond to mindfulness' quality component.

Mindfulness and Habitual Behaviors

As mentioned previously, research on mindfulness in the disciplines of psychology and medicine has grown exponentially in the last decade (UCI Mindful Health and Safety, n.d.). Studies involving mindfulness-based interventions (MBIs, usually a form of meditation instruction) demonstrate empirical support for mindfulness' effectiveness with helping participants reduce such problematic behaviors as binge and emotional eating (O'Reilly, Cook, Spruitt-Metz, & Black, 2014), use and misuse of substances such as alcohol, tobacco, cocaine, marijuana, and opiates (Chiesa & Serretti, 2014); and compulsive gambling (de Lisle, Dowling, & Allen, 2012).

Brewer (2016) proposes and supports through empirical research the notion that mindfulness' primary mechanism for helping people reduce problematic behaviors appears to be an intervention in the stimulus-response-reward cycle. This intervention creates a space of awareness between craving and the problematic behavior that would not otherwise occur. The mindful person strives for moment-to-moment awareness of internal mental and emotional events (the focus component of mindfulness), tries to refrain from judging those events (the quality component of mindfulness), de-centers (that is, dis-identifies) with those events, attempts to bring awareness to behavioral options related to the events, and tries to choose the most productive, healthy, and/or helpful behavioral option. For example, the mindful person who wants to reduce or stop smoking experiences a craving to smoke, brings awareness to that craving, refrains from judging the craving or herself as "bad," dis-identifies with that craving ("I am not the craving"), brings awareness to the behavioral options of smoking or not, and chooses not to (Brewer, 2016).

Applying this model to smartphone use, we propose that mindful people are, by definition, aware of their mindless urges to perform impulsive action, including those to check their smartphone devices or triggers, such as a frequent urge to check email, responding to an aural new text signal, or checking Facebook for responses to a post. We propose that mindful people's greater awareness of their technological urges, and their ability to refrain from being emotionally caught up in them, allows them also to refrain from action that could result from the urges.

Until now, only a few studies have explored the role of mindfulness in media use. A study by Panek, Bayer, Dal Cin, and Campbell (2015) revealed that the acting with awareness facet of trait (dispositional) mindfulness was negatively associated with dangerous texting behavior (i.e., texting while driving and walking). In a subsequent study, the researchers found that automatic texting tendencies were negatively related to the nonjudging, describing, and acting aware components of mindfulness (Bayer, Dal Cin, Campbell, & Panek, 2016). Charoensukmongkol (2016) investigated the effects of social media use in the workplace. The results suggest that mindfulness significantly moderated the effects of the intensity of social

media use on emotional exhaustion. More specifically, users who had a low level of mindfulness tended to experience higher emotional exhaustion. Furthermore, Bauer, Loy, Masur, and Schneider (2017) conducted a diary study to investigate the effects of day-specific mindfulness during instant messaging. The results showed that mindful instant messaging was positively related to users' well-being (i.e., more positive affect, less stress).

Researchers have used the term "guilty pleasure" to describe situations where individuals use media to receive immediate pleasure, although this usage behavior might damage their long-term goals (e.g., Panek, 2014). This happens frequently: In an experience sampling study among U.S. Americans, media use conflicted with goals or obligations in more than half of all observed media use situations (Reinecke & Hofmann, 2016). Enacting the desire to use media, although it conflicts with other goals, has been shown to cause feelings of guilt. Panek (2014) found that the use of media that are constantly available via smartphones (i.e., watching online videos, social networking) was related to feelings of guilt. He assumes that easy access to pleasurable media experiences fosters the enactment of desires. Supportively, it is described by mindfulness theory to result in mindful behavior (Brewer, 2016). Results from an experience sampling study by Friese and Hofmann (2016) support this assumption. They found, inter alia, that, when higher in state mindfulness, participants experienced less guilt after enacting everyday desires (e.g., food, media use). In a similar vein, trait mindfulness might prevent users from feeling guilty about their smartphone use. Based on these prior findings and the above-described model, our research will argue that the focus and quality components of trait mindfulness may help forestall or mitigate the problematic smartphone use that results in the unproductive distractions and interruptions that may continually occur (Gazzaley & Rosen, 2016). We propose the following hypotheses, which concern factors comprising the focus component of mindfulness:

- **H1a.** Mindful attention and awareness will be negatively correlated with smartphone vigilance, overall problematic smartphone use, and their component factors.

- **H1b.** Mindful observing will be negatively correlated with smartphone vigilance, overall problematic smartphone use, and their component factors.
- **H1c.** Mindful describing will be negatively correlated with smartphone vigilance, overall problematic smartphone use, and their component factors.
- **H1d.** Mindful acting with awareness will be negatively correlated with smartphone vigilance, overall problematic smartphone use, and their component factors.

We also propose the following hypotheses, which concern factors comprising the quality component of mindfulness:

- **H2a.** Non-judging of inner experience will be negatively correlated with smartphone vigilance, overall problematic smartphone use, and their component factors.
- **H2b.** Non-reactivity to inner experience will be negatively correlated with smartphone vigilance, overall problematic smartphone use, and their component factors.

Moreover, we propose the following hypothesis, which concerns feelings of guilt:

- **H3.** Non-judging of inner experience will be negatively correlated with feelings of guilt associated with smartphone use.

METHOD

Sample and Procedure

In order to test our hypotheses, we administered an online Qualtrics-based questionnaire to 401 students at a large public university in southern California and 145 participants (both students and non-students) in southwestern Germany. As an incentive for participation, the U.S. American

students were offered a small amount of extra credit in a course in which they were enrolled; the German participants were given the incentive of a small donation to a refugee aid organization for each person that participated. After removing participants who failed attention items in the questionnaire, the final number of participants analyzed was 515.

Measures

Where possible, this survey research used scales that were tried and tested. The online questionnaire was comprised of 7-point Likert scale items (strongly agree to strongly disagree) from the Mindful Awareness Attention Scale, and the Five Facet Mindfulness Questionnaire, as well as smartphone-revised versions of the Online Vigilance Scale and the Generalized Problematic Internet Use Scale 2 (see Appendix A for complete list of scale items).

Trait Mindfulness

The Mindful Awareness Attention Scale (MAAS; Brown & Ryan, 2003) is a validated and reliable single-factor scale which measures the mindful "receptive state of mind in which attention, informed by a sensitive awareness of what is occurring in the present, simply observes what is taking place" (Carlson & Brown, 2005, p. 1). The MAAS demonstrated strong reliability (Cronbach's $\alpha = .88$; $M = 3.65$; $SD = 0.94$; $n = 515$).

Because some researchers argue that mindfulness properly defined should include factors other than mindful awareness and attention, we also use the Five Facet Mindfulness Questionnaire-Short Form (FFMQ-SF; Baer et al., 2006) in this study. The FFMQ-SF is a reliable, valid, and widely used measure of mindfulness (Bohlmeijer, ten Klooster, Fledderus, Veehof, & Baer, 2011) which measures five factors of the mindfulness construct: acting with awareness (paying attention to one's actions; the items comprising this factor are the ones most similar to those of the MAAS, above), observing (moment-to-moment awareness of external and internal events), describing

(the ability to name these events), non-judging of inner experience (refraining from characterizing thoughts and feelings as good and bad and from resultant negative affect), and non-reactivity to inner experience (de-centering from emotional reactions through non-identification with one's feelings). The FFMQ-SF overall showed strong reliability (Cronbach's α = .88; M = 3.71; SD = 0.58; n = 515), as did the subscales measuring the five factors: acting with awareness (Cronbach's α = .90; M = 3.76; SD = 1.06; n = 514); observing (Cronbach's α = .75; M = 3.38; SD = 0.88; n = 514); describing (Cronbach's α = .77; M = 3.57; SD = 1.06; n = 515); non-judging of inner experience (Cronbach's α = .80; M = 3.92; SD = 1.27; n = 514); and non-reactivity to inner experience (Cronbach's α = .75; M = 3.86; SD = 0.82; n = 514).

Problematic Smartphone Use

The Online Vigilance Scale (OVS; Reinecke et al., 2016) is a validated, reliable, relatively new instrument designed to measure people's constant vigilance toward the handling "availability of online contacts and communication" (p. 1) [illegible] to quantify how engaged individuals are in online environments. The scale measures three factors: salience of the online sphere; reactibility; and monitoring. The scale authors envision online vigilance as less compulsive, less pathological, and much more prevalent than internet or smartphone addiction. The scale's items were modified slightly so that participants responded in terms of their smartphone use rather than their general online or internet behavior. The modified OVS showed good reliability overall (Cronbach's α = .70; M = 4.28; SD = 1.13; n = 515), as did its factor subscales: salience (Cronbach's α = .71; M = 4.78; SD = 1.26; n = 515); reactivity (Cronbach's α = .72; M = 3.83; SD = 1.30; n = 514); and monitoring (Cronbach's α = .70; M = 4.24; SD = 1.32; n = 514).

The Generalized Problematic Internet Use Scale 2 (GPIUS2; Caplan, 2010) is a validated and reliable instrument (Casale et al., 2016) which measures four factors considered more problematic than those measured by the Online Vigilance Scale: preference for online social interaction; mood regulation; deficient self-regulation; and negative outcomes. As with the

OVS, the scale's items were modified slightly so that participants were asked to respond in terms of their smartphone use rather than their internet use broadly. The modified GPIUS2 showed good reliability overall (Cronbach's α = .70; M = 4.94; SD = 1.12; n = 514), as did its factor subscales: preference for online social interaction (Cronbach's α = .70; M = 4.81; SD = 1.39; n = 514); mood regulation (Cronbach's α = .72; M = 4.40; SD = 1.43; n = 514); deficient self-regulation (Cronbach's α = .70; M = 4.88; SD = 1.33; n = 514); and negative outcomes (Cronbach's α = .72; M = 5.72; SD = 1.26; n = 514).

Feelings of Guilt

We adapted three items developed by Panek (2014) to measure guilt associated with smartphone use. This scale showed good reliability overall (Cronbach's α = .72; M = 4.93; SD = 1.41; n = 514).

Descriptives

The participants were 66% female and 34% male; the median age was 20; and stated racial distribution was as follows: 46.4% white; 26.6% declined to state a race; 16.7% stated "other"; 3.6% Asian; 3.3% African-American; 2.3% Native American; 0.9% Pacific Islander. 54.3% of participants described themselves as Latino, Hispanic, or Mexican-American.

Correlations

Table 1 shows correlations among the four scales and their factors.

Table 1. Correlations of the seventeen variables

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. MAAS mean	--																
2. OVS mean	- 0.45**	--															
3. GPIU2 mean	- 0.52**	0.73**	--														
4. FFMQ mean	0.59**	- 0.32**	-0.43**	--													
5. OVS: salience	- 0.51**	0.86**	0.70**	- 0.36**	--												
6. OVS: reactivity	- 0.33**	0.87**	0.55**	-0.24**	0.60**	--											
7. OVS: monitoring	- 0.45**	0.89**	0.67**	- 0.34**	0.66**	0.76**											
8. FFMQ: observing	0.16**	0.15**	0.1	-0.2	0.14**	0.12**	-0.12**										
9. FFMQ: describing	0.33**	- 0.15**	-0.29**	0.74**	- 0.22**	-0.08	-0.11*	0.13**	--								
10. FFMQ: non-judging	0.55**	- 0.38**	-0.47**	0.65**	- 0.41**	- 0.29**	-0.31**	-0.22**	0.29**	--							
11. FFMQ: non-reacting	- 0.09*	0.06	0.08	0.40**	0.06	0.02	0.07	0.47**	0.21**	-0.06	--						
12: FFMQ: acting with awareness	0.79**	- 0.52**	- 0.58**	0.70**	- 0.53**	- 0.42**	- 0.41**	- 0.09*	0.37**	0.58**	-0.01**	--					
13: GPIU2: POSI	- 0.33**	0.55**	0.74**	-0.31**	0.43**	0.33**	0.41**	0.01	-0.25**	-0.28**	0.08	-0.37**	--				
14. GPIU2: mood regulation	- 0.46**	0.55**	0.79**	-0.33**	0.53**	0.41**	0.51**	0.15**	-0.17**	-0.40**	0.02	-0.46**	0.51**	--			

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
15. GPIU2: deficient self-regulation	- 0.46**	0.77**	0.91**	-0.39**	0.71**	0.59**	0.73**	0.09**	0.25*	- 0.42**	0.06	- 0.53**	0.52**	0.62**	--		
16.GPIU2: negative. outcomes	- 0.47**	0.49**	0.78**	- 0.41**	0.55**	0.34**	0.40**	0.09*	- 0.28**	- 0.45**	0.10*	- 0.52**	0.48**	0.49**	0.64**	--	
17. Guilt items mean	- 0.41**	0.57**	0.70**	- 0.37**	0.58**	0.40**	0.50**	0.11**	- 0.24**	- 0.50**	0.07	- 0.49**	0.37**	0.49**	0.67**	0.71**	--

* $p < .05$. ** $p < .001$.

