Neural Correlates of Mindfulness and Executive Function Training in Internationally Adopted Children: A Randomized, Controlled Trial

A DISSERTATION
SUBMITTED TO THE FACULTY OF THE
UNIVERSITY OF MINNESOTA
BY

Elisa A. Esposito

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

Advisor: Megan Gunnar

June 2015

Acknowledgements

I would like to thank the families from the International Adoption Project for kindly agreeing to participate in this research. This study was supported in part by a seed grant from the Center for Neurobehavioral Development, small grants from the Institute of Child Development, and by the Interdisciplinary Training Program in Cognitive Sciences. I would like to acknowledge my advisor, Dr. Megan Gunnar for her mentorship, support, and encouragement throughout my graduate career. I would also like to thank the rest of my dissertation committee: Professors Kathleen Thomas, Phil Zelazo, and Shmuel Lissek. Special thanks goes to my co-investigator, Jamie Lawler, for her incredible support and dedication to this project over the past several years. I would also like to acknowledge the extraordinary efforts and support of the following: the volunteers who assisted with recruitment, data collection, and data processing (Jenna Allard, Amanda Burkholder, Colleen Doyle, Elise Erkens, Valkyrie Jensen, Elizabeth Lorenz, John McGrory, Natalie Ottum, Laura Somppi, Elizabeth Stein, Hannah Walker), the volunteers who assisted with intervention implementation (Sandra Ahumada, Timothy Allen, Adrienne Banny, Colleen Doyle, Allie Giovanelli, Madelyn Labella, Julia Longenecker, Natalie Ottum, Clio Pitula, , Ian Ramsay, Merav Silverman), Maria Kroupina who served as the clinical supervisor for the study, Jessie Forston, Anna Johnson, Phil Zelazo, and Kristen Lyons for their contributions to the curricula and training, the CNBD staff for their help with data collection. I would also like to extend my deepest gratitude to my friends and family (including my Gunnar Lab sisters) for their humor, patience, support, and encouragement that made this undertaking possible.

Abstract

Self-regulation, particularly attention regulation, is related to anxiety. Children who have been internationally adopted (IA) are at risk for deficits in both attention and emotion regulation. Promising evidence for focal executive function (EF) training and mindfulness training suggest that these skills can be readily improved in adults and children, and training EF independently may transfer to emotion regulation skills. This study examined the effects of mindfulness and executive function training programs on neural correlates of self-regulation in a sample of 96 IA children. Children were randomized to receive either 12 total hours of training (mindfulness vs. executive function) or a no-intervention control. Children completed a battery of executive function measures at laboratory testing sessions before and after the 6-week training period. Four months after training, parents and teachers provided additional ratings of children's self-regulation skills. Executive function training led to improvement on measures of executive attention and inhibitory control, whereas mindfulness training was related to improvements in emotion regulation. Changes in the error-related negativity (ERN) were divergent between the two groups, supporting the differential impact of training on behavior. There was no evidence of transfer of EF training to observer reports of emotion regulation.

Table of Contents

List of Tables……………………………………………………………………………...v

List of Figures……………………………………………………………………………vi

Introduction……………………………………………………………….......……..1

Attention Orienting and Anxiety…………………………………………………2

Self-Regulation and Anxiety………………………………………………………6

Internationally Adopted Children: Evidence of Suitability as a Target

Population..15

Training Self-Regulation……………………………………………………...22

Summary……………………………………………………………………………32

The Current Study……………………………………………......………..34

Method…………………………………………………….....……………………...36

Participants…………………………………………………………………………….36

Randomization…………………………………………………………………...39

Training…………………………………………………………………………..39

Procedure………………………………………………………………….…..41

Measures…………………………………………………………………....42

EEG/ERP Data Acquisition and Processing……………………………………..47

Data Analysis Plan…………………………………………………………………49

Results………………………………………………………………………………….50

Neural Correlates of EF…………………………………………………………50

Behavioral Measures of EF…………………………………………………………52

Observer Reports of EF…………………………………………………………55

Parent, Teacher, and Observer Reports of Emotion

Regulation…………………55

Predicting Change: Child vs. Dosage Effects…………………………………...57

Discussion……………………………………………………………………………..60

References……………………………………………………………………………..86

Appendix……………………………………………………………………………..107

Tables

Table 1. Means and standard deviations of laboratory measures at pre and post-testing..74

