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The Effects of Meditation on Brain Organization and the Implications for Treating ADHD

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Abstract

Attention-deficit/hyperactivity disorder (ADHD) has recently become increasingly diagnosed for children and adolescents. As of now, the most common treatment method is medication, with the purpose of changing brain organization. Recently, however, there has been increasing interest in the use of mindfulness meditation to treat the symptoms associated with ADHD. In this paper, eleven different studies, which have introduced mindfulness meditation as a treatment method for ADHD, are analyzed. The studies measure the degree to which mindfulness meditation improves common symptoms associated with ADHD. These symptoms include attentional problems, reduced mindful awareness, externalizing and internalizing problems, reduced self-control, impaired social behavior, and reduced cognition and executive functioning. Different scales were used to measure the different variables. Overall, the studies showed improvement in all ADHD symptoms, following a mindfulness meditation intervention program. The results suggest the possibility of mindfulness-meditation being the primary treatment method for individuals with ADHD. Research on this topic should continue to be conducted in order to improve the legitimacy of these findings.

Keywords: Meditation, ADHD, brain organization, children, adolescents, mindfulness, attention, awareness, cognition, intervention

Introduction

ADHD

Attention-deficit/hyperactivity disorder (ADHD) is a behaviorally defined disorder characterized by symptoms of inattentiveness, hyperactivity and impulsivity that are inappropriate for one's age. Onset of the disorder typically occurs before age seven and often times persists into adulthood. Estimates of the prevalence of ADHD often fall between 2-16%, with the majority falling between 5-10% for children and adolescents, and 4% for adults (Zylowska, Smalley & Schwartz, 2009). It is also noteworthy that individuals who are diagnosed with ADHD often experience comorbid conditions, such as conduct disorders, anxiety and mood disorders, substance abuse/dependency, delayed learning and delayed social-emotional development. The comorbidity of disorders associated with ADHD can make it difficult to conduct research. The increasing prevalence of the disorder, however, has encouraged researchers to determine exactly what ADHD is.

Recent research indicates that individuals with ADHD often display specific deficits in attentional processing and executive control. Deficits in attentional processing include difficulty maintaining an alert state (sustained attention) in the absence of a warning signal (impaired alerting and orienting). Deficits in executive control include delayed response inhibition (slow response to stimuli), impaired error monitoring (adjusting behavior after errors) and deficient resource-allocation (disengagement from one task and preparation for another task). It is important to understand that ADHD is diverse in presentation and etiology. That is, ADHD can presents itself, and develop, along a continuum of different symptoms and causes. For example, genetic, neurobehavioral, psychosocial and environmental influences have been identified as influential in the development and variability of ADHD (Zylowska et al., 2009).

Neurobiology of ADHD

To further understand the symptoms and etiology of ADHD, it is important to analyze the neurobiology of the disorder. Compared to healthy individuals, individuals with ADHD often develop atypical neural network organization among brain regions associated with attention, emotion, cognitive control, and working memory (Friedman & Rapport, 2015). The brain regions associated with the neural networks include the frontoparietal network, the attentional network, and the default mode network. The frontoparietal network is known as the executive control circuit, which guides decision-making. Hypo activation in this network is consistent with impaired executive function in individuals with ADHD. This network involves regions of the prefrontal cortex, specifically the dorsolateral prefrontal cortex and the ventral lateral prefrontal cortex, which are associated with vigilance, selective and divided attention, attention shifting, planning, executive control and working memory (Bush, Valera & Seidman, 2005). The attentional network is involved in attentional reorienting to relevant stimuli, and in interrupting ongoing activity when necessary. Hyperactivation of the attentional network may explain distractibility in ADHD patients. This network involves the anterior insula, which is responsible for orienting to stimuli, and the frontal eye fields, which are involved in attention shifting and control of spatial attention. Finally, the default mode network is a network of interacting brain regions that is typically suppressed during activity in healthy patients. For ADHD patients, however, the default mode network is often hyperactive during tasks, which may cause the disruption in cognitive performance and fluctuation in attention (Bachman, Lam & Philipsen, 2016). A key brain region of the default mode network is the anterior cingulate cortex, which is involved in internally focused, task-