- **H1a.** As mindful attention and awareness have a statistically significant negative correlation with both smartphone vigilance as measured by the modified OVS ($r = -0.45$, $p < 0.01$) and its three component factors, as well as with generalized problematic smartphone use as measured by the modified GPIU2 ($r = -0.52$, $p < 0.01$) and its four component factors, hypothesis 1a is supported.
- **H1b.** As mindful observing (one of the factors of the Five Facet Mindfulness Questionnaire, FFMQ-SF) has statistically significant positive correlations with both smartphone vigilance ($r = 0.15$, $p < 0.01$) and problematic smartphone use ($r = 0.11$, $p = 0.02$), hypothesis 1b is not supported.
- **H1c.** As mindful describing (one of the factors of the FFMQ-SF) has statistically significant negative correlations with both smartphone vigilance ($r = -0.15$, $p < 0.01$) and problematic smartphone use ($r = -0.29$, $p < 0.01$), hypothesis 1c is supported.
- **H1d.** As mindf[illegible] with awareness (one of [illegible] factors of the FF[illegible]SF) has [illegible]ly [illegible]ca[illegible] negative correlations with both smartphone [illegible]igilance [illegible]0.52, [illegible]0.01 [illegible]nd problematic smartphone use ($r = -0.38$, p [illegible]0.01), hypothesis 1d is supported.
- **H2a.** As non-judging of inner experience (one of the factors of the FFMQ-SF) has a statistically significant negative relationship to smartphone vigilance ($r = -0.38$, $p < .01$) and all three of its factors, salience ($r = -0.41$, $p < 0.01$), reactivity ($r = -0.29$, $p < 0.01$) and monitoring ($r = -0.31$, $p < 0.01$), as well as to overall problematic smartphone use ($r = -0.47$, $p < 0.01$) and all four of its factors, preference for online social interaction ($r = -0.28$, $p < 0.01$); mood regulation ($r = -0.40$, $p < 0.01$); deficient self-regulation ($r = -0.42$, $p < 0.01$); and negative outcomes ($r = -0.45$, $p < 0.01$), hypothesis 2a is supported.
- **H2b.** As non-reacting to inner experience (a factor of the FFMQ-SF) has no statistically significant relationships to overall smartphone vigilance ($r = 0.06$, $p = 0.18$) or its three factors, salience ($r = 0.06$, $p = 0.15$), reactivity ($r = 0.02$, $p = 0.57$) and monitoring ($r = 0.07$, $p = 0.14$); and as it has no statistically significant correlation

with the overall problematic smartphone use ($r = 0.08$, $p < 0.08$), its three factors preference for online social interaction ($r = 0.08$, $p = 0.07$), mood regulation ($r = 0.02$, $p = 0.59$), and deficient self-regulation ($r = 0.06$, $p = 0.01$), and a statistically significant positive correlation with the fourth factor, negative outcomes ($r = 0.10$, $p = 0.02$), hypothesis 2b is not supported.

- **H3.** Non-judging of inner experience (a factor of the FFMQ-SF) is negatively correlated with feelings of guilt ($r = - 0.50$, $p < 0.01$). H3 is thus supported.

DISCUSSION

Based on theory and empirical research that indicate mindfulness, the intentional and non-judgmental attending to the present moment, can sometimes mitigate problematic habitual behaviors, we hypothesized that the various intervention components (attention and awareness, describing, and acting with awareness and quality of attention components of trait (dispositional) mindfulness (non-judging of and non-reacting to inner experience) would be negatively correlated with smartphone vigilance and problematic smartphone use. Three of the four hypotheses concerning focus of attention factors of mindfulness, namely attention and awareness, describing, and acting with awareness, were supported, indicating that the greater the attentional aspects of mindfulness, the less is our vigilance and habitual response to smartphones and the fewer are potentially problematic aspects of smartphone use such as preference for social interaction by phone and deficient self-regulation of phone use. Also, one of the two hypotheses concerning quality of attention factors of mindfulness, namely non-judging of inner experience, was supported, indicating that refraining from judging what we think and feel is correlated with a lessening of both smartphone vigilance and problematic smartphone use. These results seem to lend support to Brewer's model of how mindfulness facilitates intervention in problematic behaviors: that we can experience urges toward compulsive

unproductive behaviors, but if we are aware of them and refrain from judging them, we can resist acting on them.

We found no support for two hypotheses that predicted a negative correlation between two FFMQ-SF factors, mindful observing (H1b) and nonreacting to inner experience (H2a), and smartphone vigilance and problematic behaviors. This is puzzling, as mindful observing would at first seem to be closely related conceptually to the main factor in the MAAS, attention and awareness, and also to another FFMQ-SF factor, acting with awareness. However, the data actually show a statistically significant negative correlation between the mindful observing factor and both MAAS' attention and awareness and the FFMQ-SF's acting with awareness (which are strongly correlated with each other). Perhaps this can be explained by the nature of the mindful observing items, which pertain largely to awareness of bodily sensations such as the effect of food and drink; the feeling of wind and sun, and smells and aromas. It may be that this kind of awareness, which is an object of focus in such mindful meditation practices as MBSR's body scan and choiceless awareness, is more typical of mindfulness cultivated through formal meditation practice rather than that of the dispositional mindfulness that was measured in this study. Likewise, the non-reacting to inner experience items, which all ask about equanimity and a lack of reaction when one experiences distressing thoughts or images, may be a quality which is cultivated through formal mindfulness instruction and practice rather than inhering in those with other dispositional mindfulness traits such as acting with awareness.

Nevertheless, the data show a statistically significant negative correlation between the nonreacting to inner experience factor and feelings of guilt associated with smartphone use (H3). Smartphones permanently provide users with a plethora of immediate gratifications. Prior research indicates that this frequently causes 'guilty pleasure" experiences to the extent that users experience media-related goal conflicts (Panek, 2014; Reinecke & Hofmann, 2016). Importantly, the finding of this study regarding H3 suggests that trait mindfulness prevents users from judging their smartphone usage behavior and thus from feeling guilty about it.

Limitations and Future Research

As this study uses the survey method, only associations, not causality, can be derived from the data. In contrast to possible outcomes in experiments, which use a mindfulness-based intervention (MBI) as treatment, we lack grounds to argue that the focus and quality components of mindfulness cause lower levels of smartphone vigilance and problematic smartphone use. A related issue is that in this study we have attempted to measure trait or dispositional mindfulness, rather than cultivated mindfulness, which is conceived as being developed through a formal mindfulness practice such a regular sitting meditation. Rau and Williams (2016) argue that increasingly research finds these two types of mindfulness are distinct and have characteristics unique to each. Future experimental research could contribute to our understanding of whether mindfulness cultivated through an MBI could contribute to a mitigation of smartphone vigilance and smartphone problematic behaviors.

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APPENDIX A: SCALES COMPRISING THE STUDY QUESTIONNAIRE

Five Facet Mindfulness Questionnaire[4]

When I'm walking, I deliberately notice the sensations of my body moving.

I'm good at finding words to describe my feelings.

*I criticize myself for having irrational or inappropriate emotions.

I perceive my feelings and emotions without having to react to them.

*When I do things, my mind wanders off and I'm easily distracted.

When I take a shower or bath, I stay alert to the sensations of water on my body.

I can easily put my beliefs, opinions, and expectations into words.

*I don't pay attention to what I'm doing because I'm daydreaming, worrying, or otherwise distracted.

I watch my feelings without getting lost in them.

*I tell myself I shouldn't be feeling the way I'm feeling.

I notice how foods and drinks affect my thoughts, bodily sensations, and emotions.

*It's hard for me to find the words to describe what I'm thinking.

*I am easily distracted.

*I believe some of my thoughts are abnormal or bad and I shouldn't think that way.

[4] *indicates reverse scoring

I pay attention to sensations, such as the wind in my hair or sun on my face.

*I have trouble thinking of the right words to express how I feel about things.

*I make judgments about whether my thoughts are good or bad.

*I find it difficult to stay focused on what's happening in the present.

When I have distressing thoughts or images, I "step back" and am aware of the thought or image without getting taken over by it.

I pay attention to sounds, such as clocks ticking, birds chirping, or cars passing.

In difficult situations, I can pause without immediately reacting.

*When I have a sensation in my body, it's difficult for me to describe it because I can't find the right words.

*It seems I am "running on automatic" without much awareness of what I'm doing.

When I have distressing thoughts or images, I feel calm soon after.

*I tell myself that I should not be thinking the way I'm thinking.

I notice the smells and aromas of things.

Even when I'm feeling terribly upset I can find a way to put it into words.

*I rush through activities without being really attentive to them.

When I have distressing thoughts or images I am able just to notice them without reacting.

*I think some of my emotions are bad or inappropriate and I shouldn't feel them.

I notice visual elements in art or nature, such as colors, shapes, textures, or patterns of light and shadow.

My natural tendency is to put my experiences into words.

When I have distressing thoughts or images, I just notice them and let them go.

*I do jobs or tasks automatically without being aware of what I'm doing.

*When I have distressing thoughts or images, I judge myself as good or bad, depending what the thought/image is about.

I pay attention to how my emotions affect my thoughts and behavior.

I can usually describe how I feel at the moment in considerable detail.

*I find myself doing things without paying attention.

*I disapprove of myself when I have irrational ideas.

Mindful Awareness and Attention Scale

*I could be experiencing some emotion and not be conscious of it until sometime later.

*I break or spill things because of carelessness, not paying attention, or thinking of something else.

*I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.

*I tend not to notice feelings of physical tension or discomfort until they really grab my attention.

*I forget a person's name almost as soon as I've been told it for the first time.

*It seems I am "running on automatic," without much awareness of what I'm doing.

*I rush through activities without being really attentive to them.

*I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.

*I do jobs or tasks automatically, without being aware of what I'm doing.

*I find myself listening with one ear, doing something else at the same time.

*I drive places on "automatic pilot" and then wonder why I went there.

*I find myself preoccupied with the future or the past.

*I find myself doing things without paying attention.

*I snack without being aware that I'm eating.

Online Vigilance Scale (Modified to Ask about Smartphones)

My thoughts often drift to my smartphone.

I have a hard time mentally disengaging from my smartphone.

Even when I am in a conversation with other people, I often think about what is happening on my smartphone in the back of my mind.

My smartphone content often occupies my thoughts even if I am dealing with other things.

When I receive a message on my smartphone, my thoughts drift there immediately.

When I receive a message on my smartphone, it triggers an impulse in me to check it right away.

When I receive a message on my smartphone, I immediately attend to it, even if I am engaged in other things right then.

