Published in final edited form as:

Psychol Inq. 2015 ; 26(4): 349–357. doi:10.1080/1047840X.2015.1076701.

Mindfulness, Mechanisms and Meaning: Perspectives from the Cognitive Neuroscience of Addiction

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Keywords

mindfulness; meditation; neuroscience; functional connectivity; addiction; psychiatry

Introduction

The Mindfulness-to-Meaning Theory (MMT; Garland et al., in press) is a process model for explaining how mindfulness might facilitate an upward spiral of positive psychological growth via both eliminative and generative mechanisms. Unlike models that strictly describe the eliminative aspects of mindfulness, MMT provides a theoretical framework for how the iterative cycle of appraisal→ decentering→ metacognitive awareness, coupled with positive reappraisals that extend into broader contexts, may help to extinguish conditioned negative affective sequela and promote positive affectivity and eudaimonic well-being.

One of the largest challenges facing the self-aware individual is the filtering and selection of interoceptive and exteroceptive information, particularly with regard to how one regulates what information is attended to and what meanings are construed from experience (Delle Fave, Massimini et al. 2011). MMT proposes that mindfulness practice, over time, can lead to a deepened capacity for meaning-making – or rather, a capacity to positively reappraise experiences of suffering and to amplify the affective experience related to natural rewards through savoring, transforming the context of these experiences in such a way that the experiences become supportive of the individual's growth-process, thus engendering eudaimonic well-being while transforming the nature of the personal narrative or 'autobiographical self' (Garland et al., in press).

Over the course of mindfulness practice, agency and self-awareness are often transformed in ways that seem to tune attentional processes towards positive information in the internal and external environment (Kiken and Shook 2011). MMT hypothesizes that, at least in part, this process of attentional tuning towards positive stimuli, and reframing ones relationship with negative stimuli, along with proactive cognitive reappraisal feedback loops, will further

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generate positive affect, ultimately engendering eudaimonic well-being and spurring motivation towards prosociality (Garland et al., in press). In this manner, MMT hones in on key, heretofore neglected, generative aspects of mindfulness, implicitly contextualized in the framework of Barbara Fredrickson's "Broaden-and-build" theory of positive emotions (Fredrickson 2004). The "Broaden-and-Build" theory models what happens at the affect-attention interface, proposing that positive and negative affect will either broaden or constrict the attentional field – resulting either in the accumulation or the conservation of psychosocial resources, respectively (Fredrickson 2004). MMT applies this theory to mindfulness practice, posturing mindfulness as a generative mechanism through which positive affect can be increased, positive reappraisals generated, and eudaimonic meaning construed from experiences of adversity.

The MMT is a novel and intriguing theoretical model that holds great potential for direct application in modern western society. Though a nascent database of scientific research on the effects of mindfulness practices on mood, cognition and well-being have begun to provide insight into both the behavioral and neural mechanisms underlying the processes described in the MMT, a significant amount of research is still needed to identify pathways from dysregulation to well-being. It remains to be seen whether mindfulness-associated positive affect, along with its sequelae, are both necessary *and* sufficient to provide for the construal of eudaimonic meaning from conditioned and unconditioned stimulus-response sequences. In other words, are the key elements of MMT (decentering, metacognitive awareness, positive reappraisal, attention to positive affect and amplification of natural rewards) necessary and sufficient to provide constant fuel to the self-realizing individual traversing the upward spiral of eudaimonic well-being? Additional longitudinal research on mindfulness will help to assess the MMT and the generalizability of this model to diverse populations (e.g., individual differences, substance use disorders, psychiatric disorders). Notwithstanding these questions, the MMT bridges a significant gap in the literature by explicating a translational model of mindfulness that may be applied to evaluating the effectiveness of mindfulness for treating the pathophysiology of dysregulated behavior, in particular drug addiction.

In the commentary to follow, we frame our discussion of the MMT in the context of a brief overview of the neural correlates of mindfulness practice, particularly with regard to distributed neural network connectivity, and discuss the relevance of mindfulness from the perspective of treating the pathophysiology of drug addiction.