specific processing (Schoenberg, 2016). The amygdala and basal ganglia are brain regions that are also impaired in individuals with ADHD. These brain regions are associated with emotional regulation. Deficits in emotional mechanisms are responsible for a phenomenon known as delay aversion, which is the tendency to avoid a delay and results in a preference for taking small, immediate reward over large, delayed rewards (Baijal & Gupta, 2008). Delay aversion is often seen in individuals with ADHD. Abnormal neurotransmitter levels have also been linked to ADHD, specifically, the neurotransmitters norepinephrine and dopamine. The alerting function in humans relies heavily on norepinephrine, where as the ability to focus attention involves dopamine. Both neurotransmitters systems are deficient in individuals with ADHD (Baijal & Gupta, 2008).

Meditation

As of now, the primary means of treating ADHD is medication, specifically the drug methylphenidate hydrochloride. However, there are significant limitations to using medication to treat ADHD, including non-responsiveness, inability to receive treatment, and possible adverse side effects such as loss of appetite, insomnia and increased blood pressure (Bachman et al., 2016). These limitations have encouraged clinicians to find alternate avenues to treat ADHD. One such avenue that has received attention recently is the use of meditation. Research on the effects of meditation is in its infancy. With that being said, the research that has been done on the use of meditation to treat ADHD is heterogeneous. One issue in this research is the lack of an operational definition of meditation. The fact that ADHD and meditation are both varying interpretable concepts makes it difficult to combine and synthesize the literature. Many of the studies I refer to in this systematic review have used different forms of meditation. With that being said, all of

the techniques used fall into a general category of meditation, which has been defined as a family of mental exercises aimed at enhancing the practitioner's ability to attain and maintain a target state, often attentional or affective in nature (Grant et al., 2013).

When using meditation to treat ADHD, clinicians and researchers typically focus on mindfulness meditation, or mindfulness awareness. Mindfulness meditation is a quality of consciousness that signifies an open and alert state of mind where a person's attention stays in the present moment, and sensations such as thought and feelings that arise are perceived and observed non-judgmentally (Bachman et al., 2016). Mindfulness meditation has been shown to target and improve neuropsychological capacities that are impaired in individuals with ADHD, including attentional control, emotion regulation and self-awareness. These neuropsychological capacities then interact to enhance self-regulation, a mechanism that is often impaired in individuals with ADHD (Tang, Holzel & Posner, 2015). Attentional control can be broken down into alerting (readiness in preparation for an impending stimulus), orienting (selection of information from sensory stimuli) and conflict monitoring (resolution of conflict between neural areas- executive attention). These components of attention are often impaired in patients with ADHD. Studies have shown improvement in these components following a mindfulness meditation intervention. Emotion regulation refers to the strategies that influence the processing of emotions, which are often impaired in individuals with ADHD. Mindfulness meditation has been found to improve components of emotion regulation, which include attentional deployment (attending to emotions), cognitive change (recognizing change in emotions) and response modulation (decreasing levels of suppression). Self-awareness is said to be linked to psychological distress, which is when an individual identifies with a static concept of 'self'.

Mindfulness meditation has been shown to facilitate detachment from a static entity to a state of simply experiencing. In this regard, meditation has been linked to a more positive self-representation, higher self-esteem and higher acceptance of one self. Individuals with ADHD often experience impaired self-awareness due to the inability to process thoughts and emotions, which has a feedback effect on their psychological well-being. Like I mentioned earlier, attentional control, emotion regulation and self-awareness all interact to enhance an individual's self-regulation.

Neurobiology of Meditation

Just as it is important to understand the neurobiology of ADHD, it is also important to understand the neurobiology of meditation, as well as how these two interact. Mindfulness meditation ameliorates the symptoms of ADHD by targeting brain areas that are often impaired in individuals with ADHD. It has been found that brain activity can be modified by repeated behaviors or experiences, a phenomenon known as the neuroplasticity effect. It has been hypothesized that myelinogensis, synaptogenesis, dendritic branching, neuronal preservation, restoration, and inhibition of apoptosis can be responsible for the change in brain organization via meditation (Bachman et al., 2016). One neuronal network targeted by mediation is the default mode network, which, as mentioned earlier, is often impaired in individuals with ADHD. Studies have shown that experienced meditators show reduced activation of the default mode network as well as stronger functional connectivity of brain regions associated with cognitive control and self-monitoring (Bachman et al., 2016). Enhanced connectivity in the default mode network increases the processing capacity to disengage and engage in the default and executive networks improving self-regulation (Schoenberg, 2016). Meditation training has also been