When I receive a message on my smartphone, I immediately give it my full attention.

I constantly monitor what is happening on my smartphone.

I often feel the urge to check what is happening on my smartphone.

I often start certain smartphone applications so I don't miss out.

I always keep an eye on what is happening on my smartphone.

General Problematic Internet Use Scale 2 (Modified to Ask about Smartphones)

Social interaction using texts or social apps on my smartphone is more comfortable for me than face-to-face interaction.

When I haven't checked my smartphone for some time, I become preoccupied with thoughts of checking it.

I prefer communicating with people by text or social apps on my smartphone rather than face-to-face.

I have used text or social apps on my smartphone to make myself feel better when I was down.

I have used text or social apps on my smartphone to talk with others when I was feeling isolated.

I have difficulty controlling the amount of time I spend texting or using social apps on my smartphone.

I have missed social engagements or activities because of my smartphone use.

I have used texting or social apps on my smartphone to make myself feel better when I've felt upset.

I would feel lost if I was unable to use texting or social apps on my smartphone.

I find it difficult to control my smartphone use.

When I am unable to use my smartphone, I think obsessively about using it.

When my smartphone is off, I have a hard time resisting the urge to use it.

I prefer social interaction using texting or social apps on my smartphone instead of face-to-face interaction.

My smartphone use has created problems for me in my life.

My smartphone use has made it difficult for me to manage my life.

For Review

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Chapter 9

MINDFULNESS TRAINING IN THE COMMUNICATION CLASSROOM: EFFECTS ON COMMUNICATION COMPETENCE, EMOTION REGULATION, AND EMOTIONAL INTELLIGENCE

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ABSTRACT

This chapter presents a study meant to assess the effects of mindfulness training in college Communication classes. Participants (N = 124) received mindfulness teaching/exercises alongside an introductory communication curriculum. They took pre- and post-tests on their trait mindfulness, emotion regulation, and emotional intelligence. They also

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had someone close to them complete pre- and post-tests assessing their communication competence. Our results showed that participants increased in their self-reports on all facets of mindfulness over the course. As predicted, students also increased in their reported ability to take others' perspective, positive appraisal, focus on planning, and positive refocusing, and they decreased their self-blame, other-blame, catastrophizing, and rumination, all aspects of emotion regulation. Participants also increased in others' reports of their communication competence and in their own assessment of trait emotional intelligence. These results suggest that communication classes combined with mindfulness training have measurable benefits and point the way toward teaching methodologies and the refinement of studies related to infusing mindfulness into communication curricula.

Keywords: mindfulness, communication, emotion regulation, emotional intelligence

INTRODUCTION

Mindfulness, as a spiritual practice, has existed for more than 2500 years and is the oldest known way to calm one's mind and gain insight into the self and the world (Huston, Garland, & Farb, 2011). It has reemerged more recently in the West as a largely secular means for promoting psychological and physical well-being, primarily generated through the work of Jon Kabat-Zinn (1990, 1994). For Kabat-Zinn (1990), people are healthiest when they celebrate life in its "full catastrophe" including "the inevitability of all its dilemmas, sorrows, tragedies, and ironies" (p. 5). To do so, however, it is easier if people are able to "live intentionally and from moment to moment" (Kabat-Zinn, 1990, p. 19). That is, people are more able to move successfully through many aspects of their lives if they do so mindfully.

Researchers who study this contemporary understanding of mindfulness describe it as "a receptive state of mind, wherein attention is kept to a bare registering of the facts observed…the basic capacities for awareness and attention permit the individual to be present to reality…rather than react to it or habitually process it" (Brown, Ryan, & Creswell, 2007, p. 212). Greco, Baer, and Smith (2011) state that elements of mindfulness include "observation of present-moment experience, behaving with awareness of

one's current actions (rather than automatically or absentmindedly), and taking a nonjudgmental and nonreactive stance toward internal experiences such as cognitions, emotions, and bodily sensations" (p. 607).

This modern conceptualization of mindfulness asserts that people have varying degrees of mindfulness both overall (i.e., trait or dispositional mindfulness) and at any one time (i.e., state mindfulness). Additionally, people can be trained and engage in ongoing practices, such as mindful meditation, that can enhance their everyday mindfulness. Importantly, greater mindfulness (either as a trait/state or brought about through training) has been linked with myriad benefits, including lower levels of depression and anxiety, addictive behavior, and chronic distress or pain (Evans, Ferrando, Carr, & Haglin, 2010; Kabat-Zinn & Chapman-Waldrop, 1988; Kerr, Josyula, & Littenberg, 2011). These benefits are thought to occur, at least in part, because being mindful discourages personal biases or reflections on past encounters that would otherwise influence evaluations of the present moment (Brown & Ryan, 2003; Teasdale, 1999).

Given its role in aiding cognition, emotion, and problematic behavior, it is no surprise that researchers have begun to study mindfulness and mindfulness training in educational settings, with the idea that reductions in maladaptive processes can aid in greater school achievement and other benefits. Ames, Richardson, Payne, and Leigh (2014), for example, provided mindfulness training in schools and found that the young people they studied had reduced depression and rumination and increased mindfulness skills and overall life quality. Moreover, the authors learned through interviews that the students thought that the training was an acceptable set of practices to undertake for people in their age group. Sibinga et al. (2013) likewise found that mindfulness training of young urban males in schools reduced the students' stress and rumination, and Jennings and Jennings (2013) reported that even a short training with peers helped students increase their mindfulness and decrease their problematic thoughts.

The research on mindfulness training in education has shown tremendous promise, but it has focused on its effects primarily in K-12 rather than college classrooms. More recently, there has been an increased call for mindfulness to be incorporated into college-level classes or as part of college

life more broadly (e.g., Kuechler & Stedham, 2018). In 1998, however, King and Sawyer argued for mindfulness instruction in relevant college-level Communication courses specifically. That is, mindfulness training is argued to have a place in higher education, and it may play a particular role within the communication discipline (Huston, 2016; Huston et al., 2011). The present paper seeks to provide additional support for the effects of mindfulness training *in college-level communication classes*, with a particular focus on the role mindfulness plays in increasing communicative competence, regulating emotion, and expanding emotional intelligence.

Mindfulness and Mindfulness Training

As noted, studies of mindfulness look both at a person's pre-existing mindfulness (usually described as trait or dispositional mindfulness) and/or mindfulness training (programs developed to provide practices for increasing mindfulness [illegible] life and instruction on what it means to [illegible]. The most [illegible] of mindfulness [illegible] Mindfulness-Based Stress Reduction (MBSR) training. MBSR courses involve an 8-week, once a week program in which participants learn various strategies designed to increase their capacity for being mindful alongside talks that help deepen their understanding of what it means to be mindful. The practices include guided meditation, group discussions, mindful yoga, and daily take-home meditation assignments. Participants who have completed the program report increases in self-esteem, ability to cope with stressful life events, and overall energy levels as well as decreases in pain levels for a number of chronic conditions (Center for Mindfulness in Medicine, Healthcare, & Society, 2013).

Other courses have developed since the creation of the MBSR that cater to particular populations (e.g., couples: Carson, Carson, Gil, & Baucom, 2004; adolescents: Ames et al., 2014). Additionally, shorter courses that do not take the same resources have been advanced, including one by Sroka, Isemann, and Walther (2017) that focuses on meditation and breath exercises with incarcerated youth. These modified courses are often adapted for the

particular population with which they are used (e.g., Brotto & Heiman, 2007, incorporated mindfulness practices into a larger psychoeducational program that they designed for women with sexual dysfunction as a result of gynecologic cancer).

Multiple measures have also been developed to tap into trait or state mindfulness, often to look for differences in mindfulness before and after training or used in correlational studies that look at dispositional mindfulness's association with other variables. Again, some of these measures were created for particular populations (e.g., Greco et al., 2011, developed the Child and Mindfulness Measure; CAAM). But most are used with a larger population (e.g., Baer, Smith, & Allen's 2004 Kentucky Inventory of Mindfulness Skills), with one of the most common being the Five-Factor Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). For a review of many of these measures and the tie to the communication discipline more broadly, see Manusov and Harvey-Knowles (2015).

Notably, Baer et al.'s (2006) factor analysis suggested several components of mindfulness: observing, describing, acting with awareness, nonjudgment, and nonreactivity. *Mindful observing* refers to individuals' ability to recognize and focus on internal and external stimuli, such as taking note of sounds, smells, or sights. *Mindful describing* is the ability to identify and express present-moment experience to others. *Acting with awareness* involves attending to only one aspect of the present-moment rather than being distracted by other external events while engaging in action. *Nonjudgment (or withholding of judgment)* includes refraining from evaluating, or negatively judging, present-moment occurrences. *Non-reactivity* assesses individuals' ability to keep from reacting negatively to undesired (internal or external) stimuli.

Mindfulness in Education

As researchers identified populations that could both be trained in and assessed for their degree of mindfulness, many of their studies centered on

mindfulness in young people. For instance, Greco et al., (2011) used the CAMM across four studies and over 1400 participants and determined that mindfulness scores correlated positively and as expected with better quality of life, academic competence, and social skills and was related negatively to "somatic complaints, internalizing symptoms, and externalizing behavior problems" (p. 606). Using a scale created for adults, Ciesla, Reilly, Dickson, Emanuel, and Updegraff (2012) also found trait mindfulness in young adults relates positively to mood and negatively to susceptibility to stress. Moreover, Jennings and Jennings (2013) found that adolescents could direct their peers in a short (four 50-minute sessions over three weeks) mindfulness training, which decreased the students' negative cognitions (e.g., self-deprecation and excessive worrying). Additionally, Shapiro, Schwartz, and Bonner (1998) asserted that mindfulness training within the educational context may work to cultivate listening skills.

As noted, the focus of much of this research has been on younger students. Grinnell, Greene, Melanson, Blissmer, and Lofgren (2011), however, looked at first-year college students and found those in their "mindfulness group gained knowledge about nutrition, health, academics, and [those] who were assessed as less stressful." Using a brief 20-minute mindfulness training, Mermelstein, Garske, and Petry (2015) learned that binge drinkers in a mindfulness training group, as compared to those in a control group, reported fewer binge episodes and negative consequences of alcohol use as well as higher self-efficacy and dispositional mindfulness. Enriquez, Ramos, and Esparza (2017), using a modified training that combined mindfulness with emotion regulation, found that their process helped college students become more empathic, have less burn out, and do better with planning, among other outcomes.

This burgeoning research on mindfulness training in higher education looks typically at the role that training *outside* of the classroom has on education-related variables for those students. More recently, work has begun to investigate how mindfulness trainings that are *incorporated into curricula* affect students' outcomes within their classes. Specifically, Keuchler and Stedham (2018) investigated the effects of mindfulness training in MBA classes centered on transformational leadership. The

authors argued that the bases of mindfulness (i.e., awareness of the present moment) are likely to enhance students' capacity for such leadership, and their analyses supported that contention. Specifically, in addition to increases in the students' mindfulness, the authors found that the students increased in their awareness of self- and other-perspective and their acceptance of novel perspectives, all key components in effective transformational leadership.

Likewise, a central question for those who study communication education is to look for associations between mindfulness and other variables and/or to measure the results of mindfulness training in our classrooms (Huston, 2010). Recent work by Huston et al. (2011) began this process by assessing the effects of mindfulness training in college communication classes. In their study, the authors compared 20 students who took an introductory course in communication that had a mindfulness component to a group of 24 students who took the same class content without the mindfulness training. In their pre-posttest design, the authors found that being in the course (with or without mindfulness) improved student ability to reappraise positively [illegible] that [illegible] attribute to the nature of the content and the [illegible] assignments and activities important component of effective communication.

