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# Mindfulness Interventions

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RUNNING HEAD: MINDFULNESS INTERVENTIONS

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**Abstract**

Mindfulness interventions aim to foster greater attention and awareness on present moment experience, and there has been a surge in randomized controlled trials (RCTs) of mindfulness interventions in recent years. This review takes stock of the growing mindfulness intervention RCT evidence to-date by reviewing and discussing: 1) mindfulness intervention effects on health, cognitive, affective, and interpersonal outcomes; 2) evidence-based applications of mindfulness interventions to new settings and populations (e.g., the workplace, military, schools); 3) psychological and neurobiological mechanisms of mindfulness interventions; 4) mindfulness intervention dosing considerations; and 5) potential risks of mindfulness interventions. There are multiple domains where mindfulness interventions have been shown to improve outcomes in methodologically rigorous RCTs (e.g., chronic pain, depression relapse, addiction). Discussion focuses on opportunities and challenges for mindfulness intervention research, and community applications.

**Keywords:** mindfulness; meditation; review; randomized controlled trial; health.

**Abbreviations:** RCT: Randomized Controlled Trial; MBSR: Mindfulness-Based Stress Reduction; MBCT: Mindfulness-Based Cognitive Therapy; MBRP: Mindfulness-Based Relapse Prevention; TAU: Treatment-As-Usual; CBT: Cognitive-Behavioral Therapy; HEP: Health Enhancement Program; PTSD: Post-Traumatic Stress Disorder.

**Glossary**: Mindfulness: a process of openly attending, with awareness, to one's present moment experience; Mindfulness-Based Stress Reduction (MBSR): an 8-week mindfulness meditation training program, that includes weekly classes, daily audio-guided home practice, and a day long retreat; Mindfulness-Based Cognitive Therapy (MBCT): an 8-week mindfulness-based program that combines elements of MBSR and Cognitive Behavioral Therapy; Wait-List Control: participants who are randomized to serve as a no treatment comparison group and placed on a wait list to receive a mindfulness intervention; Health Enhancement Program (HEP): an 8-week health education and relaxation program, developed to be a well-matched comparison program to MBSR; Decentering: a mechanism of change involving observing internal experiences from a more objective third person perspective; Resting State Functional Connectivity: a brain imaging analysis for identifying temporally correlated brain regions while participants rest quietly in the absence of any goal-directed task; Dark Night Experiences: significant adverse events that can occur with intensive mindfulness meditation interventions.

# Mindfulness Interventions

*There are few people I know on the planet who couldn't benefit more from a greater dose of awareness.*

*-- Jon Kabat-Zinn*

Readers not familiar with mindfulness meditation practices or mindfulness interventions might try a quick exercise, close your eyes for about a minute and maintain an open awareness of the sensations of breathing at your nostrils. No need to do anything special, just continuously observe the sensations of breathing in and breathing out at the nostrils with curiosity and interest. Even doing a one-minute mindfulness exercise like this can reveal that our minds are quick to race off to other places. For example, you might have had thoughts about planning dinner tonight, you might have drifted off, or noticed a strong desire to consciously control how you were breathing. Moreover, there's often a rich kaleidoscope of experiences and emotional reactions to even a short exercise such as this one, including experiences of relaxation or agitation. Formal mindfulness training exercises, such as this practice of learning how to mindfully attend to breathing, form the backbone of many mindfulness interventions. Collectively, mindfulness interventions aim to foster greater awareness of present moment experience, which as Jon Kabat-Zinn suggests in his quote above, may have manifold benefits ranging from enhancing the quality and vividness of our daily life experience to helping us better manage life's slings and arrows.

Interest in mindfulness interventions has exponentially increased over the last three decades. Much of this interest has been fueled by scientific reports and corresponding media coverage describing potential benefits of mindfulness interventions for a broad array of outcomes, ranging from mental and physical health outcomes (Ludwig & Kabat-Zinn 2008), to cognitive, affective, and interpersonal outcomes (Brown et al. 2015). Mindfulness interventions are also increasingly being integrated into institutional settings—in clinical treatment (Dimidjian & Segal 2015), the workplace (Good et al. 2015), schools (Sibinga et al. 2016), the military (Johnson et al. 2014), and prisons (Samuelson et al. 2007), just to name a few. This proliferation of interest in mindfulness interventions has been met by the scientific community with a wide range of reactions, from skepticism to fanaticism. This review takes stock of what we have learned from RCTs of mindfulness interventions in terms of their effects, applications to new populations, putative mechanisms, dosing questions, and potential risks.

## What is Mindfulness?

There has been a rich scholarly dialogue about how to define mindfulness as a construct, and one working definition of mindfulness is that it is a process of *openly attending, with awareness, to one's present moment experience.* This process of being aware of present moment experience stands in contrast to much of our daily life experience where we find ourselves unintentionally mind wandering (Killingsworth & Gilbert 2010), running on automatic pilot (Bargh & Chartrand 1999), or suppressing unwanted experiences (Kang et al. 2013). Moreover, these mindless states that predominate our daily life experience are seen as undesirable. As one example, a recent study showed that our minds wander about 47% of the time during the day and that mind wandering predicts subsequent unhappiness (Killingsworth & Gilbert 2010). By

contrast, the capacity to be mindful is associated with higher well-being in daily life (Brown & Ryan 2003).

Mindfulness has been operationalized in many different ways in the scientific literature (for a review, see Quaglia et al. 2015). Two features are common across most definitions of mindfulness. First, mindfulness is about grounding attention and awareness in one's present moment experience. The present moment experience that one attends to can take many forms, including one's body sensations, emotional reactions, mental images, mental talk, and perceptual experiences (e.g., sounds). Scholars have described this monitoring feature of mindfulness as a "watchfulness" or a "lucid awareness of each experience that presents itself" (Bodhi 2011, Brown et al. 2007, Quaglia et al. 2015). Second, many contemporary conceptualizations of mindfulness posit that mindfulness is about adopting an attitude of openness or acceptance toward one's experience. This open and accepting attitude consists of attending to experience with a curious, detached, and non-reactive orientation. Importantly, this attitude of acceptance toward experience is not one of passive resignation about one's current circumstances, but is rather one of inviting in experiences, even if they are difficult.

Although psychological scientists have been interested in mindfulness for the past three decades, it is important to keep in mind that this is a thin slice of scholarly work relative to the 2,500 year tradition of scholarship (and practice) of mindfulness interventions in many Buddhist traditions (Anālayo 2003). As such, Buddhist scholarship has informed a great deal of the psychological research on mindfulness and mindfulness interventions, but mindfulness is by no means exclusive to Buddhism or Buddhist contemplative practices. First, most of the mindfulness interventions now tested in the scientific literature are secular in nature. Second, being mindfully aware is not synonymous with Buddhism or being a Buddhist, rather it is a basic feature of being human[1]. As Bhante Gurantana (2011) states in his classic mindfulness training text, "Mindfulness is not limited by any condition. It exists to some extent in every moment, in every circumstance that arises." Similarly, Jon Kabat-Zinn has written, "We are all mindful to one degree or another, moment by moment" (Kabat-Zinn 2003). Thus, openly paying attention to our moment-to-moment experience is something we all have the capacity to do in daily life, and it is something that can be developed and deepened by mindfulness interventions.

Although mindfulness is a capacity that is available to everyone, formal mindfulness intervention exercises can feel quite effortful and challenging at first. This is understandable in light of the fact that our default state of attending to experience is commonly one of mind wandering, self-criticism, ruminating about the past, or worrying about the future. As one telling example, a recent study showed that participants preferred to receive mild electric shocks over being left alone with their thoughts (Wilson et al. 2014). By contrast, formal mindfulness intervention exercises require one to make deliberate efforts to turn toward and sustain attention on moment-to-moment experience. To borrow an expression from cognitive science, this effort of attending to present moment experience may be an example of a "desirable difficulty" (Bjork

[1] Considered in this light, it is possible that many cultural practices over the ages have been developed to help foster mindful awareness (e.g., centering prayer, journaling, surfing, psychotherapy). Indeed, some work suggests that training in tango dancing increases self-reported mindfulness (Pinniger et al. 2012). There are still many open questions about the role of various cultural practices in fostering mindfulness (or how these factors might interact with formal mindfulness training interventions). As one intriguing case in point, cultural anthropologists have recently described a more mindful culture—the Amazonian Piraha tribe's cultural practices and language are geared toward helping individuals to be more grounded in present moment awareness, with members reporting high degrees of daily well-being (Everett 2005).