shown to cause significant improvement in the attention network. Decreased distractibility and improved response inhibition and conflict monitoring indicate improvement in the attention network. Brain regions of the attentional network targeted during mindfulness meditation include the anterior cingulate cortex and the striatum (both impaired in individuals with ADHD). Meditation has also been found to be associated with increased blood flow or glucose metabolism in the prefrontal cortex. The prefrontal cortex is associated with the both emotion regulation and self-awareness (Baijal & Gupta, 2008). Mindfulness practice has also been associated with diminished activation in the amygdala in response to emotional stimuli during mindful and resting states, suggesting a decrease in emotional arousal (Tang et al., 2015). Hyper arousal in the amygdala is often seen in individuals with ADHD, impairing emotional regulation. Other brain regions targeted during meditation that are associated with emotion regulation include other limbic regions and the striatum. A review by Grant et al., (2013) also found that the thickness of cortical regions associated with mindfulness meditation overlapped with regions reported to undergo thinning in ADHD populations (cingulate, prefrontal and parietal cortices). While the study did not directly test the effects of meditation on individuals with ADHD, the findings indicate that meditative practices may induce, via change in cortical thickness, functional activation of relevant ADHD circuits (Grant et al., 2013).

Based on this review of the literature, I hypothesize that meditation can be an effective treatment for individuals with ADHD. In this paper, I will focus on analyzing studies that have used meditation to specifically treat children with ADHD. As mentioned previously, this research is in its infancy, which is why I have decided to include studies in my analysis that have used different forms of meditation intervention. Different forms of

meditation intervention used include mindfulness based cognitive therapy (MBCT), mindfulness based stress reduction (MBSR), sahaja yoga meditation (SYM), transcendental meditation (TM) and samatha meditation. The studies I have included are a combination of mindfulness training for children and adolescents with ADHD and parallel training for their parents and mindfulness training for children and adolescents with ADHD without parallel parental training. I will also analyze the similarities and differences between different intervention programs, as well as provide suggestions for future research in this field. The intent is that by broadening the focus of the research survey, the reader will get a better understanding of the research that has been done on the effects of meditation in treating ADHD.

Methods

Inclusion and exclusion criteria

When deciding which studies I would include in this paper, there were a few criteria that I wanted the studies to meet. First, participants in the studies needed to be either children or adolescents who were diagnosed, or experienced symptoms of, ADHD. Second, the studies needed to include some form of mindfulness intervention. As mentioned previously, I did not want to focus on one specific form of intervention. I also focused on what exactly the studies were measuring. I wanted to include studies that measured variables such as attention, mindful-awareness, internalizing and externalizing problems, social behavior/self esteem, and cognition/executive functioning. Finally, I wanted the studies to have a multiple base line design.

Identification of studies

Most of my studies I found were located through the ebsco search engine from the BGSU library. In some cases, I used Google scholar if I could not access the study from ebsco. When I did my initial search I chose studies based on their abstracts. I looked for key words such as ADHD, meditation, attention, cognition and mindfulness.

Study selection

After my initial identification of studies, I looked further into the methods, procedures and results sections. Some of the studies I initially found did not exactly fit the criteria that I had determined. Overall, I found eleven studies that fit the criteria for the review I planned to conduct.

Data extraction

Once I selected the studies, I began extracting the data that I wanted to use for my analysis. I broke down each study into four sections: treatment intervention, participants, measures, and results. First, I looked for what kind of treatment intervention was being used, how it was being used, and for how long. Next, I looked for how many participants were used in the study and the age range of participants. Once I found the participant composition, I analyzed the variables that were measured. Finally, I analyzed the results of the studies. Organizing the data in this way made it easier to combine the information, as well as compare and contrast the different intervention programs.

Quality Assessment

All of the studies included in this paper are primary research papers in their original form. With that being said, there were some issues that came up in some of the studies that I will consider in the discussion.