Table 2. Means and standard deviations of observer reports (experimenter, parent, and teacher) of children's self-regulation at pretest, posttest, and longitudinal follow-up……………………………………………………………………………75

Table 3. Factor structure of behavioral and experimenter report measures of self-regulation at testing…………………………………………………………....76

Table 4. Hierarchical regression predicting scores on the attention composite for children randomized to EF training………………………………………………………….77

Table 5. Hierarchical regression predicting scores on the hot EF composite for children randomized to EF training…………………………………………………………78

Table 6. Hierarchical regression predicting scores on the attention composite for children randomized to MT training.……………………………………………………...79

Table 7. Hierarchical regression predicting scores on the hot EF composite for children randomized to MT training…………………………………………………………80

Figures

Figure 1. Grand averaged waveforms of the error-related negativity (ERN) for each group at site Fz…………………………………………………………………….…81

Figure 2. Mean change in accuracy on incongruent trials of the Flanker task…………..82

Figure 3. Mean change in Dinky Toys rule violations (reversed)……………………….83

Figure 4. Mean change in parent-rated anxiety symptoms (reversed)…………………...84

Figure 5. Mean teacher ratings of emotion regulation four months after the end of the training period……………………………………………………………………

Neural Correlates of Mindfulness and Executive Function Training in Internationally Adopted Children: A Randomized, Controlled Trial

The ability to control the deployment of attention represents a key feature of the developing capacity to regulate negative emotions. As early as infancy, attention orienting constitutes a volitional strategy for regulating sensory input and maintaining optimal levels of arousal. Attention orienting may also play a central role in maintaining symptoms of anxiety; both trait and clinical levels of anxiety are associated with enhanced orienting toward threatening stimuli, and training attention away from threat results in reduced symptoms of anxiety. Executive attention, which is often considered in terms of executive function, may also play a key role in the regulation of anxiety. In adults and children, anxiety impacts neural correlates associated with executive function. Early experiences that interfere with the development of neural systems underlying attention and executive function also lead to deficits in emotion regulation and an increased risk of psychopathology during adolescence. Thus, training programs that work to directly improve executive attention and executive function in high-risk populations will allow us to study the potential transfer of these skills to emotion regulation. This is the focus of the present dissertation using children adopted internationally from conditions of adversity as the target population. However, before describing the study, background information pertinent to the hypotheses will be described. This will include: the development of attention orienting and its role in anxiety, the development of self-regulation and its role as a potential protective mechanism in anxiety, the suitability of internationally adopted children as a test population for executive function training, and a review of two approaches to training self-regulation in adults and children.

Attention Orienting and Anxiety

Posner's conceptualization of the attention process includes separate neural networks that support individual aspects of attention (Posner & Petersen, 1990). The orienting network supports the selection of stimuli from sensory inputs, and involves three basic processes: disengaging attention from the current focus, shifting attention to the new target, and engaging attention to the new target (Posner, Walker, Friedrich, & Rafal, 1984). Brain areas associated with these behaviors include the frontal eye fields, superior colliculus, as well as the reticular nucleus and pulvinar nucleus of the thalamus. Goal-directed attention orientation is associated with a dorsal fronto-parietal network, whereas attention that is stimulus-driven is associated with primarily right hemisphere ventral frontal cortex and temporoparietal junction. These networks interact to support orienting behaviors, but the precise dissociation of their functions is not yet known (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000; Corbetta & Shulman, 2002; Posner, 1980). This network develops very early in life, undergoing rapid development within the first six months (for review see Colombo, 2001). Behavioral research in large samples has detected continued improvement in this system across childhood (Mezzacappa, 2004). Konrad and colleagues (2005) noted that compared to adults, children recruited brain areas outside of the expected networks, suggesting continued immaturity of this system.