Mechanisms of Mindfulness & Addiction

1.1. Overview of a dual-systems model of neurocognitive function in mindfulness and addiction

One of the primary functions of mindfulness practice involves transformations of how the practitioner learns to filter and consciously select which intero- and exteroceptive information to attend to and construe meaning from (Delle Fave, Massimini et al. 2011) – a process which can be described in terms of both eliminative and generative mechanisms. MMT provides novel, integrative logic, clarifying mechanisms through which the practice of mindfulness may be particularly relevant to the treatment of substance-abuse disorders

(Garland, Froeliger et al. 2013) by way of: 1) extinction of bottom-up habitual responding to overlearned conditioned drug cues (e.g., stress, craving, environmental context); 2) tuning attention toward non-drug-related reward and broadening the context from which new stimulus-response relations become salient and lead to the experience of reward; 3) enhancing bidirectional communication between top-down cognitive control and bottom-up affective responding; 4) reversing the downward spiral of negativity (Garland, Fredrickson et al. 2010); and 5) promoting the restructuring of reward processing (Garland, Froeliger et al. 2014). If mindfulness practices are indeed shown to treat or facilitate the treatment of drug-addiction pathophysiology, this would represent a significant contribution to reducing suffering in individuals and in society as a whole; as, recent statistics show that 9.4% of the U.S. population has reported using illicit drugs in the past month (National Institute on Drug Abuse 2015) and nearly 18% are daily cigarette smokers (Jamal, Agaku et al. 2014), the leading cause of preventable premature death in the US (Centers for Disease Control & Prevention 2002).

The effectiveness of the mindfulness skill-set as relevant to addiction treatment, and as proposed by MMT (e.g., primarily comprising savoring and positive reappraisal), can be evaluated in terms of the dual-process model of brain function (Verdejo-Garcia and Bechara 2009). In terms of this dual-process model, addiction results from the dysregulation of bottom-up neural circuitry that codes for salience of drug-related stimuli (e.g., the mesolimbic dopamine reward system) and negative reinforcement (e.g., amygdala, insula) (Robinson and Berridge 2008, Koob and Volkow 2010), observed conjointly with impaired top-down brain circuitry (e.g., prefrontal (PFC) and anterior cingulate (ACC) cortices) (Goldstein and Volkow 2002) that subserves a broad range of cognitive-control processes including inhibitory control and the proactive regulation of attention, motivation/reward and negative affect (George and Koob 2010, Goldstein and Volkow 2011). In brief, addictive behavior arises from amplified bottom-up signaling elicited by drug cues and stress, coupled with the disruption of top-down control over behavior. Consequently, the drive to seek natural rewards and reduce negative affect is supplanted by compulsive drug-use habits that have lost their hedonic value and are repeated in attempts to quell psychological distress (Alcaro and Panksepp 2011).

The pattern of functional magnetic resonance imaging (fMRI) blood-oxygen-level-dependent (BOLD) response exhibited among individuals with a substance-use disorder is juxtaposed by that observed among mindfulness practitioners (Diekhof, Falkai et al. 2008, Garland, Froeliger et al. 2013). Neurocognitively speaking, mindfulness practice is associated with flexible recruitment of prefontal BOLD response during goal-directed behavior and emotional processing (Froeliger, Garland et al. 2012). For instance, MMT frames the transition from acute (early-stage) mindfulness practice into trait-mindfulness (middle- and advanced-stage) in terms of resource allocation; disengagement from negative affective sequelae is proposed to be accompanied by enhanced set-shifting functions (i.e., increased cognitive flexibility), concomitant with alterations in the loci of neural activations subserving reappraisal (Garland et al., in press)(Kalisch 2009). Moreover, meta-analysis of fMRI studies demonstrates consistent patterns of activation and cognitive function associated with the core components of mindfulness practices: attentional control (frontostriatal network: ACC, striatum), emotion/affect regulation (frontolimbic and frontostriatal: mPFC, dorsolateral PFC, amygdala, striatum) and self-awareness (insula, default-mode network (DMN): mPFC, posterior cingulate (PCC) and precuneus (Sperduti, Martinelli et al. 2012, Tang, Hölzel et al. 2015). Therefore, the eliminative and generative mechanisms of mindfulness are poised to potentially remediate dysregulated bottom-up (e.g., via extinction and savoring) and top-down (e.g., via reappraisal and attentional control) (Garland, Froeliger et al. 2013).