& Bjork 2011), such that the effort put forth during mindfulness training exercises can foster insight, learning, and self-regulation skills.

## Types of Mindfulness Interventions

Much of the early work on mindfulness interventions used non-randomized pre-test post-test designs, but starting in the early 2000's there has been a surge of RCTs that compare mindfulness interventions to Treatment as Usual (TAU), wait-list control, or active comparison interventions (see Figure 1). This section describes some of the most common types of mindfulness and control interventions used in the scientific literature.

[Insert Figure 1 about here]

*Mindfulness-Based Stress Reduction (MBSR) and Related Group-Based Mindfulness Interventions.* The 8-week Mindfulness-Based Stress Reduction (MBSR) program, developed by Jon Kabat-Zinn at the University of Massachusetts Medical School, is perhaps the most well-known mindfulness intervention in the scientific literature (Kabat-Zinn 1982). MBSR consists of weekly 2-2.5 hour group-based classes with a trained teacher, daily audio-guided home practice (~45 minutes per day), and a day-long mindfulness retreat (occurring during week six of the eight-week program) (Kabat-Zinn 1990). Much of the MBSR program focuses on learning how to mindfully attend to body sensations through the use of body scans, gentle stretching and yoga mindfulness exercises, along with discussions and practices geared toward applying mindful awareness to daily life experiences, including how one deals with stress. The MBSR program was initially used to treat chronic pain patients (Kabat-Zinn 1982), but it has since been applied to many other patient and community adult populations (Ludwig & Kabat-Zinn 2008).

Over the last three decades, MBSR has stimulated the development of many mindfulness interventions that share the same basic program structure but have been modified to treat specific populations or outcomes. To name just a few, these interventions have focused on treating depression (Mindfulness-Based Cognitive Therapy (MBCT), e.g., Teasdale et al. 2000), drug addiction (Mindfulness-Based Relapse Prevention (MBRP), e.g., Bowen et al. 2014), fostering healthy eating (Mason et al. 2015), and improving relationship functioning (Mindfulness-Based Relationship Enhancement (MBRE): Carson et al. 2004) (for a review, see Dimidjian & Segal 2015).

*Mindfulness Intervention Retreats and Brief Interventions.* The scientific community has often assumed MBSR (and other 8-12 week mindfulness-based programs) are the exclusive way to deliver mindfulness training, but there are other evidence-based forms of mindfulness intervention available to researchers and practitioners. Mindfulness meditation residential retreat programs, ranging from 3 days to 3 months in scientific studies, are a powerful way to deliver intensive and well-controlled doses of mindfulness intervention (Creswell et al. 2016, Rosenberg et al. 2015). Brief mindfulness meditation interventions have also been developed, ranging from 2-3 week programs (Lim et al. 2015, Mrazek et al. 2013) to lab-based 3-4 day mindfulness interventions (Creswell et al. 2014, Zeidan et al. 2011). Finally, very brief experimental mindful attention inductions have been developed and tested in the literature (e.g., Broderick 2005, Papies et al. 2015, Schofield et al. 2015, Westbrook et al. 2013)—these induction approaches offer a great deal of experimental control, but have relatively small and transient effects.

*Internet and Smartphone Application Mindfulness Interventions.* There has been an explosion of internet and smartphone-based mindfulness programs hitting the market in recent years. As just one example of this trend, the *Headspace* mindfulness smartphone app has over 2 million active users worldwide. Given that so many people are using these programs (which lack, in most cases, access to a well-trained mindfulness teacher), there are important untested questions about the safety and efficacy of these programs. However, these mindfulness intervention programs have a tremendous upside in that they are inexpensive, portable, and can be more easily implemented in harder-to-reach populations who can access the world wide web. Although there has been no research on the relative efficacy of these programs relative to in-person group-based approaches (e.g., MBSR) at this time, initial studies suggest that these internet and smartphone mindfulness interventions may have benefits (e.g., Boettcher et al. 2014, Lim et al. 2015).

*Mindfulness-Related Interventions.* The objective of this chapter is to review mindfulness-based interventions where the primary goal of the intervention is to foster mindfulness (e.g., MBSR, MBCT, brief mindfulness meditation training interventions). But there are also many mindfulness-related interventions which incorporate mindfulness training exercises as one component of a broader treatment program (e.g., Acceptance and Commitment Therapy (ACT), Dialectical Behavior Therapy (DBT), Cognitive Behavioral Stress Management (CBSM), Integrative Body-Mind Training (IBMT)). Initial efficacy evidence suggests that incorporating mindfulness training exercises can be beneficial to patients in these interventions. Space considerations preclude a careful review of these mindfulness-related interventions here, but published reviews are available for interested readers (e.g., Hayes et al. 2011).

*Control Interventions.* It is important to consider what mindfulness interventions are compared to in RCT studies (Davidson & Kaszniak 2015), and currently most published mindfulness intervention RCTs use TAU or wait-list controlled comparison groups. These studies are valuable in that they provide an initial evaluation of whether mindfulness interventions have an impact on outcomes above-and-beyond standard care or no treatment. In recent years, there have been impressive efforts in developing active treatment comparison programs that control for non-mindfulness specific intervention treatment factors (e.g., group support, home practice exercises, relaxation, placebo expectancies). These programs provide opportunities to evaluate whether there are unique treatment effects of mindfulness interventions above-and-beyond non-mindfulness specific factors and to evaluate whether mindfulness interventions can outperform gold-standard active pharmacological or behavioral treatments.

There are now many different active treatment comparator programs used in the mindfulness interventions RCT literature. The Health Enhancement Program (HEP) is an 8-week health education and relaxation program that was developed to match MBSR on program components, including group-support and education, home practice, and a day long retreat (MacCoon et al. 2012). Other active group-based interventions have been effectively implemented, ranging from relaxation interventions (Creswell et al. 2016) to targeted health education programs (Morone et al. 2016). The brief mindfulness intervention literature (consisting of interventions that last two weeks or less) also offers a number of well-matched active control interventions, ranging from attention control training programs (e.g., listening to the same guided mindfulness exercise with the instruction to count the number of verbs) (Koole et al. 2009, Schofield et al. 2015), to placebo conditioning (Zeidan et al. 2015), and health education interventions (Mrazek et al. 2013). One intriguing new approach in the brief mindfulness interventions literature offers sham mindfulness meditation training where

participants are instructed periodically "to take a deep breath as we sit here in mindfulness meditation" without any explicit instructions on how to foster mindful awareness (Zeidan et al. 2015). This sham mindfulness procedure has been effective in controlling for positive treatment expectancies in studies, yet does not show the same pain relief benefits as actual mindfulness meditation training (Zeidan et al. 2010b, 2015).

## Effects of Mindfulness Interventions

Mindfulness interventions have been shown to impact a broad range of outcomes in RCTs. Despite this proliferation of work, most mindfulness intervention RCTs have used small samples and lack high quality pre-treatment, post-treatment, and follow-up measures. These methodological limitations make it difficult to draw strong inferences about the validity and reliability of mindfulness intervention effects on many outcomes at this time. However, there are some areas where there are quite promising mindfulness intervention RCT effects, which are selectively reviewed below with an eye toward recent developments in this active area of scientific inquiry. Note that this review focuses on mindfulness-based intervention RCTs, and not on other forms of meditation interventions (e.g., Transcendental Meditation), cross-sectional studies of expert mindfulness meditators, or correlational studies relating self-report measures of mindfulness to outcomes (for a more general review, see Brown et al. 2007).