Data analysis

The data I analyzed came from analysis of variance (ANOVA) and independent sample t- tests conducted on the different variables included in the studies. Some of the studies ran separate tests for each variable, where as some studies ran tests on grouped variables. This information allowed me to recognize whether meditation was making a significant difference in treating the symptoms of ADHD

Results

I have decided to break down the results section into eight different variables that were measured repeatedly in the studies. As I present a new study, I will explain the treatment intervention as well as the participants that were used.

Attention

As mentioned in the introduction, inattentiveness is a core symptom experienced by individuals with ADHD, which is why I specifically looked for studies that measured some form of attention. Attention can be measured using a variety of different scales. One scale that is used frequently to measure attention is known as the Attention Network Test (ANT). The ANT measures the core qualities of attention: alerting (maintaining a vigilant state or preparedness), orienting (selecting a stimulus among multiple inputs) and conflict (prioritizing among competing tasks). Zylowska et al. (2008) is, surprisingly, the only study I found which used the ANT to measure attention. The study conducted an 8-week mindfulness meditation program for 8 adolescents with ADHD between the ages of 15-18. Significant improvements were found on measure of the ANT from pre-test to post-test. Other measures of attention used in this study include the Stroop Task (Golden, 1978), which measures attentional conflict, and the Trail Making Test (Retian, 1979), which

measures attentional set shifting and inhibition. Both tests showed significant improvements from pre-test to post-test. Another common measure of attention is the Youth Self Report (YSR; Achenbach, 1991), which allows children to report on ADHD symptoms, including attention. Bogels, Hoogstad, Dun Schutter, & Restifo (2008) used the YSR to measure attention. Bogels et al. (2008) introduced an 8-week mindfulness based cognitive therapy (MBCT) program for adolescents with ADHD (N=14, ages 11-18) and parallel training for their parents. The goal of MBCT is to reduce reactivity to incoming stimuli and instead accept and observe the stimulus. Participants reported a significant improvement in attention from pre-test to post-test as measured by the YSR. Bogels et al. (2008) also measured attention using the D2 test of attention (Brinckenkamp, 1994) and found significant improvements in sustained and directed attention from pre-test to post-test. Improvements were maintained for both measures of attention at an 8-week follow up. Van de Weijer-Bergsma, Formsma, de Bruin & Bogels (2012) also used the YSR to measure attention. This study employed an 8-week mindfulness intervention-training program for adolescents with ADHD (N=10, ages 11-5) and parallel training for parents. Outcomes were measured prior to training, immediately after training, 8 weeks after training and 16 weeks after training. Adolescents reported a reduction in attention problems immediately after training, as measured by the YSR. This reduction in attention problems was maintained when measured at an 8-week follow up and was diminished when measured at a 16-week follow up. Grosswald, Stixrud, Travis & Bateh (2008) is the final study I found which used the YSR to measure attention. Transcendental meditation (TM) was the treatment intervention used for 10 participants ages 11-14 diagnosed with ADHD. TM is described as restful alertness, where in the active mind settles down to a

silent yet fully awake state of awareness (Grosswald et al., 2008). Attention variables from the YSR and the Child Behavior Checklist (CBCL; Achenbach, 1991) were combined and analyzed. The CBCL allows parents to report on their child's ADHD symptoms, compared to the YSR, which allows adolescents to report on their own symptoms. A significant reduction in attentional problems was found from pre-test to post-test for the combined attention variables from the YSR and CBCL. Haydicky, Shecter, Wiener, & Ducharme, (2015) used an 8-week MBCT program, known as Mymind, for adolescents diagnosed with ADHD (N=18, ages 13-18) and parallel training for their parents. The study used the Conners- 3rd Edition assessment (Conners, 2008) to measure attention. Near significant improvements were reported in attention. These improvements were maintained when measured at a 6-week follow up. Kratter and Hogan (1982) conducted a study, which randomly placed participants (N= 24, ages 7-12) into a meditation- training group, a progressive-muscle-relaxation group, or a waiting-list control group. The study measured attention using the Fruit Distraction Test (Santostefano, 1978), which assess the manner in which a child deals with a stimulus field that contains information defined as relevant and irrelevant. The meditation group showed significant improvement in selective deployment of attention and freedom from distractibility as measured by the Fruit Distraction Test. The relaxation and waitlist group showed no significant improvements in attention.