1.2. Eliminative Mechanisms of Mindfulness – Extinction and Metacognition

Traditionally, the literature has portrayed mindfulness practice as being primarily eliminative such that it has been shown to facilitate exposure to and extinction of automatized responses to environmental stress (Hölzel, Lazar et al. 2011). According to this primarily eliminative model, the practice of mindfulness operates through basic cognitive mechanisms: exposure (which prevents thought suppression and/or distortion); decentering (which allows for non-elaborative processing and facilitates insight); and lastly, the discontinuation of automatic inference processing (mediated through reductions in priming effects and stereotyping (Kang, Gruber et al. 2013). MMT's eliminative account of mindfulness goes a step further than previous models, suggesting that the refocusing of attention on previously unappraised interoceptive information (e.g., visceral sensations) provides for a broadening of attention and the adaptive reappraisal of sensations that were previously (and unconsciously) limited to reinforcing habitual, negative appraisals (Garland et al., in press). This metacognitive transition is marked by a transient inhibition of neural regions subserving self-referential and linguistic, elaborative processing – thus freeing neural resources to be re-allocated towards other computations, such as insula-mediated interoceptive recovery (Garland et al., in press). Ultimately, these eliminative mechanisms of mindfulness, in combination with associated enhancements in attentional control and cognitive flexibility, are hypothesized to facilitate adaptive self-regulation, leading to improved health outcomes and psychosocial integration (Kang, Gruber et al. 2013), as well as increased eudaimonic well-being (Garland et al., in press). In the context of drug use, the eliminative mechanisms of mindfulness, as presented previously in the literature and more recently extended by MMT, offer avenues of therapy for addiction that focus on treating dysregulated bottom-up motivational responding and enhancing cognitive control through novel means.

1.3. Generative Mechanisms of Mindfulness – Savoring and Reappraisal

MMT's proposed generative mechanisms of mindfulness (e.g., amplification of positive affect/savoring, reorienting to adversity, and positive reappraisal of stress) are thought to complement the proposed eliminative mechanisms such that over repeated iterations of decentering and metacognition, attention is redirected away from maladaptive cognitive processes (e.g., rumination) allowing for attentional resources to be directed towards the amplification of natural rewards and to the broader socioemotional context of the event in question (Garland et al., in press). These generative components of MMT are particularly relevant to how mindfulness may treat and or re-train the emotion-cognition interactions that occur in addiction (e.g., dysregulated top-down control over affective processes) (Garland, Boettiger et al. 2011, Garland, Froeliger et al. 2013).

Of primary interest to the present discussion are key functional and neuroanatomical correlates of substance-abuse, including dysregulations in frontal regions including anterior cingulate/medial prefrontal cortex (ACC)—a region involved in reward learning (Bush, Vogt et al. 2002) and conflict monitoring (Bush, Luu et al. 2000), and lateral prefrontal cortex— which is involved in attentional (Hampshire, Chamberlain et al. 2010) and inhibitory control (Hester and Garavan 2009). For example, compared to drug-naïve controls, persons with substance-use disorders exhibit hypoactivation in frontal cognitive-control neural circuitry during conflict resolution tasks (Barrós-Loscertales, Bustamante et al. 2011, Froeliger, Modlin et al. 2013), and while processing salient emotional information (Sinha, Lacadie et al. 2005, Goldstein, Alia-Klein et al. 2009, Asensio, Romero et al. 2010, Payer, Lieberman et al. 2010, Augustus Diggs, Froeliger et al. 2013, Froeliger, Modlin et al. 2013). Moreover, acute withdrawal further exacerbates dysregulated prefrontal brain function across an array of neurocognitive tasks (Garavan, Kaufman et al. 2008, Azizian, Nestor et al. 2010, Kozink, Lutz et al. 2010, Froeliger, Beckham et al. 2012, Froeliger, Modlin et al. 2012, Froeliger, Modlin et al. 2012).

Chronic exposure to drugs of abuse produces neuroplasticity in frontostriatal (i.e., medial prefrontal cortex: mPFC, nucleus accumbens (NAcc)) circuitry, which subserves compulsive drug seeking and the loss of adaptive behavioral responding to changing environmental contingencies (Kalivas 2009). Concomitantly, long-term exposure to drugs significantly attenuates neural responses to non-drug related, intrinsically positive stimuli in the environment. Indeed, vulnerability to relapse has been attributed to increased incentive salience of drug cues and decreased salience of intrinsically pleasant stimuli (Koob and Le Moal 2001, Berridge, Robinson et al. 2009). It has been hypothesized that mindfulness training may amplify hedonic processing of natural rewards and thereby counter the allostatic effects of addiction on reward neurocircuitry (see: (Garland, Froeliger et al. 2013). A growing body of research suggests that mindfulness training can increase reward experience and positive emotion in healthy and clinical populations (Garland, Fredrickson et al. 2010), as well as among individuals with a substance use disorder (Garland, Froeliger et al. 2015).