### *Physical Health*

The earliest work with the MBSR program was focused on treating chronic pain patients who were not responding well to traditional medical treatments (Kabat-Zinn 1982), highlighting a longstanding scientific interest in applying mindfulness interventions to the treatment of physical health. Much of the interest in this physical health domain has been guided by views that mindfulness interventions can foster greater body (interoceptive) awareness, promote relaxation, and improve stress management and coping skills—which can promote physical health and reduce disease risks. We have formalized a mindfulness stress buffering account, which posits that stress reduction and resilience pathways explain mindfulness intervention effects on a broad range of physical health outcomes (Creswell & Lindsay 2014). This account is based on the view that learning how to monitor experience with acceptance is an emotion regulation skill learned in mindfulness interventions that can foster stress resilience and coping under stress (and these stress buffering effects in turn reduce the negative impacts stress have on increasing risk for stress-related disease outcomes) (see also Lindsay & Creswell, under review). Consistent with this account, there are now a growing number of rigorous RCT studies showing that mindfulness interventions impact a broad range of stress-related physical health outcomes, ranging from chronic pain, to immune system functioning, to disease-specific physical health outcomes.

*Chronic Pain.* Stress is a powerful trigger for pain symptomatology among chronic pain patients (Schwartz et al. 1994), and early non-randomized studies showed that MBSR was effective in reducing pain symptoms and dependence on pain relief medication among chronic pain patients pre-post intervention (Kabat-Zinn 1982, Ludwig & Kabat-Zinn 2008). More recently, several independent well-controlled studies have conceptually replicated and extended this early work. Morone and colleagues showed that MBSR, relative to an active healthy aging program, was effective in reducing self-reported pain disability at post-treatment in a large RCT

with chronic low back pain community adults (N=282), although these pain-related benefits were not sustained at the 6 month follow-up assessment (Morone et al. 2016). Garland and colleagues showed that an 8-week Mindfulness-Oriented Recovery Enhancement (MORE) program reduced pain severity and pain interference among chronic pain opioid-abusing patients at post-treatment and 3-month follow-up, relative to an active support group therapy program (Garland et al. 2014a). In a daily diary study of adults with rheumatoid arthritis (N=143), Davis and colleagues showed that an 8-week mindfulness training program was superior to a CBT program for pain and an arthritis education program in reducing post-treatment daily-level stress, pain-related catastrophizing, disability, and fatigue (Davis et al. 2015). And in one of the largest mindfulness intervention RCTs to date (N=342), MBSR reduced functional limitations due to pain among chronic back pain participants at 4-month and 10-month follow-up, compared to TAU (Cherkin et al. 2016). While this large RCT study showed that MBSR provided a clinically meaningful improvement in pain management in a greater percentage of participants at follow-up (61%) relative to TAU (44%), there was no evidence in this study that MBSR was superior to a matched CBT program (58%).[2]

*Immunity.* The immune system plays a central role in protecting the body from a variety of pathogens and infectious agents. Yet chronic stress impairs the immune system's functional response in a number of ways, including its capacity to mount antibody responses and to produce lymphocyte proliferative and natural killer cell responses (for a review, see Segerstrom & Miller 2004). Furthermore, stress has been linked to increases in circulating markers of inflammation (C Reactive Protein and Interleukin-6), which are linked with morbidity and accelerated mortality. Mindfulness interventions have the potential to modulate these stress-related immune outcomes, with initial RCTs demonstrating promising effects on some immune markers (for a review, see Black & Slavich 2016). For example, several initial well-controlled studies show that mindfulness interventions may reduce markers of pro-inflammation, including circulating blood markers of C Reactive Protein (Malarkey et al. 2013), Interleukin-6 (Creswell et al. 2016), and one's stress-induced inflammatory skin flare response (Garland et al. 2014a) (although MBSR failed to affect stimulated Interleukin-6 responses in rheumatoid arthritis patients, see Zautra et al. 2008). In contrast to inflammatory effects, there is currently mixed evidence on whether mindfulness interventions can boost antibody levels or one's antibody response to vaccination (Hayney et al. 2014, Moynihan et al. 2013).

Stress also plays an important role in accelerating HIV infection to full-blown AIDS, in part by attacking CD4+ T lymphocytes. Three RCTs show that mindfulness interventions can buffer declines in (or can increase) CD4+ T lymphocyte counts in stressed HIV+ adults at post-treatment, and up to 9-months follow-up (Creswell et al. 2009, Gonzalez-Garcia et al. 2013, SeyedAlinaghi et al. 2012).

*Clinical Symptoms and Disease-Specific Outcomes.* Some of the most encouraging RCT research in the mindfulness intervention-physical health literature focuses on whether mindfulness interventions affect clinically-relevant measures of health and disease. An initial large RCT (N=154) showed that MBSR may reduce the number of self-reported illness days (and illness duration) over the course of a cold/flu season relative to a no treatment group (Barrett et

[2] Given the promising evidence for mindfulness intervention-pain management effects, one interesting question is whether these mindfulness pain reduction effects are driven by alterations in pain sensation processing, or in fostering the regulation of one's emotional reactivity to pain (i.e., reducing pain unpleasantness). Some initial evidence suggesting that mindfulness interventions can modulate both neural sensory and emotional reactivity pain pathways (Zeidan et al. 2011).

al. 2012). However, MBSR showed no relative advantage on illness-related outcomes compared to a moderate aerobic exercise program in this trial, although there was some evidence that MBSR reduced the total number of acute respiratory infection-related work days missed (16 days), more so than the aerobic exercise (32 days) and no treatment control (67 days) groups. There have also been some initial large well-controlled RCT studies showing that mindfulness interventions (relative to controls) reduce physical symptoms and improve quality of life in fibromyalgia patients (Schmidt et al. 2011), in women with irritable-bowel syndrome (IBS) (Gaylord et al. 2011), and among distressed breast cancer survivors (Carlson et al. 2013). Finally, there is some initial evidence that brief audio-guided mindfulness training practices during lightbooth phototherapy can accelerate skin clearing in psoriasis patients, with a trial showing a four-fold faster clearing rate in the mindfulness intervention group relative to TAU (Kabat-Zinn et al. 1998). There have been some questions raised about whether the group training context is necessary for mindfulness intervention benefits, and this psoriasis study joins others that have trained participants individually (with audio-guided mindfulness practices only) (also see Creswell et al. 2014, Zeidan et al. 2011), suggesting that the group training context may not be a necessary feature for mindfulness intervention benefits.

*Health Behaviors.* It is well known that stress disrupts health behaviors such as sleep, exercise, smoking, and diet, and that these stress-related disruptions in health behaviors negatively impact physical health and disease outcomes. Despite these established links, very little rigorous empirical work has tested whether mindfulness interventions impact health behaviors. There's some initial RCT evidence that mindfulness interventions can reduce smoking among heavy smokers (Brewer et al. 2011), alter dietary behaviors such as eating less sweets (Arch et al. 2016, Mason et al. 2015), and may improve self-reported and polysomnographic markers of sleep, although the sleep outcomes evidence is mixed (Black et al. 2015, Britton et al. 2010, 2012; Garland et al. 2014b).

*Interim Summary of Physical Health Effects.* There is now compelling evidence in several large RCTs that mindfulness interventions improve chronic pain management relative to TAU, and some initial evidence that mindfulness interventions may be superior to some active treatments (support groups, health education programs) but not to other treatments (CBT). There is promising initial evidence that mindfulness interventions may reduce immune markers of pro-inflammation among stressed individuals and buffer declines in CD4+ T lymphocytes (in HIV-infected adults), although large well-controlled trials are needed to evaluate mindfulness-immunity links. Mindfulness interventions show promising initial effects in reducing symptoms and improving quality of life across a broad range of stress-related conditions (e.g., fibromyalgia, IBS, breast cancer, psoriasis), while still relatively little is known about how mindfulness interventions affect health behaviors.

### *Mental Health*

There is a great deal of interest among clinical psychologists in using mindfulness interventions for treating a broad range of mental health outcomes. Indeed, some clinical scientists have posited that mindfulness and acceptance interventions are a "third-wave" treatment approach, following behavioral and cognitive-behavioral treatment approaches (Hayes et al. 2004). This interest among clinicians, in part, has been built on views that mindfulness interventions can help individuals notice and regulate maladaptive thoughts, emotional responses, and automatic behaviors that underlie mental health problems.