Mindful awareness

The next variable I decided to focus on was mindful awareness. All of the studies I found which measured mindful awareness, used the Mindful Attention and Awareness Scale (MAAS; Brown and Ryan, 2003). The MAAS measures the most important characteristics of mindfulness, namely an open and receptive awareness of, and attention

for, what is happening here and now (Bogels et al., 2008). Typically, individuals diagnosed with ADHD struggle with being mindfully aware. Bogels et al. (2008) found significant improvements in mindful awareness, as measured by the MAAS. Improvements were maintained when measured at an 8-week follow up. Van de Weijer-Bergsma et al. (2012) also used the MAAS to measure mindful awareness and found no significant changes from pre-test to post-test, including the 8-week and 16-week follow up. Oord, Bogels & Peinenburg (2012) conducted an 8-week mindfulness training intervention program for children with ADHD (N=22, ages 8-12) and parallel training for their parents. The study used MBCT and mindfulness based stress reduction (MBSR) as intervention methods. The goal of MBSR is to recognize the ability to choose how an individual reacts to stimuli. Outcomes were measured before intervention, immediately after the 8-week training and at an 8-week follow up. The study used the MAAS to measure mindful awareness and found significant improvements in mindful awareness for both children and parents. This improvement was maintained at the 8-week follow up. Abdolahzadeh, Mashhadi & Tabibi (2017) is the final study I found which used the MAAS to measure mindful awareness. Eight 90-minute sessions of MBSR treatment was introduced to 15 female high school students (age 12-18). There were 30 participants total used in the study, however, 15 were assigned to a control group, which did not receive treatment. Significant improvements were found in mindful awareness for the experimental group but not the control.

Externalizing problems

Externalizing problems are defined as problems of behavioral control, inattention, and impulsivity that are primarily manifested in in children's outward behavior rather than in their internal thoughts and feelings (Bogels et al. 2008). Externalizing problems can lead

to the development of oppositional defiant disorder (ODD) and conduct disorder (CD), which are often experienced co-morbidly with ADHD. Bogels et al (2008) used the YSR to measure externalizing problems based on adolescent self-report. Children reported significant improvement on all measure of the YSR, including externalizing problems, from pre-test to post-test. Improvements were maintained when measured at the 8-week follow up. Bogels et al. (2008) also used the CBCL to measure externalizing problems. Parents reported no improvement in their child's externalizing problems immediately after the 8-week intervention. However, significant improvements were reported at the 8-week follow up. Oord et al. (2012) used the Disruptive Behavior Disorder Rating Scale (DBDRS; Pelham et al. 1992) to measure externalizing disorders. The goal of the DBDRS is to measure inattention, hyperactivity, ODD, and CD. The study found a significant reduction in externalizing symptoms as rated by the parent. Reduction in problems was maintained at the 8-week follow up, as well as a reduction in parental externalizing symptoms. Van de Weijer-Bergsma et al. (2012) also used the YSR to measure externalizing problems. Adolescents reported borderline significant reduction in externalizing disorders immediately after intervention, which was maintained when measured at an 8-week follow up. At the 16-week follow up, reduction in self-report externalizing behavior was diminished. Haydicky et al. (2015) used the Conners- 3rd Edition assessment to measure externalizing problems, specifically aggression, oppositionality, hyperactivity and impulsivity. Both parents and adolescents completed the assessment. Parents reported significant improvement in their adolescent's aggression and oppositionality, however, no improvement was reported for hyperactivity and impulsivity. Adolescents reported no significant improvement for any of the externalizing problems. Jensen and Kenny (2004)

conducted a study in which 14 boys, ages 8-13, were randomly assigned to an experimental group, which attended 20 weekly 1-hour yoga sessions, or a control group, which engaged in games and activities. The Conners Teacher Rating Scale- Revised: Long (CTRS-R: L; Conners, 1997) was used to measure parent and teacher reports of children's ADHD symptoms. Specifically, the scale measured opposition, global index restless/impulsive and DSM-IV hyperactive/impulse. Significant improvements were found for all externalizing measures of the CTRS-R: L.