Theoretically, mindful reappraisal may help restore functional communication between top-down, frontal executive brain regions (e.g., ACC; lateral prefrontal cortex) and bottom-up emotional (e.g., amygdala) and motivational (e.g., NAcc) systems that are ***functionally disconnected*** in drug addiction (Hong, Gu et al. 2009, Gu, Salmeron et al. 2010, Ma, Liu et al. 2010, Motzkin, Baskin-Sommers et al. 2014, Froeliger, McConnell et al. under review). Furthermore, the process of savoring offers a potential complementary therapeutic mechanism to help restructure reward processing and prevent relapse in addicted populations (Garland, Froeliger et al. 2014).

1.4. Mindfulness as a means for restructuring neural circuitry function

Functional connectivity fMRI has emerged as an effective method for examining systems-level functional connectivity present during different activities and characterized as different ‘brain states’ (Biswal, Yetkin et al. 1995) (i.e., fluctuating BOLD activation in distributed neural networks (Shmuel and Leopold 2008)). Tang and colleagues (2012) define ‘brain states' as "reliable patterns of brain activity that involve the activation and/or connectivity of multiple large-scale brain networks" and cite the ability to maintain and switch between brain states as being critical for both self-regulation and adaptation to variable environmental contingencies (Tang, Rothbart et al. 2012). Indeed, functional connectivity research has provided evidence that mindfulness practice might strengthen coupling within and between key task-negative (i.e., resting-state) and task-positive (e.g., attention and cognitive control) networks (Hasenkamp and Barsalou 2012). These mindfulness-associated neural network alterations may reflect possible increases in, or more efficient communication between, attention and affective neurocircuitry (Froeliger, Garland et al. 2012), as well as potential increases in flexible and adaptive goal-directed behavior (Vago and Silbersweig 2012).

Thus far, mindfulness research has focused primarily on investigation of the default mode network (DMN)—a canonical resting-state network involved with self-referential processes (Raichle, MacLeod et al. 2001) and the primary neural network involved in the development of mindfulness-expertise (Jao, Li et al. 2015); but, DMN is also a pivotal network involved in the maintenance of psychopathologies such as depression (Hamilton, Farmer et al. 2015), addiction (Sutherland, McHugh et al. 2012) and in neuropsychiatric disorders more broadly (Greicius 2008). In order to understand the neural mechanisms through which mindfulness practice may help treat addictive disorders, it is important to consider what is happening within and across distributed neural networks both while resting (Koob and Volkow 2010) and during the meditation activity. During the resting-state (e.g., suggesting either mindful dispositionality and/or accrued effects of practice), mindfulness practice has been shown to correlate with strengthened resting-state functional connectivity (rsFC) within the DMN (Jang, Jung et al. 2011), with increased rsFC between DMN nodes subserving attention and cognitive control, yet with weakened connectivity between DMN nodes implicated in self-referential processing and emotional appraisal – interpreted by the authors as suggesting increased present moment awareness, mood and well-being (Taylor, Daneault et al. 2012).

During meditation (i.e., meditation-state functional connectivity (msFC)), strengthening of connectivity between DMN, dorsal attention network (DAN) and salience network nodes (Froeliger, Garland et al. 2012), and between DMN nodes and cognitive control/error monitoring nodes have been observed (Brewer, Worhunsky et al. 2011), concomitantly with DMN BOLD deactivations (Brewer, Worhunsky et al. 2011) which exceed those typically observed during task-positive activities (Garrison, Zeffiro et al. 2015). In addition to msFC patterns of increased connectivity, coupling of DAN nodes with mPFC (a primary DMN node) and insula—a region involved in interoception (Craig 2011) and drug craving (Naqvi, Rudrauf et al. 2007, Naqvi and Bechara 2010)—has been shown to decrease, again suggesting functional alterations in intra- and inter-network coupling in regions subserving attention, self-referential processing and affective responses (Froeliger, Garland et al. 2012). Decreased meditation-state activation in the DMN is related to meditation-associated reductions in mind-wandering and has also been linked to more stable patterns of functional connectivity with dACC across resting-state and meditation-state – suggesting the potential emergence of a new hybrid DMN characterized by increased self-monitoring and cognitive control (Brewer, Worhunsky et al. 2011). Employing graph-theory, researchers have elaborated this idea, providing evidence that meditation practice results in dynamic and wide-spread reconfigurations of neural networks involved in sensory and self-referential processing (Jao, Li et al. 2015).