Importantly, however, those with the mindfulness curriculum also increased in their mindfulness scores, which may have affected the nature of their positive reappraisal. Specifically, the control group's reappraisal correlated with a shift in blame from self to other, whereas the reappraisal of the mindfulness group was associated with an increased ability to articulate their feelings (positively describe) and refrain from reacting to negativity (non-react). A path analysis also showed that their positive reappraisal predicted less likelihood of blaming others, all of which is consistent with Kabat-Zinn's (1990) definition of being mindful and a way of being that is more likely to bring about salutary effects on communication ability. Although promising, particularly "as one mechanism for reducing negative reactivity in communication" (Huston et al., 2011, p. 406), the small size of the study suggests that more research to explore this outcome is important.

Mindfulness and Communication

Understanding the possible connections between communication and mindfulness may help in exploring the ways in which incorporating mindfulness into communication classes may have benefit. A range of scholars have called for mindfulness to be studied as related to or affecting communication or related constructs, such as empathy (e.g., Dekeyser, Raes, Leijssen, Leysen, & Dewulf, 2008; Jones & Hansen, 2015; Manusov & Harvey-Knowles, 2015; Ucok, 2006), and for assessing what "mindful communication" might entail (Huston, 2010; Stroud, 2010), though most of this has not been applied to the communication classroom. Ucok (2006), for example, argues for, but does not measure, the role that mindfulness can play in our ability to listen and in nonverbal engagement. In empirical validations of this, Jones, Bodie, and Hughes (2016) found that components of mindfulness (i.e., mindful observing and describing) predict active listening and empathy, and Stofle, Manusov, Crowley, and Harvey-Knowles (2015) studied couples' active empathic listening, and skills, mindfulness scores, and relational quality, and found that [illegible] mediated the relationship between mindful skills and listening and the association between listening and relational satisfaction. Harvey-Knowles, Manusov, and Crowley (2015) also assessed trait mindfulness and found that it correlates with self-reported conflict behavior. In particular, people whose scores on acting with awareness and nonjudgment were higher reported that they used less dominance in their conflict; those higher in the mindful ability to describe reported a greater tendency to compromise and less tendency to avoid conflict.

Huston et al., (2011), as noted, had a particular interest in the effects of mindfulness training in the communication classroom. They focused specifically on the relationships between mindfulness and people's ability to open more fully to any moment—whether there is conflict happening or not—recognize internal and external influences on their behavior, and use that awareness to make effective decisions about how to communicate in that moment. The authors note in particular that positive reappraisal ("a cognitive process through which stressful events are re-constructed as

benign, beneficial, and/or meaningful" p. 497) is part of one's overall communication efficacy, and thus looking for how it can be enhanced is meaningful. Like Jones et al. (2016), who studied people's ability to facilitate reappraisals while providing social support, Huston et al. (2011) found that teaching about communication itself enhances positive reappraisal, but those who also received mindfulness training ("as [an] explicit means of changing communication strategies"; p. 415) in the communication classroom improved the use of positive reappraisal, which as predicted correlated with decreased other-blame, a finding that did not occur with those who took the course without the mindfulness component.

Garland, Farb, Goldin, and Fredrickson (2015a, b) provide a model for why mindfulness may work as it does for enhancing reappraisals. In their mindfulness-to-meaning theory, an evolution from an earlier "mindful coping" model (Garland, Gaylord, & Park, 2009), the authors work to "undo the conflation of mindfulness with reappraisal" (Garland et al., 2015b, p. 378). Although other work has asserted that mindfulness is "antithetical to reappraisal due to its nonjudgmental or nonconceptual approach to affective experience" (Garland et al., 2015, p. 377), the authors note that the traditional Buddhist conception of mindfulness and its ability to stabilize attention and affect (i.e., increase emotion regulation), which then allows for greater cognitive insight, including productive reappraisal or "reenvisioning adversity" (p. 308). These findings lead to our first three hypotheses:

- **H1:** Students in communication classes with mindfulness training will increase in their trait mindfulness from assessments at the start of the course.
- **H2:** Students with mindfulness training in their communication course will report greater emotion regulation at the end of the course than at the start of the course, particularly through positive reappraisal.
- **H3:** Post-class reports of trait mindfulness and facets of emotion regulation that enhance positive reappraisal will be positively correlated for students taking communication courses with

mindfulness training incorporated; those facets of emotion regulation that are detrimental (e.g., rumination) will be negatively associated with mindfulness factors.

Additionally, in other work (Huston, 2010, 2016), mindfulness in the communication classroom is argued to enhance emotional intelligence (Mayer & Salovey, 1997). Goleman (2008) defines emotional intelligence as "being intelligent about our social life: more aware, better able to handle disturbing emotions, more sensitive to the emotions of others—and able to put all that together to create effective, nourishing interactions" (p. ix). Huston (2016) asserts that increasing mindfulness can help people during the "refractory period" (Ekman, 2003) during an emotional experience when it is difficult for most people to calm themselves enough to appraise the experience effectively. Huston (2016) also contends, however, that it is not just in emotionally charged situations when people's perception can be "off": Mindfulness can help people increase their awareness of internal and external influences in all of the communication experiences. This leads to our fourth prediction:

- **H4:** Students in communication courses with mindfulness training will increase in their emotional intelligence from assessments at the start of the course.

Given that both mindfulness and communication learning in the classroom have been found to enhance communication skills (Huston et al., 2011; Morreale, Hackman, & Neer, 1998), and because it is important not to "trade off" one capacity for another (i.e., the benefits in their own communication as a result of taking a more typical communication curriculum), we propose a final prediction:

- **H5:** Students in communication courses with mindfulness training will increase in others' reports of their communication competence from assessments at the start of the course.

METHOD

Participants

Participants (N = 124) in this study were students enrolled in introductory communication classes at a small Northeast community college. Of these, 87 identified as female (70%) and 35 as male (28%). Two did not identify their sex. Their mean age was 22.3, ranging from 17 to 58 (SD = 7.14). They represented 11 majors. Twenty-three said that they were first semester freshmen, 42 were returning freshmen, 23 were "seniors" (last year), and 36 were "other."

Procedure

After IRB review was complete, students enrolled in an introduction to communication class, [illegible] several instructors, were given the opportunity to take surveys at the start and the end of the semester for extra credit and to invite someone with whom they interacted often to also complete two measures about them. These classes occurred between Autumn 2012 and Spring 2014. Students were told that the study was being conducted to identify specific outcomes of communication courses at the college. They were assured of the voluntary and anonymous nature of the project.

The communication classes focused on three areas: intrapersonal communication, interpersonal communication, and public speaking. Topics included the self-concept, verbal and nonverbal communication, listening skills, self-perception, other-perception, as well as cultural and ethical dimensions of communication (the same as are covered in the class without mindfulness instruction). The classes for this study also included instruction in mindfulness and meditation. All of the instructors for these classes had mindfulness training and active practices. For eight weeks out of the 15-week semesters (consistent with the MBSR), that instruction included the following:

1. Students were told the premise of the course, which was as follows: There are no hard and fast rules of what one "should" do in order to communicate effectively. Each moment is different. Therefore, the ability to communicate effectively is largely dependent on a person's ability to be fully present and aware of the particular components of any given situation. They are encouraged to consider communication concepts as internal and external influences on their behavior and to use an increased awareness of those concepts to make effective decisions in any given situation. Those decisions often differ from the habitual, reactive communication patterns that people often develop over the course of their lives. Teachers explained to students that mindfulness is essentially the ability to be fully present, which is not as easy as it may sound, and that part of this course, therefore, incudes activities and assignments that nurture that ability, including mindfulness meditation.
2. Class discussions included what students noticed in their day-to-day lives when they "ope[ned]" to the moments of their lives by continuously re[fr]aming the[m] as "this moment has never happened before and will never occur again." For many students, this was a new way of paying attention: They are not looking for anything in particular; instead, they are allowing themselves to experience the fleeting, fresh quality of each moment before imposing judgments, expectations, or assumptions on those moments. Students kept an "awareness notebook" to prepare for these discussions.
3. Exercises that relate to communication theory, concepts, and skills were included. Though these exercises are not necessarily specific to mindfulness, teachers related some of the concepts to aspects of mindfulness.
4. The mindfulness meditations done in class are similar to those done in MBSR classes, including breath-centered meditation; awareness of sounds, thoughts, and emotions; the practice of "noting" or "affect labeling"; body scans; loving-kindness; and open-presence meditation. Students were given access to these recorded

meditations and were invited—but not required—to do them on their own outside of class. They range in length from 7 minutes to 20 minutes.

5. Students used a textbook specifically written to teach mindful communication (Huston, 2016). Chapters include information about mindfulness, communication theory, and emotional intelligence. Each chapter ends with an application journal that consists of questions designed to encourage students to apply mindful communication in their lives.

The remaining seven weeks of the semester consisted primarily of completing speeches and group projects similar to those included in most introductory communication courses. Students in the mindfulness sections were, however, given suggestions for how to apply aspects of mindfulness and mindful communication to the completion of those assignments. More information on these steps can be attained from the second author.

Survey Measures

Participants in this study completed demographic information at the start of the course and three measures at the start (pre-test) and the completion of the semester (post-test). When a participant completed the pre-test (via a link to a website), he/she also was asked to provide the name and contact information of someone he/she interacts with regularly who was willing to participate in the study by completing a separate pre- and post-survey with questions about the student's communication skills. The third party was sent a link to both the pre- and post-tests independently of the student's links and included boyfriend/girlfriends, close friends, cousins, children, parents, step-parents, friends, spouses, and fiancé/es. About half of the participants had someone complete both sets of these measures.

Reliabilities in the following section were conducted on the pre-measures. Missing data were substituted with that person's most common score.

Five-Factor Mindfulness Questionnaire (FFMQ)

This assessment was developed by Baer et al. (2006) and is a widely-used 39-item (5 point scale) measure that assesses five dimensions of mindfulness: nonreactivity; observing; acting with awareness (a reverse-coded variable); mindful describing; and nonjudgment (reverse-coded) (Baer et al., 2006, provide evidence for its conceptual and measurement validity), *with higher scores indicating greater mindfulness once all are reverse-coded*. Sample questions in the FFMQ include "In difficult situations, I can pause without immediately reacting" and "I notice visual elements in art or nature, such as colors, shapes, textures, or patterns of light and shadow." Cronbach's *alphas* in the present study were .79 (observe), .91 (describe), .89 (acting with awareness), .89 (nonjudgment), and .70 (nonreact).

Cognitive Emotion Regulation Questionnaire (CERQ)

The CERQ was dev[illegible] by Garnefski, Kraaiji, and Spinoven (2001) a[illegible] go[illegible]ternal c[illegible]iste[illegible] an[illegible]dity (see Garnefski et al., 2001) for [illegible]k[illegible] the meas[illegible]p[illegible]cip[illegible]the[illegible]win[illegible] 'E[illegible]y[illegible]ge[illegible] co[illegible]ited[illegible]th negativ[illegible]r un[illegible]asa[illegible]nts no[illegible]and t[illegible]n, an[illegible]yone responds to them in his or her own way. By the following questions you are asked to indicate what you generally think, when you experience negative or unpleasant events." Response scales of the items ranged from 1 = (al*most) never* to 5 = (*almost) always.* Individual subscale scores were obtained by summing up the scores belonging to the particular subscale (possible range per subscale: 4–20). Higher scores refer to more common use of the specific construct.