Internalizing problems

Internalizing problems are problems in which a person keeps thoughts, feelings and emotions, to themselves and suppresses them. This can lead to a number of different issues including anxiety and depression. While externalizing disorders are more commonly seen in individuals with ADHD, internalizing problems are also very common. Haydicky et al. (2015) used the Revised Child Anxiety and Depression Scale (RCADS; Chorpita et al. 2000) to measure internalizing problems. The RCADS screens for depression and anxiety disorders in individuals ages 6-18. No significant reduction in internalizing disorders was found immediately after the last day of intervention. However, when measured again 6 weeks after intervention, adolescents reported a significant reduction in depression, anxiety and total internalizing problems. Bogels et al. (2008) used the YSR and CBCL to measure internalizing problems. Children reported borderline significant improvement of internalizing problems as measured by the YSR. Improvements were maintained at an 8-week follow up. Parents reported no significant improvements in child's internalizing problems immediately after intervention, as measured by the CBCT. This was maintained at an 8-week follow up. Van de Weijer et al. (2012) also used the YSR to measure internalizing

problems for adolescents with ADHD. Immediately after training, internalizing problems were reduced, which was maintained at the 8-week follow up. During the 16-week follow up, however, reduction in internalizing problems was diminished. Zylowska et al. (2008) used the Revised Children's Manifest Anxiety Scale (RCMAS; Reynolds & Richmond, 1978) to measure anxiety, and the Child Depression Inventory (Kovacs, 1992) to measure depression. No significant changes were found in depression and anxiety (internalizing problems) from pre-test to post-test. Grosswald et al. (2008) also used the RCMAS to measure internalizing problems for adolescents. The study yielded significant improvement in internalizing symptoms from pre-test to post-test.

Self control

Self-control, or behavior regulation, was another common variable that was measured in these studies. Lack of self-control, which leads to impulsivity, is sometimes considered an externalizing problem. However, many of the studies I selected measured self-control as a separate distinct variable, which is why I chose to analyze it independently. Grosswald et al. (2008) and Weijer et al. (2012) used the Behavior Rating Inventory of Executive Function (BRIEF; Goia, et al., 2000), which measures behavior regulation and meta-cognition. For the sake of this section, we will focus on behavior regulation. Significant improvements in behavior regulation were observed for both studies from pre-test to post-test. Improvements in behavior regulation were maintained for the Weijer et al. (2012) study at the 8-week follow up, and diminished at the 16-week follow up. Bogels et al. (2008) used the Self Control Rating Scale (SCRC; Kendall, 1979) to measure parent reports of their child's self control. Immediately after intervention, parents reported improvements in their child's self control. This improvement in self-control was

maintained, and even strengthened, at the 8-week follow-up. Kratter and Hogan (1982) used the Nowicki-Strickland Locus of Control Scale (LCS; Nowicki & Strickland, 1973) to assess changes in the locus of control. Locus of control is the degree to which a person believes they have control over the things that happen to them. While this is not quite the same as self-control, I believe the concept of being in control of yourself and your environment is similar. Unfortunately, however, no significant changes in control were observed over the course of the study.

Social behavior and self-esteem

I decided to combine measures of social behavior and self-esteem because I believe that an individual's social behavior is somewhat dependent on their self-esteem. For example, if a person has a high self-esteem they are more likely to engage themselves socially. Likewise, if a person has a low-self esteem, they are more likely to withdraw from social situations. With that being said, negative social behavior and low self-esteem are common symptoms for individuals diagnosed with ADHD. Bogels et al. (2008) used the YSR to measure social problems, based on child and adolescent self-report. Significant improvements were reported in social problems from pre-test to post-test. Improvements were maintained at the 8-week follow up. Bogels et al. (2008) also used the Children's Social Behavior Questionnaire (CSBQ; Luteijn, Luteijn, Jackson, Volkmar and Minderaa, 2000) to measure parent reports of their child's social behavior. The questionnaire is broken down into seven measures including not attuned to others, tendency to withdraw, orientation problems, lack of understanding, stereotypical behavior and fear of change. No significant improvement was reported for any of the measures immediately after intervention. At the 8-week follow up, however, parents reported significant improvement