As shown thus far, these preliminary characterizations of mindfulness-associated functional connectivity juxtapose the neural network dysregulations observed in addiction (Cole, Beckmann et al. 2010), including uncoupling of regions governing top-down cognitive control and regions subserving bottom-up affective/motivational responding (Froeliger et al., under review; Gu et al., 2010; Hong et al., 2009; Ma et al., 2010; Motzkin, Baskin-Sommers, Newman, Kiehl, & Koenigs, 2014). Mindfulness practice is associated with transient prefrontal (top-down) neural response in regions subserving attention (Froeliger, Garland et al. 2012) and self-referential and elaborative processing (Brewer, Worhunsky et al. 2011, Garrison, Zeffiro et al. 2015), suggesting flexible and adaptive engagement and disengagement of cognitive and emotional neural resources as a function of context-relevant demands. In contrast, as compared to controls, substance abusers exhibit sustained hypofrontality in regions subserving cognitive control and error monitoring (Sinha, Lacadie et al. 2005, Goldstein, Alia-Klein et al. 2009, Asensio, Romero et al. 2010, Payer, Lieberman et al. 2010, Barrós-Loscertales, Bustamante et al. 2011, Augustus Diggs, Froeliger et al. 2013, Froeliger, Modlin et al. 2013). Interestingly, among nicotine-dependent cigarette smokers, smoking abstinence as compared to satiety results in hyperfrontal response during neurocognitive tasks, without producing significant improvements in task performance or measured behavior (Kozink, Lutz et al. 2010, Froeliger, Modlin et al. 2012, Froeliger, Modlin et al. 2012). Taken together, these findings, along with the broader literature (Goldstein and Volkow 2002), demonstrate that drug state-dependent sustained patterns of dysregulated top-down prefrontal neural function undergirds maladaptive behaviors found in substance-use disorders. Theoretically, mindfulness practice may be well-situated to help remediate some addiction-related dysfunction, particularly with regard to improving cognitive control and emotional processing, but also by potentially reducing negative self-reflective narrative (e.g., rumination) and maladaptive core beliefs (Beck and Alford 2009).

Summary and Conclusions

While it is clear that mindfulness practice is predictive of rsFC variance within and across multiple neural networks during rest and during meditation (Froeliger, Garland et al. 2012), it remains uncertain to what extent the dynamic relationships between networks are altered as a function of practice (e.g., flexible coupling and decoupling of resting-state and attention networks during different tasks such as mindful reappraisal and emotion regulation). As noted, msFC experiments have provided evidence that the meditation-state is associated with functional alterations in intra- and inter-network coupling and decoupling (Froeliger, Garland et al. 2012); but, dynamic functional connectivity assessments of the meditation state are needed to determine the extent of moment-to-moment fluctuations in neural network coupling. In fact, it may very well be that the degree of flexibility in network dynamics (rather than steady-state functional connectivity/disconnectivity) is a driving force behind the cognitive and affective benefits that appear to accompany mindfulness meditation practice.

Furthermore, it seems plausible that extensive mindfulness training may result in the emergence of new neural networks functioning in a sense as hybrid-networks (Brewer, Worhunsky et al. 2011), which may subserve the novel and superordinary states of awareness commonly associated with high-level mindfulness practice (Beauregard and Paquette 2006, Josipovic 2014). For example, although experiences of non-duality (e.g., the complete cessation of self-referential processing) are touted as a potential outcome of extensive mindfulness practice (Hölzel and Ott 2006, Josipovic 2014), very limited research exists examining the neural correlates of this superordinary state. Recently, results from a novel functional connectivity study support the hypothesis that alterations in the functional architecture and coupling of canonically 'anti-correlated' neural networks (e.g., attention- and default-mode networks) associated with mindfulness practice may indeed be indicative of emergent hybrid neural networks characterizing the non-dual state of awareness (Brewer, Worhunsky et al. 2011, Josipovic 2014). Moreover, evidence suggests that the intrinsic/extrinsic classification of canonical anti-correlated, competitive networks (e.g., DMN/DAN) is not immutable and may undergo profound reorganizations as a function of various forms of meditation and practices of consciousness alteration (Josipovic, Dinstein et al. 2011). Further work employing longitudinal research methods is needed in order to explicitly test the extent to which patterns of flexible neural network coupling, both at rest and during task, are indicative of emergent and novel brain states. Furthermore, given the critical roles played by the DMN in meditation (Froeliger, Garland et al. 2012), well-being (Kringelbach and Berridge 2009), yet also in psychopathology (Greicius, Flores et al. 2007, Sutherland, McHugh et al. 2012, Hamilton, Farmer et al. 2015), DMN connectivity stands poised as a therapeutically-relevant biomarker for assessing mindfulness-based treatment outcomes (Fox and Greicius 2010, Simon and Engström 2015).