*Depression Relapse.* Some of the strongest evidence to-date in the mindfulness intervention literature shows that the MBCT program is effective in reducing depression relapse during follow-up periods in at-risk populations. There are now a number of RCTs showing that 8-week MBCT is a cost-effective treatment that significantly reduces the risk of depression relapse among individuals who have had three or more previous lifetime major depressive episodes, compared to TAU (e.g. Ma & Teasdale 2004, Teasdale et al. 2000). This body of work is impressive in that there has been careful clinician condition-blinded assessment of depression during long-term follow-up periods ranging from 12 months to 2 years, with studies demonstrating that MBCT reduces depression relapse by about 50% relative to TAU during these periods. Furthermore, these MBCT benefits seem to be most pronounced among those at the greatest risk for relapse, such as among individuals with 4 or more previous major depressive episodes (Ma & Teasdale 2004) or among individuals who suffered from maltreatment during childhood (Ma & Teasdale 2004, Williams et al. 2014). Many at-risk individuals prefer not to use antidepressant medications (e.g., during pregnancy or to avoid side effect symptoms), and two RCTs indicate that MBCT (with a 4 week taper off antidepressant medications during the 8-week program) has depression relapse prevention benefits on par with maintenance antidepressant medication treatments during 18-24 month follow-up periods (Kuyken et al. 2015, Segal et al. 2010); although a recent trial suggests that the combination of MBCT plus maintenance antidepressant medication is optimal (Huijbers et al. 2016).

*Depression and Anxiety Symptoms.* The previous section highlights the benefits of offering mindfulness interventions to individuals who are not currently depressed but are at risk for depression relapse; might mindfulness interventions also help individuals with mood disorders who are currently experiencing high levels of anxiety and/or depressive symptoms? Mindfulness interventions aim to foster an open and accepting perception of one's thoughts and feelings, including an observant stance toward thought patterns and body experiences when one feels acutely anxious or depressed. This process of turning attention and awareness toward these experiences has been posited to help reduce the experiential avoidance, self-judgment, and rumination that is often triggered by acute depression and anxiety (Roemer & Orsillo 2009). Some initial well-controlled studies indicate that MBCT may be effective in reducing depressive symptoms among acutely depressed individuals (Strauss et al. 2014). In one of the most well-controlled trials to date, Eisendrath and colleagues tested a modified MBCT program for treatment resistant depression, and showed that MBCT reduced depressive symptoms post-treatment compared to a well-matched HEP comparison program in a sample of treatment-resistant depressed patients (Eisendrath et al. 2016). These mindfulness intervention effects were specific to reducing depressive symptoms, there were no differences between the MBCT and HEP groups on depression remission rates at post-treatment.

Meta-analyses indicate that mindfulness interventions significantly reduce anxiety among anxiety disordered populations pre-post intervention, but are mixed about whether mindfulness interventions reduce anxiety symptoms more so than controls (Strauss et al. 2014, Vøllestad et al. 2012). Furthermore, at this time there is not consistent evidence that mindfulness interventions are any better for anxiety symptom reduction compared to CBT interventions (Goldin et al. 2016), although some work suggests that MBSR may be more effective for participants with moderate to severe dysphoria whereas CBT may be more effective for participants with mild dysphoria in anxiety disorder groups (Arch & Ayers 2013). New trials not included in the previous meta-analyses show that mindfulness training may be effective in reducing anxiety symptoms compared to some active treatments- for example, a recent internet-

based mindfulness intervention was effective in reducing anxiety at post-treatment compared to a supervised online discussion group program (Boettcher et al. 2014). Hoge and colleagues also showed that MBSR reduced some measures of anxiety symptoms (including anxiety in response to a laboratory social stress challenge task) compared to an active stress management education program group in a sample of generalized anxiety disorder participants (Hoge et al. 2013). Also, mood disorders are prevalent among individuals with Post-Traumatic Stress Disorder (PTSD), and there is initial well-controlled evidence in Vietnam war veterans that MBSR reduces self-reported (and clinician-rated) PTSD symptomatology at 2-months post-treatment (Polusny et al. 2015).

*Addiction and Addictive Disorders.* We all experience cravings at one time or another and have felt their strong pull to act on them with consummatory behaviors, such as eating, sex or using addictive substances. Sometimes these behaviors can spiral out of control into full-blown addiction where engaging in them interferes with daily life functioning or causes harm to the self or others (e.g., alcoholism, gambling, smoking, internet addiction). Mindfulness interventions foster an ability to observe the rise and fall of cravings and the behaviors they encourage, and offer the opportunity to meet these experiences with more skillful action. As such, mindfulness interventions have tremendous potential for addressing craving, addiction, and addictive disorders (Bowen et al. 2015). The late Alan Marlatt and colleagues developed an 8-week Mindfulness-Based Relapse Prevention (MBRP) program which integrates mindfulness meditation practices from MBSR with CBT techniques for drug relapse prevention, including practices focused on mindfully attending to cravings (e.g., "urge surfing") (Bowen et al. 2009).

Several well-controlled studies suggest that mindfulness interventions impact craving, drug use, and drug relapse rates in at-risk individuals. Mindfully attending to drug cues reduces neural and self-reported craving among smokers (Westbrook et al. 2013), with some initial indication that mindfulness interventions reduce cravings more so than CBT treatment (Garland et al. 2016). Moreover, mindfulness interventions can disrupt the effects cravings have on increasing suffering and substance abuse (Witkiewitz & Bowen 2010). Initial RCTs show that mindfulness interventions, compared to TAU or other relapse prevention programs, reduce substance abuse in at-risk populations. For example, MBRP has been shown to reduce drug use days and reduce the number of legal problems at 15-week follow-up among substance-abusing female criminal offenders, compared to a standard relapse prevention program (Witkiewitz et al. 2014). A four-week mindfulness training program, compared to a standard four-week smoking cessation treatment, reduced cigarette use among heavy smokers at post-treatment and at 3-month follow-up (Brewer et al. 2011). Finally, in one of the largest trials to-date (N=286), Bowen and colleagues randomly assigned substance abusing individuals at a treatment facility to either MBRP, a cognitive-behavioral relapse prevention program, or standard treatment (a 12-step program) and then monitored their reported substance abuse during a 12-month follow-up period (Bowen et al. 2014). Compared to the standard 12-step treatment group, both the MBRP and cognitive-behavioral relapse prevention groups demonstrated a 54% reduction in drug relapse and a 59% reduction in relapse to heavy drinking. Interestingly, the cognitive-behavioral relapse prevention program had early advantages in delaying the time to first drug relapse relative to the MBRP program, but the MBRP program appeared to have long-term advantages at the 12-month follow-up time point in reducing the number of drug using days (Bowen et al. 2014).

*Interim Summary of Mental Health Effects.* There is strong RCT evidence that mindfulness interventions reduce depression relapse rates in at-risk individuals and improve the

treatment of drug addiction. Specifically, multiple large RCTs indicate that MBCT reliably reduces the risk of depression relapse during follow-up periods among individuals with 3 or more previous major depression episodes, and that MBRP (relative to standard relapse prevention programs) improves substance abuse outcomes. There are also several well-controlled studies showing that mindfulness interventions can reduce anxiety, depression, and PTSD symptomatology. In the mindfulness interventions literature, the mental health outcomes area has made the greatest advances in comparing mindfulness interventions to other gold-standard clinical treatments, and there are some initial indications of contexts where mindfulness interventions offer similar or additional long-term benefits over gold-standard treatments (e.g., antidepressant medication, relapse prevention programs, CBT).

*Cognitive and Affective Outcomes*

Formal mindfulness training practices focus on training multiple features of attention, such as noticing when the mind wanders, repeatedly re-orienting attention back to a focus area (e.g., sensations of breathing), developing sustained attention, and learning how to foster an open accepting form of attention so as not to get 'caught up' in thoughts, emotions, or body sensations. These attention skills would be expected to improve attention-related cognitive outcomes, and there are now RCT studies in predominantly healthy young adult samples showing that mindfulness interventions improve behavioral measures of sustained attention (Jensen et al. 2012, Jha et al. 2015, Mrazek et al. 2012, Semple 2010, Zeidan et al. 2010a), working memory performance (Jensen et al. 2012, Mrazek et al. 2013, Zeidan et al. 2010a), and problem-solving performance (Mrazek et al. 2013, Ostafin & Kassman 2012). It could be argued that mindfulness interventions might benefit all types of attention-related outcomes (e.g., sustained attention, task-switching, working memory), but in one of the most well-controlled trials to-date, Jensen and colleagues showed that MBSR demonstrated superior sustained attention and working memory benefits at post-treatment compared to a relaxation group or an incentivized (motivated) control group, but no relative advantage on some measures of set-shifting or attentional vigilance/effort (Jensen et al. 2012).