in the measure of "not attuned to others" and "tendency to withdraw". Haydicky et al. (2015) used the Conners- 3rd edition in order to measure social behavior, specifically relationships with others. Parents reported a significant reduction in peer relation problems immediately after intervention, which was maintained at the 6-week follow up. Harrison, Manocha and Rubia (2004) used a 6-wekk Sahaja Yoga Meditation (SYM) intervention to treat children (N=35 ages 4-12) diagnosed with ADHD, and parallel training for their parents. The Bio Behavioral Indicators of Self-Esteem Questionnaire (Burnett, 1998) was used in this study to measure parent rated child behavior, specifically, social interaction, confidence, and involvement. Outcomes were measured prior to intervention, at the midway point of the program (week 3), and at the end of the program (week 6). Significant improvements were observed for all parent-rated measures at the midway point of the program. Improvement in parent reports of confidence and social behavior were maintained, and strengthened, when measure at the end of the program.

Cognition/executive functioning

I combined measures of cognition and executive functioning because I believe they are often used in parallel. Cognition is a mental process, which facilitates thinking, learning, understanding and memory. Executive function is the process of using this information to make decisions. Both of these functions are often impaired in individuals diagnosed with ADHD. These impairments often manifest into learning disorders, which are often experienced co-morbidly with ADHD. Van de Weijer et al. (2012) used the BRIEF to measure meta-cognition for adolescents diagnosed with ADHD. Meta-cognition is the awareness of ones own thought processes. Adolescents reported improvement in meta-cognition immediately after training. This improvement was maintained at the 8-week

follow up but diminished at the 16-week follow up. Grosswald et al. (2008) also used the BRIEF to measure meta-cognition. Adolescents reported significant improvements in meta-cognition from pre-test to post-test. Grosswald et al. (2008) also used the Delis-Kaplan Executive Function System (D-KEFS) Verbal Fluency Test to measure an individual's ability to generate words fluently, generate words in categories, and shift attention from one category to another. Significant improvements were observed in category fluency and category shifting measures (verbal fluency was not analyzed). Haydicky et al. (2015) used the Conners- 3rd edition to measure cognition, specifically learning problems. Parents and adolescents reported a significant reduction in learning problems immediately after intervention. This reduction was maintained at the 6-week follow up. Kratter and Hogan (1982) used the Hatching Familiar Figures Test (HFFT; Kagan, 1996) in order to measure cognition. The test measures the tendency to reflect on the validity of problem solving when several possible alternatives are available, and there is uncertainty over which one is most important. If an individual responds quickly they are more like to make errors (more impulsive). If an individual reflects on the response alternatives they are more likely to choose the correct answer (reflective). The meditation and the relaxation group in this study showed significant decreases in impulsivity and improvement in reflectiveness. Singh, Lancioni, Karazsia, Felver, Myers and Nugent (2016) introduced Samatha meditation to four 5th grade students who were diagnosed with ADHD. Singh defines Samatha meditation as resting awareness on a give object of meditation (the breath) and using mindfulness in a regulatory capacity to ensure that concentration does not deviate from the object of meditative placement. The study sought to measure two cognitive processes, active engagement and math skills. Active engagement was measured using a professional

observer, and math skills were measured using a math quiz. The study found significant improvements in active engagement and significant increases in math problems solved correctly from baseline to meditation practice.

Discussion

Overall, there is a general trend towards improvement of ADHD symptoms when mindfulness meditation is used as a treatment method. All of the studies that measured attention showed improvements in attentional processes compared to baseline. Van de Weijer et al. (2012) was the only study that measured mindful awareness that did not report improvement on the MAAS. The study attributed the null results on the basis that the MAAS measures mindfulness as a trait and not as a skill that can be applied. However, since the other studies which used the MAAS to measure mindful awareness reported improvement, I would argue that the null results could be attributable to the small sample size of the study (N=10). There was also an overall improvement in externalizing problems. Bogels et al. (2008) did not report improvement in externalizing problems immediately after training. However, improvements were observed at the 8-week follow up. This occurs frequently for different measures throughout this review. Some of the studies attributed this to the fact that, immediately after the training, the children had not yet solidified the practice of mindfulness meditation. After a period of time, however, children were given the chance to practice on their own time and could apply these new skills in real world situations. It is important to note that, for all of the studies, children were encouraged to practice at home during the intervention, as well as following the completion of intervention. An overall improvement in internalizing problems was also observed. Zylowska et al. (2008) was the only study that measured internalizing problems that did