Critically, brain-state switching, shown to be preeminent in the study of mindfulness-based adaptations and mindfulness-based symptom relief, may be influenced by developmental factors such as aging, the emergence of pathologies, history of trauma, or by more general individual differences in genetic expression. For example, a study investigating age-related changes in DMN, attentional and cognitive control networks found that the dissociability of disparate brain networks varied as a function of healthy aging (i.e., older adults exhibited sustained coupling of cognitive control regions with both the DMN and attentional regions during a visuospatial planning task, while younger adults did not)(Spreng and Schacter 2012). More broadly, molecular mechanisms (e.g., synaptic function, ion channel activity) underlying the establishment and maintenance of more common neural networks have been shown to correlate with widespread gene expression (Richiardi, Altmann et al. 2015). Finally, combined human rsFC and magnetic resonance spectroscopy (MRS) evidence has been reported linking mPFC glutamate concentrations to rsFC in frontostriatal circuitry (Duncan, Wiebking et al. 2013). Therefore, individual variability of this nature is critically important to consider when evaluating potential interactive effects of mindfulness practice, reappraisal and well-being.

Somewhat complicating the study of mindfulness-reappraisal-well-being interactions, the practice of developing mindfulness expertise may be confounded and/or collinear with the development of reappraisal expertise (changes in eudaimonic and hedonic well-being notwithstanding). Meta-analyses of reappraisal have shown patterns of spreading neural activation within a single reappraisal episode – with activation tending to spread from left towards right, and from posterior to anterior lateral PFC as a function of reappraisal duration (Kalisch 2009). Still, the literature remains silent with regard to how developments in mindfulness-skill expertise, in conjunction with developing reappraisal skill and associated alterations in eudaimonia, might translate into durable alterations in neural structure and function. Nonetheless, this practice may be well suited to address not only affective states that are known to precipitate drug use (Koob and Le Moal 1997), but also to strengthen deficient top-down control over bottom-up driven motivational responding (Goldstein and Volkow 2002, Garland, Froeliger et al. 2014). Some important questions regarding the potential therapeutic benefits of mindfulness for helping to treat substance use disorders include: 1) whether or not, or to what extent, mindfulness practice is useful for treating the neuropathophysiology of addiction; 2) what is the optimal timing of mindfulness interventions in the course of treatment (e.g., ideal duration prior to and following a quit attempt); 3) what 'dose' of mindfulness (e.g., frequency/duration) is required for a clinically meaningful change; and 4) whether or not, or to what extent, mindfulness practice, and positive reappraisal/savoring, are necessary and/or sufficient to engender eudaimonia in substance abusing populations.

In sum, new integrative bio-behavioral models are needed in order to help prevent and treat stress-related disorders, reduce suffering and promote a greater sense of well-being. The MMT is one such model that provides a theoretical framework for how mindfulness may produce well-being through both eliminative and generative mechanisms. A number of features discussed here are particularly relevant to the potential prevention and treatment of substance-use disorders. However, in spite of the Western cultural renaissance for mindfulness discourse with regard to designing treatments for stress-related disorders, there remains a dearth of well-designed (e.g., active control group)(Shallcross, Gross et al.), longitudinal (e.g., greater than 10 weeks), large-scale controlled trials evaluating the effectiveness of mindfulness training for treating the bio-behavioral mechanisms governing the onset and maintenance of substance-use disorders. Despite the somewhat ambiguous early days of mindfulness science, the MMT provides a theoretical framework for which to begin to rigorously investigate specific components of mindfulness and their contributions to an upward spiral of positive health outcomes.

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