In the first year of life, endogenous orienting of attention serves as a mechanism for modulating distress (Harman, Rothbart, & Posner, 1997). As discussed in the previous section, before three months of age infants cannot reliably disengage their attention from an object, shift it, and re-engage their attention to a new object. By roughly four months, infants can volitionally avert their gaze from objects or events that may be overly arousing, or they may orient towards aspects of their environment that provide sources of comfort (Posner & Rothbart, 1998). Indeed, longitudinal work has shown that orienting serves as the primary method of emotion regulation across infancy. Parent reports of infants' orienting was negatively correlated with negative affect and positively correlated with positive affect at seven months of age, but orienting was no longer related to affect by age two (Posner & Rothbart, 2009; Rothbart, Sheese, Rueda, & Posner, 2011).

Negatively biased attentional orienting has been of particular interest to researchers investigating cognitive processes that underlie the onset or maintenance of anxiety disorders. A recent meta-analysis demonstrates that, overall, the association between attention biases and anxiety is sufficiently robust that more than 11,000 subsequent studies with null findings would be required to reduce this effect to insignificance. An attentional bias to threat has been consistently observed across multiple studies of both clinically anxious participants as well as individuals high on measures of trait anxiety, but not in samples with low levels of trait anxiety or without a diagnosis of an anxiety disorder. Notably, the effect sizes for clinical populations and those with high levels of self-reported anxiety did not differ (Bar-Haim et al., 2007).

Studies that train attention towards or away from threatening stimuli are beginning to provide evidence that attention orienting may play a causal role in anxiety. Attention bias modification (ABM) training paradigms are based on the dot-probe task; when participants are trained to selectively attend away from threat, the probe consistently appears in the location of the non-threatening stimulus. Typically, training stimuli are presented at supraliminal intervals, but recent work has begun to investigate the potential utility of training attention at the subliminal level (e.g., Maoz, Abend, Fox, Pine, & Bar-Haim, 2013). Initial reports in healthy adults suggested that training attentional biases results in shifts in negative emotional responses to a stressor as well as decreases in trait anxiety (Mathews & MacLeod, 2002; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). Notably, studies that train attention *toward* threat (e.g., Eldar, Ricon, & Bar-Haim, 2008; MacLeod et al., 2002; Suway et al., 2013) show subsequent increases in vulnerability to a stressor, providing further evidence that attentional processes are causally related to affective outcomes. Following promising early findings, numerous investigations have been launched to test the efficacy of ABM as a treatment for anxiety. Training attention away from threat has led to reductions in anxiety among clinical (e.g., Amir, Beard, Burns, & Bomyea, 2009) and non-selected samples (e.g., Mathews & MacLeod, 2002), which has been further bolstered by findings from two recent meta-analyses (Beard, Sawyer, & Hofman, 2012; Hakamata et al., 2010). Though the number of studies examined was small, Hakamata and colleagues (2010) noted a larger effect size of ABMT—similar to that seen with CBT or SSRIs—in clinical samples compared to high anxious individuals. This study noted a significant effect of number of training sessions on attention bias score, but not on anxiety symptoms. Beard and colleagues' (2012) analysis found that number of training sessions significantly moderated the effect of ABM on subjective experience of state anxiety. Taken together, these studies highlight the overall efficacy of ABM, and suggest a dose-dependent effect of training on outcomes.