The CERQ consists of 36 items that measure nine cognitions (measured with four items each): (1) *positive reappraisal*, which involves thoughts that attaching a positive meaning to the events in terms of personal growth or development (e.g., "I think I can learn something from what happened") (2) *refocus on planning*, which refers to thinking about steps to take and how to handle negative events and does not automatically imply that actual behavior will follow (e.g., "I think about how to change the situation"), (3)

catastrophizing or thoughts that emphasize the terror of the experiences (e.g., "I often think what I experienced is the worst that can happen to a person"), (4) *blame others* (e.g., I feel that basically the cause lies with others"), (5) *self-blame* or thoughts of blaming oneself for what one has experienced (e.g., "I feel that I am the one to blame for it"), (6) *acceptance*, which involves thoughts of accepting what one has experienced and resigning oneself to what has happened (e.g., "I think that I have to accept that this has happened"), (7) *rumination or focus on thought* refers to thinking about the feelings and thoughts associated with negative events (e.g., "I often think about how I feel about what I have experienced"), (8) *putting into perspective*, which "plays down" the seriousness of the events or emphasizing its relativity when compared to other events (e.g., "I tell myself that there are worse things in life"), and (9) *positive refocusing*, which involves thoughts about joyful and pleasant issues rather than about the actual events (e.g., "I think of something nice instead of what has happened"). Cronbach *alpha* reliabilities in the present study were as follows: .77 for positive appraisals, .70 for focus on planning, .71 for catastrophizing, .72 for self-blame, .74 for self-blame, .[illegible] for acceptance, .[illegible] for rumination, .76 for putting into perspective, and .74 for positive refocusing.

Trait Emotional Intelligence Questionnaire (TEIQue-SF)

This measure was created by Petrides and Furnham (2006) to assess overall emotional intelligence (in both a long, multi-factor and short form, which we use here). It is based on previous measures and has strong psychometric properties (Petrides, 2009). It is a 30-item measure, assessed on 7-point scales (1 = completely disagree and 7 = completely agree). Sample items include "I'm normally able to 'get into someone's shoes' and experience their emotions" and "Those close to me often complain that I don't treat them right" (recoded). Scores were created (after recoding negatively worded items) by adding the 30 items together. Cronbach's *alpha* for this measure in the current study was .89.

Communication Competence Scale

Created by Weimann in 1977, this 36-item measure uses a 5-point scale (1 = strongly agree; 5 = strongly disagree) and is designed to measure assessments of another's communicative ability (items include "treats people as individuals" and "interrupts me too much"). Weimann reports that the measure should be treated as unidimensional (with a reported scale reliability of .96), although there are five subcomponents of this measure: flexibility, interaction management, affiliation, empathy, and social relaxation. As noted, participants in this study were asked to have someone with whom they interacted often complete this measure (e.g., friends, family members, or coworkers) at the start and end of the semester. Cronbach's *alpha* for the measure in the current study was .91.

RESULTS

[illegible] one pre-[illegible] st[illegible] a[illegible]mi[illegible] w[illegible] mindfulness components would increase in their mindfulness scores when comparing pre- and post-class assessment. Consistent with the scale (Baer et al., 2006), we assessed each of the five factors of mindfulness separately. To test the hypothesis, we conducted five paired-sample t-tests, one with each of the five mindfulness factors. All results were consistent with expectations: Participants were more likely to report that they would be less reactive after the class (M = 23.03) than before (M = 19.33), $t(123) = 9.38$, $p < .05$. They also had higher mindful observe scores after the class (M = 28.95) than before (M = 25.95), $t(123) = 6.25$, $p < .05$. (M = 23.03). Their scores on nonjudgment (M = 21.74 pre-class; M = 23.53 post-class, $t[123] = 3.29$, $p < .05$) and acting with awareness also went up after the class (M = 26.84) as compared to before (M = 22.95), $t(123) = 6.56$, $p = .05$. Likewise, students' scores on mindful describing also went up (M = 25.85 pre-class; M = 28.15 post-class, $t[123] = 4.91$, $p < .05$). Hypothesis one was fully supported.

To assess whether these effects were consistent across teachers, we created difference scores by subtracting pre-scores from post-scores for each

of the five mindfulness factors (one teacher had only one student in the class who participated; the analysis requires at least three per cell, so that participant was not included in this analysis). We found no significant teacher differences. Reviewing the means, however, we noted that some teachers had mean scores that went down (lower mindfulness) on acting with awareness (one teacher), nonjudgment (two teachers), and mindful describe (two teachers). We offer ideas based on these findings in the discussion section.

Hypothesis two predicted that students in a communication course with a mindfulness component would increase in their emotion regulation scores when comparing pre- and post-class assessment. This hypothesis was almost fully supported. Students were less likely to self-blame after the class (M = 9.63) than before (M = 10.79), $t(123) = 3.62$, $p < .05$. They were less likely ruminate after the class (M = 11.06) than before (M = 11.75), $t(123) = 1.95$, $p = .05$. Students were more likely to positively refocus after the class (M = 11.74) than before (M = 10.14), $t(123) = 5.23$, $p < .05$, and they were more likely to focus on planning after the class (M = 13.73) than before (M = 13.71), $t(123) = 3.66$, $p < .05$. Additionally, they reported more likely to positively reappraise after the class (M = 14.93) than before (M = 13.58), $t(123) = 4.32$, $p < .05$ and to take another's perspective after the class (M = 13.77) than before (M = 13.07), $t(123) = 3.62$, $p < .05$. Finally, they were less likely to catastrophize after the class (M = 7.34) than before (M = 8.34), $t(123) = 3.04$ $p < .05$ as well as less likely to other-blame after the class (M = 8.31) than before (M = 7.82), $t(123) = 1.98$, $p < .05$. The only variable that did not show a significant change was acceptance, $t(123) = .64$, $p > .05$.

Hypothesis three predicted correlations among the post-class mindfulness subscales and the post-class CERQ subscales, consistent with Huston et al. (2011). We found significant ($p \leq .05$) positive 1-tailed Pearson correlations between mindful describing and positive refocus (r = .29), acceptance (r = .27), planning (r = .46), perspective-taking (r = .33), and positive reappraisal (r = .42), as expected; we also found significant negative correlations, consistent with the hypothesis: catastrophizing (r = -20.), rumination (r = -.33), self-blame (r = -.21), and other-blame (r = -.27) that also supported our predictions. There were also significant positive

correlations between mindful observing and positive refocus (r = .20), acceptance (r = .27), planning (r = .47), perspective (r = .31), and positive reappraisal (r = .47) and a negative correlation with other-blame (r = -.22). Positive correlations were also found with mindful non-react and positive refocus (r = .28), acceptance (r = .27), planning (r = .47), positive reappraisal (r = .47), and taking another's perspective (r = .32), and an expected negative correlation with catastrophizing (r = -.29). For nonjudgment, there were expected positive relationships with some variables (positive refocus = .20, planning = .26, positive reappraisal = .33) and predicted negative ones with others (rumination = -.34, catastrophizing = -.43, and other blame = -.35). Acting with awareness correlated positively with planning = .37, positive refocus = .18, positive reappraisal = .50, and perspective-taking = .26, and it correlated negatively with rumination = -.29, catastrophizing = -.40, self-blame = -.22, and other blame = -.38. Hypothesis three was largely supported. Hypothesis four predicted that students in a communication course with a mindfulness component would increase in their emotional intelligence scores when comparing pre- and post-class assessments. A paired-sample t-test with the trait emotional intelligence scores and pre-class confirmed the hypothesis. Students scores were higher after the class (M = 150.81) than before (M = 141.56), $t(123) = 5.41$, $p < .05$. Finally, hypothesis five predicted that students taking a communication course with a mindfulness component would improve in their communication competence, as assessed by someone who interacts with them regularly. A paired-sample t-test was performed for others' assessment pre- and post-class for those with completed measures (n = 67). It was significant, $t(66) = 1.99$, p = .05. Students scored more highly after the class (M = 134, SD = 13.49) than prior to the course (M = 131, SD = 13.36). The hypothesis was confirmed.

DISCUSSION

As mindfulness in education grows, one challenge is finding a way to infuse the teaching of mindfulness into already full schedules that make up

many degree programs. A means for doing so is to find courses in which including mindfulness would not only allow for the teaching of mindfulness *but also enhance the understanding of the course's core content and outcomes*. This study and others (e.g., Huston et al., 2011) suggest that the infusion of mindfulness into introductory communication courses may serve both purposes. In the present study, our participants, in classes that included mindfulness concepts and practices, increased in assessments of their emotional control, emotional intelligence, and communicative competence. Huston et al. (2011) found similar results and were also able to compare students taking a course with a mindfulness component to one that had a "regular" communication curriculum, revealing that the mindfulness group improved in its ability to reappraise stressful events alongside an increased ability to identify and express emotions and experience less reactivity to negative stimuli and other-blame in a way not seen in the control group. In our study, we looked further into the effects of mindfulness training embedded into an introduction to communication course, assessing changes in mindfulness and emotion regulation. Huston et al. had dealt with ... gers and ... but also ... ling ... d ... s class ... as ... communication competence, ... assessed by others, ... of emotional intelligence.

All but one of the facets of emotion regulation went in a more "positive" direction. That is, people at the end of the class reported that they were more likely to reappraise positively, take another's perceptive, and engage in positive refocusing and planning while reducing their rumination, blaming self and others, and catastrophizing. The only exception was "acceptance" (i.e., being resigned to what has happened), for which there was no change. This is not surprising, as the concept includes both what can be seen as positive (acceptance of what is) with a more negative form of acceptance (resignation). The results also showed increases in students' emotional intelligence and others' reports of the participants' communicative competence when comparing scores pre- and post-class. These results are promising and consistent with expectations for the salutary effects of mindfulness training. As predicted, across classes in our study, assessments of all facets of mindfulness increased. Huston et al. (2011) also found that

scores on the observe mindfulness subscale (as well as mindfulness as a composite variable) increased during the course for students with a mindfulness curriculum; in our current study, however, we found even more support for elevated mindfulness following introductory communication courses with mindfulness concepts and practice embedded. Importantly, the correlation of mindfulness factors with emotional intelligence and emotion regulation suggest that the "improvement" in constructs likely to enhance communication may allow for students to gain greater depth of understanding and embodying factors that underlie effective communication.

Although we do not report the data here, a control group ($N = 35$) taking the same course, at the same college, and at the same time but assigned to teachers who taught the curriculum without the mindfulness component did not increase in their mindfulness across the course (even taking into account the lesser statistical power of the sample size), emotional intelligence, or emotion regulation (a result that differs from Huston et al., 2011, who found that positive appraisal, but also other-blame, increased in their control group). The means suggested increases in communication competence, but among 11 students had lower-assessments of their competence; this result was not significant.

Recent scholarship has suggested that teaching mindfulness and/or its practices may not always have the straightforward effects that we found here, however. Tagney, Dobbins, Stuewig, and Schrader (2017), for example, found a *decrease* in nonjudgment following mindfulness training with both inmates and students; importantly, they also noted that increased emotion regulation helped mitigate this effect, reflecting further the connection between mindfulness and emotion regulation. Specifically, when students first learn about mindfulness, and most notably when they begin to meditate, they often become more aware of their own thinking, particularly some of their negative thought processes (Kabat-Zinn, 1994). This can make them more conscious than they were before of what it actually occurring for them. Chödrön (2018) likewise argues that meditation "dissolves the armor of self-protection we've tried so hard to create around ourselves." As such, some students may score lower on mindfulness measures, not because they

are in fact less mindful, but because they are more aware of the limits to their own mindfulness. This is particularly likely for the nonjudgment facet: New learners of mindfulness, in watching their thoughts, may discover a greater tendency to evaluate than they were cognizant of before. The same may occur for acting with awareness, which helps learners notice their tendency to behave automatically and to be distracted. In communication classes, the mindful ability to describe (as a communicative act) may also receive greater scrutiny by students. Thus, in classes incorporating mindfulness into their curricula, *teachers should be aware that challenges may arise for the students*. Although there were no statistically significant effects across the teachers, as noted, the means on three factors (nonjudgment, acting with awareness, and mindful describing) in our study went down for students enrolled in certain teachers' classes. To make the study more generalizable, we had seven teachers as part of our design. As noted, each was a mindfulness practitioner, and each incorporated the same materials into the class. It is likely, however, that the teachers emphasized some different aspects and/or taught the material with some distinctions. In the present study, it may be that some of the teachers worked more directly to help them to see beyond the initial observations they may have of their students to help them get to a place where they could better act with awareness in the present moment, describe or label with words what is occurring in their minds, and remove some of the judgment they make about their own thoughts. We argue, therefore, that incorporating mindfulness into a communication curriculum is not a straightforward process: Instructors need to be aware that "waking" their students to greater mindfulness can not only increase their emotion regulation and intelligence but also make them more aware of where they are not mindful. Adding explicit discussion of and activities for moving beyond any challenging observations should be included in their mindfulness training.