Not only do mindfulness interventions train attention, but they also focus on developing skills of maintaining an open and accepting attitude toward experience, which may be an important skill for emotion regulation and affective outcomes (Slutsky et al. in press). As highlighted in the mental health outcomes section, there is now mounting evidence that mindfulness interventions reduce negative affect-related outcomes, such as reducing depression and anxiety symptoms, or risk for depression relapse in at-risk individuals. There is also some evidence that mindfulness interventions may reduce self-reported measures of negative affect and improve measures of positive affect in healthy populations. For example, Jain and colleagues showed that a 4-week MBSR program reduced rumination and increased positive states of mind more so than a 4-week somatic relaxation program during a final exam period in students (Jain et al. 2007). However, both the mindfulness and relaxation programs had comparable benefits in reducing self-reported psychological distress at post-intervention relative to a no treatment control group. These RCT studies reviewed here provide some examples of mindfulness intervention effects on cognitive and affective outcomes, with more detailed narrative and meta-analytic reviews of these literatures published elsewhere (e.g., Arch & Landy 2015, Eberth & Sedlmeier 2012, van Vugt 2015).

*Interim Summary of Cognitive and Affective Outcomes.* Among healthy young adult samples, there is mounting RCT evidence that mindfulness interventions can improve attention-related outcomes (e.g., sustained attention, working memory) and affective outcomes (e.g., reducing rumination).

*Interpersonal Outcomes*

Minimal research has been conducted on how mindfulness interventions impact social and relational outcomes, which is surprising given that anecdotal reports abound about how mindfulness training increases feelings of compassion toward others and can enhance one's close relationships. Indeed, some scholars have argued that kindness and compassion toward others might be a critical marker for evaluating whether mindfulness interventions "work" (e.g., Grossman 2011), highlighting the need for more research on this topic. Several lines of research suggest that studies on this topic would be fruitful. First, mindfulness interventions have been shown to improve basic processes associated with better interpersonal functioning outcomes, such as in buffering stress and increasing perspective taking (for a theoretical and empirical review, see Karremans et al. 2015). Second, initial RCTs using wait-list control designs suggest that 8-week mindfulness interventions impact social functioning outcomes, such as reducing loneliness among older adults (Creswell et al. 2012) and in improving relationship satisfaction in adult couples (Carson et al. 2004). In the latter case, Carson and colleagues conducted one of the first daily diary studies to show that 8-week mindfulness training improved daily reports of relationship satisfaction (Carson et al. 2004). Moreover, among mindfulness intervention participants, day-level analyses showed that home mindfulness meditation practice (day 1) was significantly associated with higher levels of lagged 2$^{nd}$ and 3$^{rd}$ day relationship satisfaction, indicating potentially important daily carry-over benefits of home mindfulness meditation practice.

Mindfulness meditation teachers have long emphasized that mindful awareness can foster insights into the nature of one's suffering, and that this understanding naturally gives rise to feelings of compassion toward the self and others (Gunaratana 2011), yet little scientific work has attempted to link mindfulness interventions with compassion-related outcomes. Two small RCT studies show that mindfulness meditation training increases compassionate pro-social behaviors to a lab helping incident, such that participants who either completed a 2-week Headspace mindfulness smartphone app intervention or an 8-week group-based mindfulness intervention were more likely to give up their chair to a female confederate on crutches, which was operationalized as a lab-based behavioral measure of compassion (Condon et al. 2013, Lim et al. 2015). This work provides an initial indication that mindfulness interventions increase pro-social outcomes, with more research needed to evaluate whether feelings of compassion mediate these behavioral effects.

It is important to note that mindfulness interventions can be distinguished from compassion (or loving-kindness) meditation programs, which have been receiving more scientific interest in recent years (e.g., Fredrickson et al. 2008). Little is known about the comparative effects of mindfulness versus compassion interventions, but in the above study, Condon et al (2013) showed that the 8-week mindfulness intervention produced equivalent elevated levels of pro-social behavior at post-intervention compared to a well-matched 8-week compassion meditation intervention. One intriguing possibility is that these intervention benefits occurred via dissociable pathways. Loving-kindness meditation practices focus on the explicit

generation of positive feelings toward the self and others whereas mindfulness meditation practices aim to foster an open awareness of experience (as opposed to fostering any specific positive affective states). As such, one prediction is that compassion meditation interventions affect outcomes via positive affect mechanisms, whereas mindfulness interventions affect outcomes through meta-cognitive awareness/decentering mechanisms (Feldman et al. 2010) (see Mechanisms section below).

*Interim Summary of Interpersonal Outcomes.* There is currently very little mindfulness intervention RCT research on interpersonal outcomes, with initial studies suggesting that mindfulness interventions may improve relational outcomes (e.g., relationship satisfaction and pro-social behaviors).

## Embedding Mindfulness Interventions in Institutions and Across the Lifespan

First generation mindfulness intervention studies primarily focused on treating adult patients in clinic settings. Over the last ten years there has been a shift in moving mindfulness intervention RCTs out of the clinic into institutional settings (e.g., the workplace, schools, prisons, the military, and sport settings) and into populations spanning the entire lifespan (e.g., during pregnancy, kids, older adults). High quality RCT studies are needed to evaluate the safety, efficacy, and effectiveness of mindfulness interventions in these particular contexts. Some initial studies suggest that embedding mindfulness interventions into the workplace (either with group-based or internet-based training programs) may reduce stress and boost job satisfaction among workers (for a review, see Good et al. 2015). Likewise, mindfulness training programs may be effective in buffering the negative effects of stress during high-stress periods in soldiers (Jha et al. 2010, Johnson et al. 2014).

Initial studies of mindfulness interventions across the lifespan are also promising. Some pilot RCT evidence shows that mindfulness interventions reduce pregnancy anxiety and depressive symptoms during and following pregnancy (Dimidjian et al. 2016, Guardino et al. 2014). A current hot topic is the development of adapted mindfulness interventions for children, with some initial evidence that classroom mindfulness interventions reduce stress and aggressive behavior, and improve cognitive performance (Flook et al. 2015, Schonert-Reichl et al. 2015, Zenner et al. 2013). In one of the largest RCTs to-date (N=300), low-income and predominantly African American urban middle school kids were randomly assigned to receive either a classroom-adapted MBSR program or a health education program. At post-treatment, MBSR program participants had greater self-reported improvements in mood, coping, and rumination relative to health education program participants (Sibinga et al. 2016). Finally, in moving from early life to late life, wait-list controlled RCTs also suggest that mindfulness interventions have the potential to improve markers of healthy aging among older adults (e.g., executive function, inflammation) (Creswell et al. 2012, Moynihan et al. 2013).

## Mechanisms of Mindfulness Interventions

With the first wave of higher quality mindfulness intervention RCTs demonstrating promising initial effects on outcomes, there has been growing interest in the mechanisms driving these effects. Certainly mindfulness interventions change a number of processes, including both mindfulness-specific (e.g., acceptance and emotion regulation mechanisms) and non-mindfulness specific processes (e.g., positive treatment expectancies) (e.g., Creswell et al. 2014). But which

mechanistic processes are critical for helping explain mindfulness intervention effects on outcomes? Here I consider some of the initial psychological and neurobiological mechanisms of mindfulness interventions studied to-date (for some recent reviews, see Brown et al. 2015, Creswell & Lindsay 2014, Hölzel et al. 2011b, Tang et al. 2015).