not report improvements. I would argue that this could be a result of the tests that were used to measure internalizing problems (Revised Children's Manifest Anxiety Scale and the Child Depression Inventory). These tests, compared to other tests that were used to measure internalizing problems, gauge whether or not an individual has anxiety and depression. Other tests that were used measured the symptoms of anxiety and depression, not necessarily whether the person could be diagnosed as depressed or anxious. Haydicky et. al (2015) did not report improvement in internalizing problems immediately after intervention, however, improvements were observed at the 6-week follow up. Self-control measures showed overall improvements for all of the studies besides Kratter and Hogan (1982). This could be due to the fact that they were measuring locus of control and not necessarily self-control. Measures of social behavior showed overall improvement. Again, however, Bogels et al. (2008) reported no improvement immediately after training but improvement was observed at the 8-week follow up. All measures of cognition reported improvement following a mindfulness-meditation intervention.

All of the studies in this review used similar intervention strategies. Most of the studies conducted 8-week long programs. Two programs were shorter (4- weeks and 6-weeks) and two were longer (3 months and 20 weeks). Trained professionals were used to conduct the intervention for all of the programs. Most of the studies only measured outcomes at baseline and immediately after the intervention program. Four of the studies, however, measured outcomes at later dates (6-weeks after, 8-weeks after, 16-weeks after). Here, I think it is important to discuss the Van de Weijer et al. (2012) study. Besides mindful awareness, the study reported improvement for all symptoms immediately after training, and improvements were maintained at the 8-week follow up. At the 16-week

follow up, however, improvements for all symptoms were diminished. The study attributed this diminishing improvement to the fact that not all participants were available for follow up measures, so the already small sample size (N=10), became even smaller. I think this could also be the result of a decrease in practice. At 8 weeks, children may still be motivated to continue practicing what they learned during the intervention. At 16-weeks, however, children may have lost the enthusiasm to continue practicing.

As I hypothesized, mindfulness meditation was an effective means to treating the symptoms of ADHD. Unfortunately, not enough research has been done to determine that meditation changes brain organization for individuals with ADHD. Based on the literature review I conducted, however, I would argue that the improvement in ADHD symptoms in these studies is attributable to the fact that the intervention programs targeted specific brain regions that are impaired in individuals with ADHD. Impairment in these brain regions is responsible for attention problems, decreased mindful awareness, externalizing and internalizing problems, lack of self-control, negative social behavior and self esteem, and reduced cognition and executive functioning. Based on improvements in these common ADHD symptoms, I would argue that there is significant potential for using mindfulness-meditation as a treatment method for treating ADHD.

As I have mentioned repeatedly, this research is in its infancy. In the future, a few things could be done to improve the legitimacy of these findings. First, it is important that future studies strive to have larger sample sizes. Harrison et al. (2004) had the largest sample size of the studies I reviewed (N=35), and the only variable I used from this study was social behavior. While I understand that the population of children and adolescents with ADHD is rather small, increasing the sample size will likely produce more significant

results and increase the validity of the findings. I think it would also be useful to include neurological measures, such as cortical thickness, in order to determine if changes in brain organization are occurring. Using a multiple group design might also be beneficial in order to determine which form of mindfulness meditation is most effective. I also think it is important to include follow-up measures, as some of the studies in this review did. The studies that included follow-up measures generally reported sustained improvement. The Van de Weijer et al. (2012) study was the only study that had a follow up period of longer than 8-weeks (16-weeks). At the 16-week follow up, all improvements were diminished. I believe this indicates that mindfulness meditation, like medication, may need to be continually administered in order to be effective. With that being said, I believe that mindfulness meditation is a much safer and more sustainable intervention method compared to medication. If research continues to be done on this topic, I think there is potential that mindfulness-meditation could be used as the main, and preferred, method for treating attention deficit/hyperactivity disorder.

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