Mindful communication is clearly not a simple set of "rules"; instead, it is predicated on the ability to be fully present and, we argue, to use knowledge of communication concepts to observe factors involved in any given situation to make effective decisions for how to communicate productively in that moment. Moreover, the increase in emotion regulation

and emotional intelligence experienced as a result of the study of mindful communication, coupled with their improved assessed communication skills, however, has promise to set students on a path of communication "improvement" throughout their lives. Mindfulness can "wake us up" to thoughts and behaviors we engage in that are not productive, and people may become discouraged when they come to these realizations. Mindfulness training, however, ideally helps students to see more clearly without becoming as enmeshed in critical commentary that can be discouraging and cause them to feel shame and give up. The nonjudgmental piece of mindfulness in particular encourages us to see our faults without succumbing to the belief that we are incompetent or incapable of change. Therefore, we are able to see where there is room for improvement and to have greater wherewithal to identify how to approach meaningful change. The increase in emotional intelligence and emotion regulation that students experienced in this study supports these suppositions and may help in furthering their ability to communicate mindfully: that is, making in-the-moment communication decisions based on an increased awareness of the internal and external influences that [illegible] any given moment. In our studies, these are limited to the present time. Second, as we were able to see the effects of mindfulness training across instructors, which allows for greater generalizations, the number of students in this study who studied with the individual instructors was not equal. This had to do both with who taught more than one section and the number of students who volunteered to be in the study from each section. Moreover, we employed a commonly-used assessment for general communication competence, but it is not one that allows for the measurement of in-the-moment reappraisals of behavior. As such, we have only an overall view of how others perceived the communication of the students in the study. Moreover, not all of the students in the study were able to get another person to perform one or both assessments, so, while significant statistically, our findings were based on fewer students than were the other measures. To help with these limitations, future research should better measure the specific thoughts and behaviors that are conceptually expected from a change in mindfulness, including more focused attention, the ability to notice subtleties impacting communication

as it occurs (e.g., inner monologue, other people's nonverbal behavior), respect for others, less reaction, and greater thoughtfulness and responsiveness. Future work should also focus on the ability for students to maintain their more mindful state—and the thoughts and behaviors that appear to stem from that—over time. Overall, however, the results of our study suggest that introductory communication courses with mindfulness training embedded into them increase, not only students' communication skills, but also their emotional intelligence and emotion-regulation abilities. The data suggest mindfulness plays a key role in the development of some of these abilities in particular, namely positive refocusing, planning, positive reappraisal, and perspective-taking. Meanwhile, although all of the mindfulness factors improved over the course when looking at the aggregate, those that went down for particular students or across individual instructors provide a potentially useful direction for teachers of mindful communication to consider in terms of curriculum refinement and/or development. We believe that this sets up a challenge for teaching mindfulness rather than a detriment. If students are encouraged to become aware of their thoughts and emotions as mindfulness can help them become, with acceptance of their thoughts that [illegible] they believe they are. Such challenges, however, when handled well in the classroom, should lead ultimately to changes in those patterns and more mindful engagement overall. As such, teachers should realize that teaching mindfulness may at first make some students uncomfortable, but in doing so, and with the right classroom support (e.g., exercises that move them through the discomfort and help them focus on themselves with more clarity and less judgment), students can emerge from the communication classroom even more prepared to engage mindfully in their own lives.

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Chapter 10

AN ASSESSMENT FRAMEWORK FOR CONTEMPLATIVE PRACTICE IN HIGHER EDUCATION

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ABSTRACT

Contemplative practice in higher education has evolved in recent years from a strategy associated with individual faculty or select courses to a unified, multidisciplinary initiative to support student learning and well-being. The assessment of contemplative practice within this collaborative context, however, remains largely undocumented. While the diversity of activities and disciplines supports the universality of contemplative practice, it also presents methodological challenges and poses philosophical quandaries for integrated approaches to assessment. This chapter

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details the complexity inherent in creating a comprehensive assessment framework and shares a process for working toward this collective goal within a single university. Strategies for identifying common activities, outcomes, and measures are reviewed and implications for assessment at both a course-level and a program-level are discussed.

Keywords: contemplative practice, assessment, higher education, methodology

INTRODUCTION

Contemplative practice has become important in educational settings in recent years, in general (Barbezat & Bush, 2013; S. Brown, 2009; Deckro et al., 2002; Flor Rotne & Flor Rotne, 2013; Lin, Oxford, & Brantmeier, 2013; O'Reilley, 1998; Palmer, Zajonc, & Scribner, 2010; Rendón, 2009; Zajonc, 2006, 2008, 2013) and within various disciplines (Gunaugson, Sarath, S[illegible] & B[illegible]4; Sim[illegible]-B[illegible]n & [illegible], 2011). Contemplative practice provides an answer to [illegible]quest[illegible]ion[illegible] to be [illegible] human, [illegible]ve[illegible] deeply meaningful life (Chö[illegible]n, [illegible], Gold[illegible]g, 1[illegible]6; [illegible]012). Contemplative practices, including meditation and mindfulness, are not new, nor is their study. Benefits, such as decreased stress, anxiety, depression and pain, and increased awareness, resilience, happiness and creativity have been studied experientially and scientifically in both the medical and community context. The benefits of these practices for students within higher education, however, are still largely unexplored. Thus, the purpose of this chapter is to present a process for creating an assessment framework that documents the success of contemplative pedagogy and practice in enhancing the overall student experience and community climate.

With the goal of enhancing student development and promoting academic excellence in tandem with personal wellbeing—the overall student experience—contemplative and mindfulness-based practices, including reflection, meditation, creative arts, civic engagement, free writing, and close reading may be especially useful in educational settings. These practices relate directly to evidence-based effective strategies to improve

teaching and learning, which emphasize holistic student development and emotional regulation, self-awareness and self-monitoring, and metacognition (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010). The value of focus and breathing — and paying attention — are especially important in the world students inhabit. The constant barrage of messages, images, and sounds compete for students' attention and suggest to them that communication, learning new information, and thinking can be accomplished in quick bursts with minimal study or reflection. Contemplative practices support learning, discovery, and application of knowledge by focusing and "drilling down" rather than skimming the surface and proceeding to the next stimulus. Students need practice grappling with complexity—in thinking deeply and broadly. In short, they need to "attend to" their own thoughts, experiences, and feelings, and ultimately to those of others. Reflective practices can provide insight, understanding, and a break from the din of living in a cacophonous world. Moreover, contemplative pedagogy offers a unique opportunity for institutions of higher education to integrate their commitment to science with their obligation to promote student self-knowledge and responsibility to the moral citizenship (Braga 2

Contemplative practices offer benefits that are critical for both undergraduates and graduate students: Physical and psychological health benefits have been well-documented (Atwood & Maltin, 1991; Bergen-Cico, Possemato, & Cheon, 2013; Dowd & McCleery, 2007; Felder, Aten, Neudeck, Shiomi-Chen, & Robbins, 2014). Examples of such benefits include reductions in alcohol consumption, anxiety, chronic pain, depressive symptoms, brain injury, diabetes, posttraumatic stress disorder (PTSD), and chronic fatigue (Bergen-Cico & Cheon, 2014; Bergen-Cico, Pigeon, & Possemato, 2014; Evans, Ferrando, Carr, & Haglin, 2011; Kerr, Josyula, & Littenberg, 2011; Zylowska et al., 2008). Findings suggest mindfulness is also associated with improved coping strategies (Jones & Hansen, 2013), enhanced self-regulation (K. W. Brown, Ryan, & Creswell, 2007), the use of positive conflict strategies, the ability to forgive after transgressions, and increased nonverbal cue sensitivity (Crowley, 2014), as well as an interest in exploring the meaning of life (Astin et al., 2005; McMurtrie, 2014).

Practices with such life-changing potential must be carefully assessed, but that is not a simple task. This chapter focuses on one university's evolving conversations around creating an assessment framework for its contemplative courses. While cognizant that not all contemplative practice in higher education takes place within formal classroom settings, assessing the outcomes of such contemplative practice may be more straightforward and a reasonable starting point for such an initiative, as assessment is an expected part of classroom teaching. The chapter remains grounded in the particulars of one university, and in fact presents a case study of how one course might be assessed, given the framework created. The broader goal of this work, however, is to provide guidance for other groups looking to develop a comprehensive assessment framework, as the processes and complexities shared here are not unique to a single course or to a single university, but rather can be generalized across diverse curricula and institutions of higher education.

AN ASSESSMENT FRAMEWORK FOR CONTEMPLATIVE PRACTICE IN HIGHER EDUCATION

Assessment in higher education is "the systematic collection, review, and use of information about educational programs undertaken for the purpose of improving student learning and development" (Palomba & Banta, 1999, p. 4). In their foundational book, Palomba and Banta (1999) identify six core components of successful assessment, which include: (1) specifying or refining learning objectives; (2) planning an assessment design; (3) involving faculty, staff, and students; (4) selecting and designing measures; (5) collecting data and reporting the results; and (6) assessing the assessment plan. In brief, the assessment process provides the opportunity for faculty and administrators to reflect on the goals and objectives of a course or program, discuss challenges and successes, and enact necessary curricular and/or programmatic change. Assessment has been of heightened importance in higher education, with an argument being made for a "culture

of assessment" in the context of accountability. Accountability for learning no longer lies solely with the student, but rather increasingly reflects the responsibility of the institution (Lingenfelter, 2003). Thus, ongoing assessment has become an integral process underlying institutional accountability for higher quality education among many colleges and universities.

In 2015, the authors, working with the Director of the University's Office of Faculty Development, received a Teaching and Learning Center (TLC) grant from the Center for Contemplative Mind in Society (C-Mind) for a proposal entitled *Assessing the Outcomes of Contemplative Pedagogy*. The purpose of these competitive grants was to encourage recipient campuses to "support, develop, and extend the use of contemplative practices throughout their institutions and assess their impacts" (C-Mind, 2016). A private university in Upstate New York, Syracuse University is home to the Contemplative Collaborative, a diverse group with over 170 members, who teach, research, practice or have job responsibilities related to contemplative practices (http://mendeley.syr.edu/services-and-initiatives/contemplative-collaborative.html). The group was conceived as a space for critical for student learning as well as a means to address stress and anxiety students and other university members report. Ultimately, the Collaborative seeks to engage in practices that encourage more focused attention, careful listening, and overall wellness and satisfaction among members of the university community.

There are approximately 14 courses that include some type of contemplative practice at Syracuse University. Syracuse also offers a Mindfulness and Contemplative Studies minor, daily meditation opportunities, a stress reduction room (MindSpa), and a Buddhist Chaplain. It also offers the opportunity for special contemplative practices, including a free weekly yoga class, eight-week Mindfulness Based Stress Reduction classes, as well as mindful eating seminars for students, faculty and staff. A six-session non-credit Introduction to Mindful Awareness Practice class through the Counseling Center is also available for students. Other offerings have included Tai Chi classes for faculty and staff and annual campus and

community events such as "Yoga in the Dome" or "Meditation on the Quad."