*Psychological Mechanisms*

A great deal of research has focused on self-reported mindfulness (as measured by questionnaire measures of mindfulness) as a primary psychological mechanism of change, but the evidence is mixed. A recent meta-analysis indicates a moderate positive effect size in mindfulness interventions increasing self-reported mindfulness ($g$=.53), and there is initial evidence in at least 10 studies that increases in self-reported mindfulness statistically mediate improvements in self-reported outcomes, such as reductions in perceived stress or anxiety symptoms (see Table 2 in Visted et al. 2014). As one recent example, MBSR was shown to increase self-reported mindfulness compared to an active present-centered group therapy program (without a mindfulness component), and these MBSR increases in self-reported mindfulness were associated with decreases in PTSD symptomatology among veterans (Polusny et al. 2015). But these promising effects are offset by the fact that about 50% of mindfulness intervention studies fail to show a significant increase in self-reported mindfulness pre-post intervention (37 out of 72 trials in a recent meta-analysis) (Visted et al. 2014). Furthermore, there is currently limited evidence for mindfulness interventions increasing self-reported mindfulness more so than active comparison treatments (e.g., relaxation interventions). Some have argued that there are problems inherent with self-reporting mindfulness that undermine the validity of these measures (e.g., social desirable responding and retrospective reporting biases, it is difficult to know how attentive and aware one is on a daily basis, the meaning of self-reported mindfulness can change with more formal mindfulness training experiences) (Grossman 2011). Given these concerns, investigators have recently started to develop and test task-based measures of mindfulness (e.g., Levinson et al. 2013) and 2$^{nd}$ person mindfulness teacher assessments of mindfulness. It is expected that advances in the development of mindfulness measures will help clarify the mechanistic role of self-report and behavioral measures of mindfulness in the coming years (for a commentary, see Davidson & Kaszniak 2015).

Mindfulness interventions foster an ability to more objectively observe one's moment-to-moment experience, and this "decentered" mindset has been proposed as an important psychological mechanism of change (also described with terms such as meta-cognitive awareness or non-attachment). Decentering involves observing internal experiences from a more objective third person stance (Bernstein et al. 2015), which may help one more effectively decide how they want to respond to thoughts, emotions, or behaviors (Feldman et al. 2010, Golubickis et al. 2016, Papies et al. 2015). Decentering processes holds promise as a mechanism of mindfulness intervention effects in some studies. For example, an early study showed that MBCT improved meta-cognitive awareness in recovered depressed patients (Teasdale et al. 2002), and more recently, two well-controlled studies showed that self-reported increases in decentering mediated MBSR treatment effects on anxiety reduction in generalized anxiety disorder patients (Hoge et al. 2014) and MBCT decreases in depressive symptoms among individuals at risk for depression relapse (Bieling et al. 2012).

Other psychological and behavioral mechanisms of change in mindfulness intervention RCTs have been proposed, although there are few methodologically rigorous mindfulness

intervention studies testing these mechanisms in statistical mediation analyses (or experiments) at this time. These include psychological processes such as acceptance and emotion regulation skills (Hölzel et al. 2011b, Lindsay & Creswell 2015), exposure (Baer 2003), reducing ruminative thoughts (Jain et al. 2007), or changing aspects of one's self concept (e.g., quieting the egoic self) (Carlson 2013, Golubickis et al. 2016). Finally, formal daily home mindfulness meditation practice has been implicitly assumed to be a behavioral mechanism of change for mindfulness intervention effects (considered in more detail in the Dosing section below), although few well-controlled studies have rigorously evaluated this assumption in RCT studies (Carmody & Baer 2009).

*Neurobiological Mechanisms*

Mindfulness intervention effects on outcomes are certainly mediated by the brain, and there have been some recent mindfulness intervention RCT studies that employ structural and functional neuroimaging to evaluate neurobiological mechanisms (for a review, see Tang et al. 2015). Formal mindfulness meditation practices (e.g., mindful awareness of breathing) have been shown to activate a distributed network of brain regions, including the insula, putamen, somatosensory cortex, and portions of the anterior cingulate cortex and prefrontal cortex (Hölzel et al. 2007, Tomasino & Fabbro 2016, Zeidan et al. 2015). There is also some initial evidence that mindfulness interventions might structurally alter the brain, increasing gray matter density in the hippocampus (Hölzel et al. 2011a), although well-controlled mindfulness intervention studies are lacking. Despite these advances, less is known about the neural mechanisms linking mindfulness interventions with outcomes.

Our mindfulness stress buffering account posits that mindfulness training interventions increase activity and functional connectivity of prefrontal cortical regions important in top-down stress regulation, while decreasing activity and functional connectivity in neural regions important in gating the fight-or-flight stress response (e.g., amygdala, subgenual anterior cingulate cortex) (Creswell & Lindsay 2014). We have provided some initial supportive evidence for this neural mechanistic account with a RCT of mindfulness vs relaxation training in stressed unemployed adults (Creswell et al. 2016, Taren et al. 2015). Specifically, we showed that a mindfulness meditation retreat (relative to a well-matched relaxation retreat without a mindfulness component), increased resting state functional connectivity of the default mode network with stress regulatory areas of prefrontal cortex (dorsolateral prefrontal cortex), while also decreasing stress-related resting state functional connectivity of the amygdala with subgenual anterior cingulate cortex. Importantly, we describe some initial associations linking these brain changes with reduced stress biomarkers (i.e., cortisol, circulating Interleukin-6) at 4-month follow-up (Creswell et al. 2016, Taren et al. 2015).

Beyond neural stress-health mechanisms, there are also initial mindfulness intervention studies linking brain changes with affective outcomes. Holzel and colleagues showed that MBSR intervention increases in ventrolateral prefrontal cortex activity (and amygdala-prefrontal connectivity) during an affect labeling task were associated with reductions in anxiety symptoms in a generalized anxiety disorder patient sample (Hölzel et al. 2013). Zeidan and colleagues showed that a brief mindfulness intervention (20 minutes per day for four days) decreased both pain intensity and pain unpleasantness ratings to a noxious thermal pain stimulation to the calf, and that the neural mechanisms of these mindfulness-pain reduction effects were dissociable from the neural mechanisms driving placebo conditioning effects on pain reduction (Zeidan et al.

2011, 2015). In combination, these initial studies suggest some promise for identifying putative brain mechanisms for mindfulness intervention effects, although all of these studies had small sample sizes and focus only on a small subset of the outcomes in the growing mindfulness intervention literature.

**Dosing: How Much Mindfulness Intervention is Needed for Benefits?**

One of the most common questions posed by individuals contemplating whether they should enroll in a mindfulness intervention concerns the amount of mindfulness intervention they need to experience benefits. The current evidence base suggests that even very brief mindfulness interventions (e.g., 5-10 minute guided mindfulness inductions, 3-4 session mindfulness meditation training) can buffer affective reactivity and reduce impulsive behaviors immediately following training (e.g., negative affect, craving, pain) (Broderick 2005, Papies et al. 2015, Westbrook et al. 2013, Zeidan et al. 2011), although a recent meta-analysis suggests that these brief training effects are small in magnitude ($g$=.21) (Schumer et al, in prep). By contrast, larger doses of mindfulness interventions, such as the 8-week MBSR program, produce moderate to large overall effects pre-post training (Baer 2003, Goyal et al. 2014). One illustrative study measured anxiety symptomatology weekly before, during, and after an MBSR intervention in anxiety disorder patients, and showed relatively linear declines in anxiety symptoms over the intervention (which were maintained at follow-up) (see Figure 2)—suggesting a potential dose-response effect of interventions, with greater doses of mindfulness intervention producing larger scalable effects over the 8-week intervention. However, few published RCTs have tested for mindfulness intervention dose-response effects (either by experimentally manipulating intervention dose or by relating measures of class attendance and home mindfulness practice duration with outcomes), which is an area that is in need of more research (cf. Carmody & Baer 2009).

[Insert Figure 2 about here]

Among mindfulness intervention teachers there is a wide range of "recommended" daily formal mindfulness practice advice, ranging from 10 minutes to an hour per day, or more. There is no one-size-fits-all recommendation for how one should dose their mindfulness intervention training programs. Dosing of mindfulness interventions might follow the same general rules of thumb as dosing aerobic exercise interventions. Larger doses are likely to produce larger effects, the periodicity of the dose is probably important (with regular daily home practice producing larger effects), and there is an upper bound dose of formal mindfulness intervention that is probably not helpful to participants new to mindfulness practices. Finally, while dosing is important, it is critically important for participants to learn how to apply formal mindfulness training skills to "hot" daily life experiences, so that mindfulness skill development can translate into more effective coping.