Scientific studies of contemplative practices, including studies of assessment, can help garner support for the types of contemplative courses and programs mentioned above, and can provide methods and inspiration for others to empirically study contemplative practices in higher education. Useful and nuanced methods for studying a range of contemplative practices need to be developed, tested, and shared, to document both challenges and successes and move the field forward. In encouraging the systematic study of these practices, programs may receive increased support for contemplative pedagogy and universities, students, faculty, and staff may benefit from these learning opportunities. The goal of our University's project was to consider deeply the evaluation of student wellness and educational outcomes of contemplative pedagogy, including the development of an assessment plan that suited the needs of our institution.

Specifically, our original goals were to (1) create and pilot an assessment plan that could be used to coordinate across multiple contemplative courses to help understand student outcomes associated with engaging in contemplative practice, both for all courses and develop course-specific and course-specific items. Early in our planning with an outside expert (B. Grace Bullock, PhD, mindfulness expert, organizational strategist, and Founding Director and CEO of the International Science & Education Alliance; see Chapter 1), we realized these goals were unrealistic. There were a range of disciplines and types of courses, as well as differences in the centrality of contemplative practice to each course. There was also a range of methodological perspectives and commitments. Realizing that other universities interested in contemplative practices and assessment may have similar issues, we reframed our first goal to be a contribution that documented the process of group deliberation and learning surrounding the original aims. We also narrowed our second goal so that we could discuss how to identify key student outcomes that overlap across disciplines and assess them using validated measures.

We approached these revised goals via a two-part Assessment Institute that involved internal discussion among faculty, staff, and students at the university (Part 1), followed by guided conversations led by Dr. Bullock (Part 2). The intent of this two-step process was to first understand how contemplative pedagogy was currently integrated into and assessed across courses at the university and then to use this information to develop a framework for comprehensive assessment. Institute participants included faculty who taught courses with a contemplative component as well as those interested in drawing on additional expertise to create and pilot an assessment plan that could be used broadly across multiple contemplative courses to help document key outcomes and explore students' perceptions of these experiences.

The aim of Part 1 of the Assessment Institute was to document the variety of contemplative practices that were being used across diverse courses at the university and to identify issues and challenges for assessing the outcomes associated with contemplative pedagogy. Through discussions about individual courses, the participants identified student learning and engagement outcomes and explored ways of measuring and documenting these outcomes during strategies currently in use on campus. For example, some instructors asked students to complete surveys tapping wellness outcomes, such as anxiety or mindfulness, at the beginning and end of the course; others examined change in student thinking and engagement via an analysis of journals across the semester. While these assessment strategies were helpful in the context of documenting change in specific courses, they did not reflect practices that would allow for comparison across courses.

Thus, one objective for Part 2 of the Assessment Institute that materialized from these discussions was to identify methodologies needed for multidisciplinary assessment, such as common outcome measures and appropriate comparison groups. Another objective for Part 2 that we became aware of during the Part 1 discussion was the need for a comprehensive logic model documenting how contemplative pedagogy can be systematically implemented and evaluated in higher education settings. In preparation for this goal, a survey was created and circulated to select faculty across

multiple disciplines to gather information about the specific contemplative practices employed in classes and instructors' expectations about how the practices impact student engagement and wellbeing as well as class dynamics. The survey yielded quantifiable data on specific practices respondents employed and their anticipated outcomes across approximately 10 regularized courses routinely taught at the University. More specifically, the survey identified 31 different practices being incorporated in classes and 22 student outcomes. These data served as a starting point for discussions in Part 2 of the Assessment Institute, a 2-day workshop led by Dr. Bullock, in her role as a mindfulness assessment consultant.

As previously noted, the purpose of Part 2 of the Assessment Institute was to have our mindfulness assessment consultant facilitate conversations focused on (1) identifying common learning outcomes for contemplative practices being employed in classes and (2) exploring appropriate means for assessing the success of these practices in meeting those outcomes. The process essentially paralleled the steps required in creating a logic model that outlined the associations among the resources, activities, outputs, and outcomes for contemplative pedagogy at the University. Rather than the streamlined and campus-wide [illegible] originally imagined, these rich conversations included the perspectives of faculty, staff, and students and resulted in a framework that will influence how we assess our outcomes going forward. Thus, the logic model presented in Table 1 does not represent a final product, but rather serves as a starting point for future reflection and planning. Additional documentation on the process is included below, as we follow through on our revised goals and our emergent conclusion that our journey might be useful for other groups hoping to assess contemplative pedagogy on their campuses.

Day 1 of the workshop included presentations on key assessment principles included in logic models (for an overview of logic models, see W. K. Kellogg Foundation, 2004) and examples of both quantitative and qualitative methodologies. The participants (18 faculty, academic staff, and graduate students) engaged in an individual and group activity to identify reasons for introducing contemplative practices in their courses/programs.

Table 1. Logic Model for Contemplative Pedagogy in Higher Education

Goals of Campus Initiative: Use coursework to engage students in contemplative practices that promote focused attention, careful listening, and overall wellness and satisfaction				
Inputs: • Experienced faculty and staff representing diverse disciplines. • Campus Office of Assessment. • MindSpa campus wellness center. • Funding [illegible] contemp[illegible] practition[illegible] e.g., yoga or M[illegible]R instructors) to guest lecture in classes. • Space and equipment (e.g., MindSpa or stress-reduction rooms, shared classroom with yoga mats, meditation cushions.)	**Activities:** • Implement various contemplative practices via coursework. • Recruit students into the Mindfulness and Contemplative Studies (MCS) minor. • Provide training for faculty [illegible] and [illegible]s in co[illegible]pl[illegible]e pedagogy ([illegible]AC[illegible]E summer institute), research (e.g., Mind-Life Institute Research Conference) or practice (e.g., MBSR or yoga certification. • Develop yoga, meditation, and mindfulness-based workshops or classes for students outside of coursework.	**Outputs:** • # courses implementing contemplative practices. • # faculty trained in contemplative pedagogy. • # guest lectures by practitioners of [illegible]mplative practice. • [illegible]ulty [illegible] • [illegible]fied [illegible] [illegible] • # students completing courses with contemplative components. • # student visits to MindSpa or stress-reduction room. • # student-based wellness events.	**Outcomes:** • Increased student engagement in class (e.g., attendance, participation, grades). • Improved management of stress, evidenced through quantitative measures of student attention and [illegible] • [illegible]ecre[illegible]d s[illegible] withd[illegible]als [illegible] [illegible] or leaves of absence. • Increased sustainability of contemplative practices beyond the course. • Increased student use of campus resources that support contemplative practice. • Higher course evaluations among classes that use contemplative practice.	**Implication:** • Students will play a more active role in their learning and education. • Students will be better able to manage stress effectively, resulting in increased [illegible]ntal [illegible]lth and [illegible]a[illegible]nal success. St[illegible]s will be less likely to engage in substance use and other risky behaviors. • The campus will evolve into a more conscientious and compassionate community that respects and celebrates diversity.

Figure 1 depicts "The Funnel," which represents the group's collective reasons for introducing mindfulness to students and the expected outcomes and impact. The group agreed that the campus was experiencing uncertainty and anxiety with new leadership and a more corporate ethos. The increased conflict and aggression around the world also weakened their confidence about the future. The group also acknowledged that students experienced high levels of stress in their daily lives, which resulted in risky and harmful behaviors. This activity was helpful because it demonstrated that intentions were both individual and collective and identified shared ideas regarding why contemplative pedagogy is needed both more generally in higher education and specifically at the university.

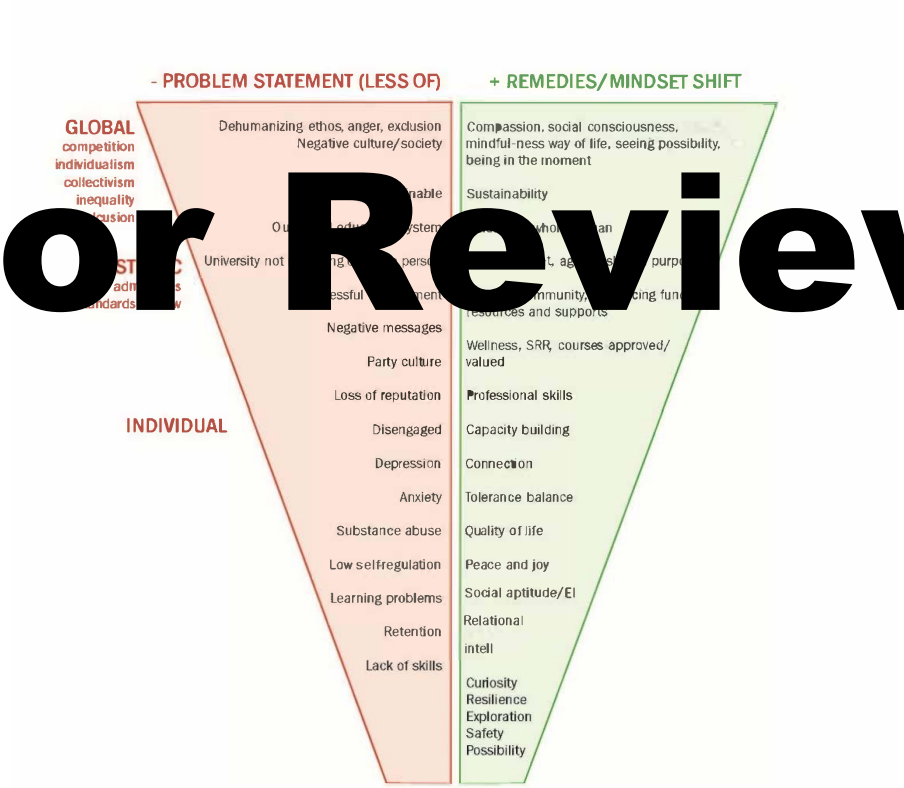

Figure 1. Problems/Remedies Funnel. This figure shows a list of global, systemic and individual problems at the university and the impacts that contemplative practices may have on them (SRR = Stress Reduction Room, EI = Emotional Intelligence).

Day 2 of the workshop focused on organizing the previously collected survey data into a logic model. In particular, the group discussed the variety of practices used with students and engaged in dialogue about why these specific practices were chosen for implementation (see Table 2). The diversity of practices was impressive and reflected both commonality as well as specificity across the disciplines. Thus, one challenge in creating an assessment framework was how to capture this diversity but also integrate data across courses for analysis and interpretation on a program level. A related activity used post-it notes to create commonality among the diverse outcomes identified by the group. Participants wrote down what they identified as the important outcomes of contemplative practice and classified them as reflecting individual and/or systemic change. Similar or related outcomes were combined into themes and then with guidance from Dr. Bullock, the group identified outcomes for which questionnaires and quantitative scales exist, such as stress (Perceived Stress Scale; Cohen, Kamarck, & Mermelstein, 1983), self-regulation (Self-Regulation Questionnaire; K. M. Brown, Miller, & Lawendowski, 1999), resilience (Connor-Davidson Resilience Scale; Connor & Davidson, 2003), happiness (Subjective Happiness Scale; Lyubomirsky & Lepper, 1999), quality of life (Satisfaction with Life Scale; Diener, Emmons, Larsen, & Griffin, 1985), anxiety (Generalized Anxiety Disorder Scale-7; Spitzer, Kroenke, Williams, & Lowe, 2006), attention awareness (Mindful Attention Awareness Scale; K. W. Brown & Ryan, 2003), empathy (Basic Empathy Scale in Adults; Stefaniak, D'Ambrosio, Bensalah, & Besche-Richard, 2013), gratitude (Gratitude, Resentment, and Appreciation Scale; Watkins, Woodward, Stone, & Kolts, 2003), and self-compassion (Self-Compassion Scale; Neff, 2003). It was agreed that other outcomes, such as creativity, connectedness, accomplishment, and respect, would require qualitative methods for deeper inquiry and interpretation.