**Risks of Participating in Mindfulness Interventions**

It is not uncommon for participants in mindfulness interventions to report various unpleasant reactions during formal mindfulness training exercises, such as agitation, anxiety, discomfort, or confusion (note that participants also commonly report relaxation and

contentment). Indeed, these negative reactions are viewed as a key feature of the psychotherapeutic change process in mindfulness interventions—as sustained mindful attention on one's experience is thought to help participants explore and understand the full embodied experience of these reactions, to learn that the experience of these reactions is temporary, and to foster insight into how one reacts to these uncomfortable experiences. These more benign risks aside, there have been recent calls to study whether mindfulness interventions can trigger more significant adverse events (Lustyk et al. 2009, Shapiro 1992). For example, a participant who has a life history of trauma might have these trauma memories resurface during mindfulness training exercises, potentially triggering a major depressive episode. There has also been the concern that individuals who are at risk for psychosis (e.g., schizophrenia) or seizures (e.g., epilepsy) might put themselves at elevated risk for exacerbation of these symptoms if they participate in formal mindfulness exercises (e.g., Walsh & Roche 1979). Currently, there is little empirical published research on the prevalence, type, and severity of these more significant 'dark night' experiences with mindfulness interventions. Some early observational research suggests that these severe adverse events can occur (albeit infrequently) among individuals going through more intensive residential mindfulness meditation retreats lasting 2 weeks to three months (e.g., Shapiro 1992). The current evidence-based mindfulness interventions (e.g., MBSR, MBCT), which are offered in smaller spaced doses by trained instructors, carry minimal risks for significant adverse events; furthermore, these mindfulness interventions show the greatest benefits among high trauma/stress populations (Creswell & Lindsay 2014, Polusny et al. 2015, Williams et al. 2014).

Beyond specific risks and adverse events, it is interesting to consider the possibility that the conscious effort at maintaining awareness on present moment experience might have cognitive costs among individuals who are new to mindfulness interventions. Some studies suggest that training in mindfulness can be cognitively depleting at first. For example, a brief mindful awareness induction was shown to decrease pain tolerance to a cold pressor challenge task, depleting self-regulatory strength (Evans et al. 2014). We also showed that a brief mindfulness meditation training program (25 minutes per day for 3 consecutive days) buffered psychological perceptions of stress to a laboratory stress challenge task, but also increased cortisol reactivity (Creswell et al. 2014). One explanation for this finding is that brief mindfulness training helped foster emotion regulation skills (decreasing psychological stress perceptions) but that the extra effort of using a new mindful awareness strategy during a stress task increased cortisol reactivity.

Beyond short-term depleting effects, it is also possible that the cognitive demands of adopting this more reflective awareness of one's present moment experience might disrupt, slow, or bias one's responses on cognitive tasks. While some initial research indicates that very brief mindfulness inductions can reduce evaluative cognitive biases such as the correspondence bias and sunk cost bias (Hafenbrack et al. 2014, Hopthrow et al. in press), but that they can also increase false memory recall (Wilson et al. 2015). There are still many open questions about how mindfulness interventions affect cognitive processing variables at this time.

## Discussion

Our scientific understanding of mindfulness interventions has accelerated in recent years, and this review provides some selective highlights in this literature. RCTs provide quite promising evidence that mindfulness interventions can improve mental and physical health, cognitive and affective factors, and interpersonal outcomes. Some of the strongest and most

reliable RCT evidence indicates that mindfulness interventions (and particularly 8-week mindfulness programs, such MBSR and MBCT) improve the management of chronic pain, reduce depression relapse rates in at-risk individuals, and improve substance abuse outcomes. In these RCT studies, there is consistent evidence that mindfulness interventions improve outcomes relative to TAU or no treatment control groups, some evidence that mindfulness interventions can improve some outcomes when compared to other active behavioral treatments (e.g., relaxation or health education programs), and limited evidence for a relative advantage of mindfulness interventions over other gold-standard pharmacological or behavioral treatments (e.g., CBT)[3]. Still very few RCT studies have been conducted examining mindfulness intervention effects on interpersonal outcomes (Karremans et al. 2015) or in institutional settings beyond medical or psychological clinics (e.g., prisons, workplaces, schools), areas that are ripe for high quality RCT research.

Although this review has focused on some of the higher quality RCT mindfulness intervention studies, most of the mindfulness intervention literature to-date has methodological limitations (i.e., small samples, lack of active control groups, limited use of high quality measures, non-blinding of outcome assessors) that preclude any definitive statements about the efficacy of mindfulness interventions on many outcomes at this time. Two important areas are especially in need of research attention in the mindfulness interventions literature: the measurement of formal (and informal) mindfulness practices during and after mindfulness interventions, and testing for treatment effects at follow-up time points. Regarding the first point, very few mindfulness studies carefully measure and report the amount of daily formal mindfulness practices (and the amount of informal mindful awareness practices) completed during mindfulness interventions, even fewer studies measure whether the amount of daily practice statistically mediates outcomes, and almost no studies have reported how much daily practice participants continue to do in the weeks, months, and years following the completion of formal mindfulness intervention programs (cf. Barkan et al. 2016). The second issue is related, and that is the need for RCT studies which include follow-up time point assessments to measure stability of treatment effects. This review has highlighted some of the trials that include follow-up assessments, with mixed evidence about the maintenance of effects up to two years following intervention. It is currently unclear what factors are important for determining when beneficial effects are observed at follow-up time points after mindfulness interventions (e.g., in 2-year follow-up periods among participants at risk for depressive relapse), or when post-intervention treatment effects disappear at follow-up time points (e.g., pain reduction benefits disappearing at 6-month follow-up, Morone et al., 2016). One implicit assumption (that has gone untested) is that sustained daily mindfulness practices drives the maintenance of intervention effects.

I began this chapter by recognizing the dramatic growth in our scientific understanding of mindfulness, and how the response among scientists has been wide-ranging, from skepticism to fanaticism. This chapter aimed to provide a balanced review of the current mindfulness intervention RCT evidence base, with a consideration of when and where mindfulness interventions show benefits, identification of some promising mechanisms for these effects, and a consideration of their potential risks. Certainly, there are many contexts where public interest

[3] The comparison of CBT to mindfulness interventions is a conceptually curious one, in that some mindfulness interventions are hybridized mindfulness-CBT treatments (e.g., MBCT, MBRP), and it is certainly possible that CBT approaches, which aim to bring awareness to automatic thoughts and their effects on behavior, may be increasing a form of mindful awareness as a central mechanism of change.

in the benefits of mindfulness interventions has resulted in some fanaticism about mindfulness training as a panacea treatment. For example, mindfulness interventions are being integrated into schools and the workplace, in the absence of a corpus of high quality well-controlled RCT studies. Many investigators are using mindfulness interventions with patient populations without regard to active mechanisms of change in affecting specific outcomes of interest (Dimidjian & Segal 2015). New research on the mechanisms of mindfulness interventions and specification of how (and for whom) mindfulness interventions work will accelerate our basic and clinical efforts in this area.

With the growth of the mindfulness interventions literature, there are also skeptics about the value of mindfulness interventions and how they are implemented. There have been recent discussions about the risks of mindfulness interventions, such as so-called 'dark night' experiences that are potentially triggered by mindfulness training (see Risks section above). Our current understanding of 8-week mindfulness intervention trials indicate a very low prevalence of these significant adverse events, with most individuals having a side effect profile consisting of greater insight, well-being, and self-regulated behavior. There have also been skeptics about the value of secularized forms of mindfulness interventions (such as MBSR and MBCT) that are stripped of the Buddhist ethical and compassion teachings that are common to many Buddhist forms of mindfulness meditation training (Grossman 2011). More research is needed to evaluate these concerns, but initial work suggests that secular forms of mindfulness meditation training may be just as beneficial as spiritual forms of mindfulness training (Feuille & Pargament 2015).