Given that a shared goal of many of the contemplative practices is to promote mindfulness, there was also discussion concerning the direct assessment of this construct. While there are widely used scales that include subscales for the different dimensions of mindfulness, such as the Five Facet Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, &

Toney, 2006), there are also limitations associated with these self-report tools. For example, the very practice of mindfulness may change how individuals interpret or respond to the items, making the analysis of change over time more difficult (see Chapter 2 for additional discussion). Thus, more objective measurements of mindfulness, such as brain activity (see Chapter 5), or related outcomes, such as cortisol stress-response, may provide physiological and/or biological evidence of change that can advance the field.

Table 2. "What are the practices?"

Somatic awareness	**Breath work**	**Journaling**
Feldenkrais/somatic education	Child-focused exercises	Reflection exercises - writing/sharing
Sitting meditation	Curiosity grid	Free writing
Body scan	Talking circle	Photography
Yoga	Community work	Poetry
Tai Chi	Compassion meditation	Drawing/doodling
Movement/dance	Just sit/mediate/reduce	Music
Mindful walking/walking meditation	Multiplying good meditation	Video/art making
Qigong	Safe space meditation	Contemplative arranging

This table lists the various contemplative practices used at Syracuse University in its contemplative courses

In sum, the activities of the Institute were fundamental in identifying both the diverse range of desired outcomes of contemplative practice in higher education, as well as the shared objectives of the group. Commonality around the group's most important outcomes revealed three systems-level themes: (1) social climate—inclusivity, (2) wellness—healthy choices, and (3) student learning—creativity and innovation. These themes serve as starting points for establishing an assessment framework that would be useful for both the needs of individual faculty examining specific course-related objectives as well as for examining outcomes across collections of courses and/or programs. Thus, important components of a comprehensive

framework include: (a) measures/questionnaires that are discipline-specific and course-specific, (b) quantitative measures/questionnaires that reflect common outcomes themes of the group, (c) qualitative techniques that examine complex phenomena, and (d) mixed-methods techniques that capture student experience.

IMPLICATIONS AND FUTURE DIRECTIONS

The Assessment Institute was instrumental for conceptualizing a framework that reflected a more realistic and complex understanding of contemplative assessment in higher education. One critical discovery was the amount of planning required on the front end of this type of an assessment initiative. Much of the activity of the Institute—articulating why faculty were introducing contemplative practices in their classes, being clear about what specific p[illegible]were being implemente[illegible]in the classes, a[illegible]ting [illegible]expecte[illegible]ut[illegible]es, [illegible]o [illegible]her a[illegible]gic[illegible]l th[illegible]flec[illegible]t[illegible]goals of [illegible]p[illegible]rt [illegible]that cou[illegible]rve [illegible]a[illegible]mplate fo[illegible]establishing a formal framework. This process was no easy feat, given the variety of perspectives on assessment and measurement across the various disciplines. The conversations that took place in the Institute were necessary for the acknowledgement of all of the voices in the group and for brainstorming about how assessment that was already happening at a course level could inform a multidisciplinary program-level assessment framework.

The grant was timely in that it also coincided with the start of a three-year assessment effort for Syracuse University, as part of the accreditation procedure required by the Middle States Commission on Higher Education. The accreditation procedure requires that all programs, including the Mindfulness and Contemplative Studies minor, participate in the university-wide assessment. Given the infancy of the minor, we are still in early stages of the process. The diversity of the courses is both a strength of the minor and a challenge for the assessment. We can look to specific courses, however, to serve as a guide for how to approach the assessment of the minor. The next sections present a case study for assessing contemplative

practice in a communication course and discuss important factors that need to be considered when moving to a multidisciplinary and comprehensive assessment framework.

Mindful Communication

We now turn to the discipline, course, and outcomes that are the subject of the case study. The course, Mindful Communication Skills, includes in-class yoga and meditation and requires a daily meditation practice outside of class (see Chapter 9 for discussion of a class using the same textbook; Huston, 2016). Other contemplative practices are introduced and can be included in the at-home practice. The course begins by exposing the students to the neuroscience of mindfulness. The overall outcomes fit with those discussed above, with additional ones more focused on communication. For example, outcomes such as recognizing that no two moments are alike, expanding layers of perception (Wahlstrom, 1999), reducing negative reactivity when communicating (Langer & Moldoveanu, 2000), learning listening, nonjudgment, acceptance, empathy, and patience (Shapiro & Schwartz, 1999) are in the service of mindful communication. Unexamined assumptions and preconceptions are brought to awareness allowing students to perceive themselves, others, and situations more accurately. "Undivided observation of what is occurring both internally and externally" (K. W. Brown & Ryan, 2003, p. 823) allows communication to be more accurate and productive.

In Mindful Communication Skills, students actually live the course material. They study themselves as they observe their reactions and begin to mindfully respond to communication experiences rather than rely on their taken-for-granted patterns of behavior. Specifically, students learn to (a) observe the impact their words and actions have on their communication experiences, (b) recognize the impact self-talk has on how they communicate, (c) begin to recognize the constructedness of their self-concept, (d) become aware of self-fulfilling prophecies, (e) develop and practice active listening skills, and (f) experience how automatic appraisal

of life events can cause people to react rather than respond. During the course, students also come to appreciate and understand the connections between mindfulness, neuroscience and emotional intelligence.

In terms of assessment, outcomes for which there are quantitative scales, such as empathy or self-compassion, align well with the goals of the Mindful Communication Skills course. Many of the more specific communication-related outcomes, however, may require qualitative methods such as careful content analysis of meditation journals or observation of group and class discussion. Thoughtful reflection on self-talk, interactions that went well or badly, and eventually timely self-intervention, for example, would suggest that the outcomes were being met. As an initial step, listening, as a departmental learning outcome, was chosen for assessment in this class and completed by analyzing journal accounts of a deep listening exercise and whether (and how) students discussed listening in their final course reflection. Of course, contemplative practice and assessment would play out quite differently in an art or physics course, with different practices chosen and different ways of relating to the discipline-specific concepts and theories. The challenges associated with integrating assessment of the multiple disciplines into a comprehensive framework are addressed next.

CONSIDERATIONS FOR A COMPREHENSIVE ASSESSMENT FRAMEWORK

Once a global/comprehensive framework is conceived, there are also several significant methodological challenges that need to be addressed. First, how do we quantify the contemplative practice and/or pedagogy within a course? Do we need to evaluate the two domains separately? This divided approach may be necessary, as there are obvious differences in practice-based courses that include substantial experiential activities that directly support mindfulness-based skills, such as focused attention and managing difficult emotions, compared to information-based courses that focus more

on fostering student reflection and connection to the course material via contemplative pedagogy or teaching style. Even within practice-based courses, however, there may be considerable variation in the exercises used as well as the amount of time spent in practice. For example, a course that includes three minutes of focused breathing at the beginning of every class may be very different from a course that incorporates 25-30 minutes of contemplative practice per session. Variation may also exist in the amount of time devoted to contemplative teaching strategies, as opportunities for deep reflection and connection to the material may differ across faculty and courses. These questions themselves may be of interest to evaluators. For example, variations in outcomes across courses could help identify a threshold in terms of the amount of time required to result in meaningful change, or reveal a gradient or dose-relationship effect of contemplative practice. Another critical point presented, however, was that meditation or practice that is required for a course may be very different from practice that is done voluntarily. Thus, even quantifying minutes of practice may be a challenge, as some individuals or disciplines may not consider time in class required of a course as valid independent practice. Another significant challenge centered on how to identify an appropriate comparison group. The gold standard in scientific research is a randomized control design in which individuals are randomly assigned to either the treatment or control group; then the degree of change across the two groups can be compared and interpreted in terms of statistical significance. Given that this design is not feasible in higher education, mainly due to student self-selection into classes, the identification of a valid comparison group is critical. Possible options may include students in different courses taught by the same professor (one group that experiences contemplative pedagogy and/practice and one group that does not), or the students in the same course taught by different instructors (one of whom incorporates contemplative methods and one or others who do not). For courses that are small and fill up quickly, there may be a way to implement a wait-list control design, where students who took the course are compared to those who wanted to take the course but were unable to due to limited class size. This approach may help ensure the groups are more comparable, as there may be fewer

preexisting differences between these two groups of students given their shared interest. Of course, this design presents another challenge, which is how to effectively follow students over time for assessment, particularly those whom were unable to register for the course. Moreover, it is also possible that students, particularly those with an interest in meditation or yoga, may already have a practice or may find another venue for practice if they are unable to take a course, such as MBSR courses sponsored by the student counseling center, daily meditations at the campus interfaith chapel, yoga in physical education, or resources outside of the university, such as community organizations and wellness studios. Students' participation in these activities would also be critical for assessment, as they could influence their experience in the courses or program and muddle the comparisons across groups.

The methodological issues presented above highlight another critical requirement for successful implementation of a comprehensive assessment framework, which is substantial support from administration. In order for the framework to be realized, it would be critical to fit assessment of contemplative curriculum into wider departmental, college, and university assessment plans for it to be developed. One option would be to use existing programs, such as a minor, to pilot test an evaluation. Students in the minor could be followed over time and compared to similar students on key outcomes using student records. Given that students declare minors at different points in their academic careers, retrospective data that examines GPA for instance, may identify individual trajectories from admission to graduation. This type of approach would also help address issues of sample size, which has implications for statistical power, or the likelihood of detecting an effect when there is an effect to detect. Similarly, larger sample sizes are required to establish themes and reach saturation in qualitative studies. Thus, being able to access and engage a substantive student body is critical for the assessment process.

There may be other systematic ways of collecting data on student wellbeing and/or learning outcomes, such as wellness surveys and questionnaires sponsored by the University. Other data that could be systematically collected via survey include faculty and staff training

opportunities and certifications, course-specific information on the use of contemplative practice (e.g., number of courses, type of practices, and quantity of practice), and workshop opportunities (e.g., frequency, attendance, satisfaction). As opportunities for contemplative pedagogy grow on campus, surveys that tap campus climate could also be used to gather important information for assessment. For instance, significant changes in social climate over time could be detected and integrated with data on graduation rates, transfer rates, disciplinary actions, and drug or alcohol-related incidents on campus. Thus, significant institutional resources would be required for the framework to evolve from individual-level assessment to system-level assessment.

Not surprisingly, many of the methodological issues associated with an assessment framework for contemplative practice in higher education (e.g., quantity and type of practice, random assignment, appropriate comparison groups, small samples, subjective measures) are similar to those raised by researchers in regard to evaluating mindfulness-based interventions in elementary and secondary education (Felver, Celis-de Hoyos, Tezanos, & Singh, 2016; Zenner, Herrnleben-Kurz, & Walach, 2014). These challenges may be magnified in higher education due to factors such as less time spent with students and contrasting levels of control over course content (in higher education, instructors have more control at the individual course level but administrators have less at the system level, as compared to K-12). However, there may be opportunities for advancement of assessment in education on a more global level by integrating insights from these related fields.

CONCLUSION

In brief, an ideal assessment plan would do at least three things: (1) use mixed-method research to collect data across key outcomes, (2) further the discussion of institutionalizing contemplative courses on campus, and (3) build a foundation for securing funding for contemplative activities. At the time of this chapter, our group was still working with the framework that we drafted to understand the next best step to actualizing our plan under limited

resources. The logic model may be useful for quantifying change on select outcomes, such as the percent of students in a course who demonstrate significant improvement on mindfulness or anxiety. We envision focus groups with faculty, staff, and students to identify feasible parts of the assessment plan to implement as a pilot test of the plan. We also recognize that the assessment plan is dynamic; it is always changing and evolving based on feedback.

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