As we begin to develop some reliable efficacy indications for mindfulness interventions in RCT studies, it will be important to shift our focus into translating this knowledge into effective and sustainable community mindfulness intervention programs—and currently there is very little effectiveness research in this area (Dimidjian & Segal 2015). Recent epidemiological work suggests that more affluent healthy white adults are the ones who are most likely to seek out and use mindfulness practices, whereas mindfulness practices are underutilized among low-income minorities with worse health (Olano et al. 2015). From an effectiveness standpoint this is problematic because our RCT evidence to-date suggests that these more high-stress, low-income, and health-compromised individuals would be the types of individuals who would benefit the most from mindfulness interventions (Creswell & Lindsay 2014). As such, we need to develop effectiveness studies that carefully consider how we can reach out to communities of need with evidence-based, cost-effective, and sustainable mindfulness interventions in the coming years.

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## Figure Captions

Figure 1. A non-cumulative plot of the number of mindfulness RCTs published during 3-year periods. PubMed abstract/title search (Feb 2016) using “mindfulness” and “randomized controlled trial” in human clinical trial studies.

Figure 2. Mean Beck Anxiety Inventory Ratings Before, During, and After Treatment of Patients in a Meditation-Based Stress Reduction Program (adapted from Kabat-Zinn et al., 1992, Figure 1).

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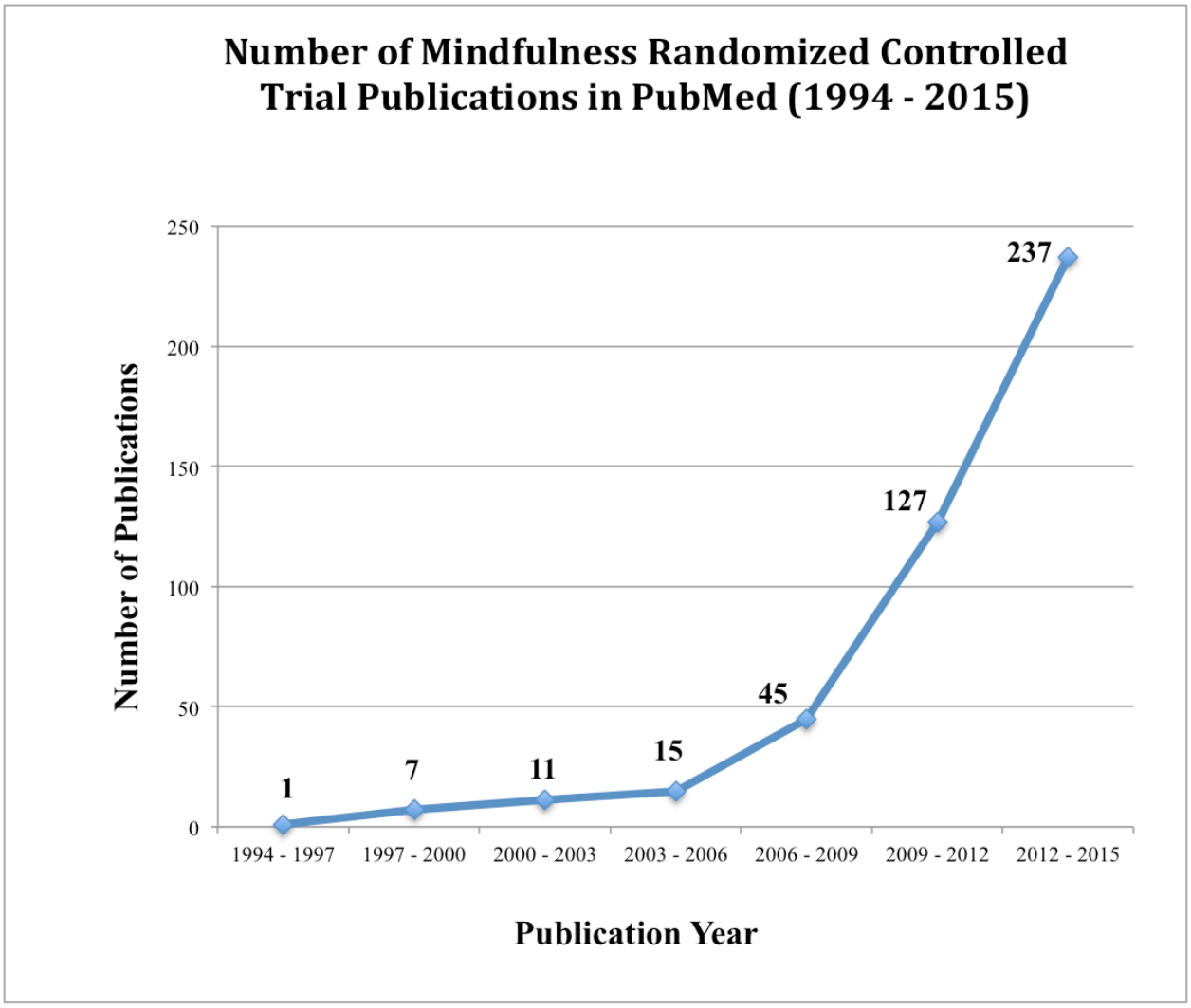

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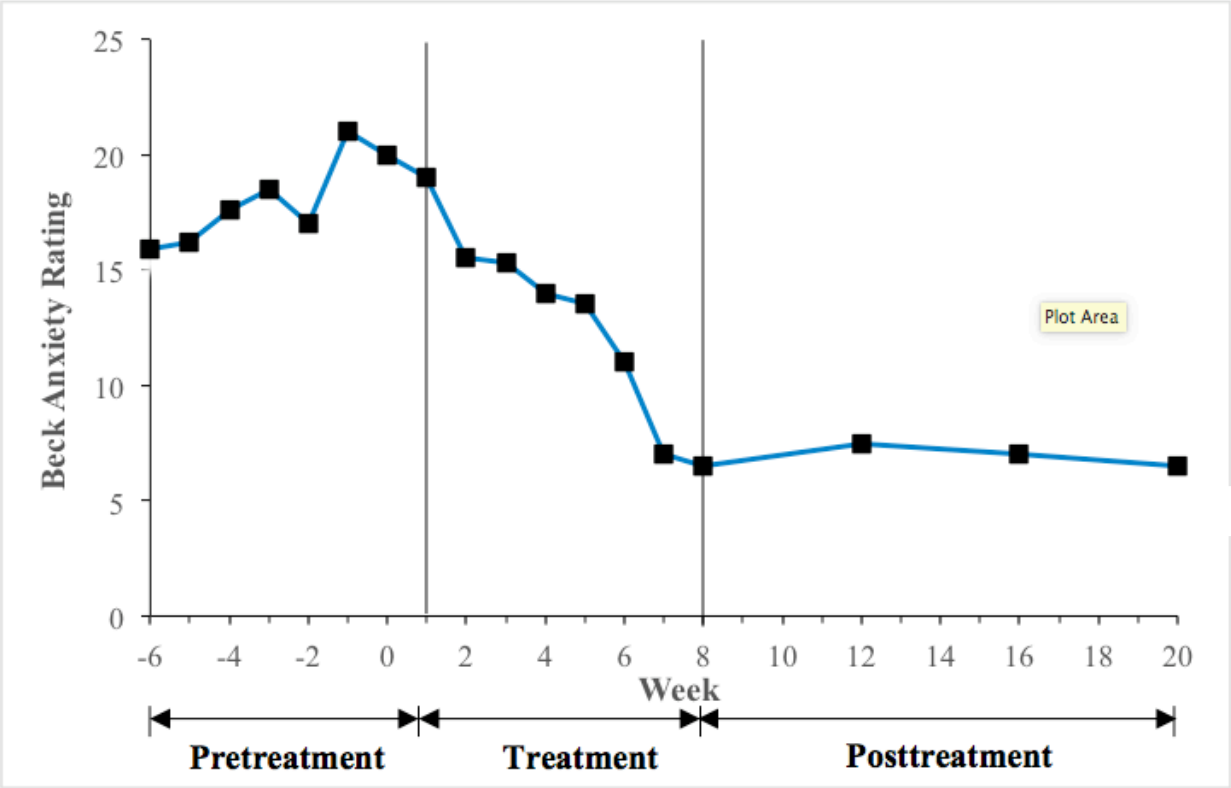

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