Eldar and colleagues (2008) were the first to note a causal relationship between experimentally manipulated attentional bias and anxiety in children. In a small sample of typically developing children, the group trained to bias attention toward threat showed a significant increase in anxiety following a stressor task. The group trained to attend away from threat showed no change in post-stressor anxiety, similar to findings in healthy adults (MacLeod et al., 2002). Among children with chronic high anxiety, ABM training using an emotional spatial cueing paradigm (in which 100% of threat cues were invalid for the treatment group) yielded significant effects on state anxiety following a stressor. Whereas children in the placebo condition appeared to be sensitized to the stressor at post-test, children who received ABM showed no significant change in stressor-related anxiety from following training. Further, children who became more effective at disregarding irrelevant threat cues across the course of training had lower anxiety scores following the stressor (Bar-Haim, Morag, & Glickman, 2011).

Recent work with clinically anxious children using the classic dot-probe ABM training paradigm has also demonstrated efficacy, with significant reductions in symptom count and severity occurring exclusively in the ABM group. However, there was no significant relation between change in attention bias score and symptom reduction (Eldar et al., 2012). Training attention toward positive stimuli using a visual search paradigm has also led to reductions in anxiety symptoms in children. In this paradigm, children in the training group practiced searching a matrix for happy faces among angry ones. Following training, 50% of children in this condition no longer met criteria for their principal diagnosis whereas only 8% of children in the control condition were below clinical cutoffs at post-test (Waters, Pittaway, Mogg, Bradley, & Pine, 2013). In clinical samples, the evidence for the efficacy of ABM is promising. One report even found that clinical improvement following ABM was maintained at a four-month follow-up (Schmidt, Richey, Buckner, & Timpano, 2009).

Association studies and experimental work with training paradigms have consistently demonstrated that attention orienting plays a role in processes relating to the development or maintenance of anxiety. However, this perspective ignores the potential role of higher-order regulation of attention in emotion regulatory processes. Given that executive attention works to override and control activity in the orienting network (Fan et al., 2009), it is likely that controlled or selective attention also plays an important role in emotion. The regulation of attention is a central construct of self-regulation, which broadly refers to an individual's ability to control thoughts, behaviors, and emotions in service of achieving a goal. Within this conceptualization, the executive attention system recruits executive functions to organize and implement control of behavior and emotions (Blair & Raver, 2015).

Self-Regulation and Anxiety

Executive Attention. Executive attention is involved in controlled aspects of attention: inhibiting attentional orienting to irrelevant stimuli, and resolving conflict among elements of a target stimulus. The functioning in this network is mediated by the anterior cingulate cortex (ACC; Matsumoto & Tanaka, 2004) and lateral prefrontal cortex, which are both targets of dopaminergic projections from the ventral tegmental area (Posner & Rothbart, 2007). The ACC appears to play a role in monitoring and signaling the presence of conflict to the lateral prefrontal cortex, which supports cognitive control processes necessary to overcome conflict and the appropriate response to the stimulus (Bunge, Hazeltine, Scanlon, Rosen, & Gabrielli, 2002; Kerns et al., 2004).

The executive network also controls the detection of errors, which can be conceptualized as the detection of conflict between a completed behavioral response and the attentional set and also appears to be mediated by activity in the ACC (vanVeen & Carter, 2002; Rueda, Posner, & Rothbart, 2005).

Executive attention skills are present in rudimentary forms during infancy and undergo rapid development across the preschool years (Rothbart, Ellis, Rueda, & Posner, 2003). In a study of 24-, 30-, and 36-month old children, Gerardi-Caulton (2000) used a simple task where children were instructed to press a response button that matched a picture presented on the screen. Conflict was introduced on trials where the location of the stimulus did not match the location of the response button. At two years of age, most children failed to resolve the conflict, but by age three they were able to do so with high levels of accuracy. The conflict effect (the slowing of reaction time on incongruent trials) was smaller for older children. Some behavioral research suggests that executive attention approaches adult levels during middle childhood (Ridderinkhoff & van der Stelt, 2000; Rueda et al., 2004), but imaging work suggests that these systems are still immature, with children recruiting different brain areas compared to adults (Bunge et al., 2002; Konrad et al., 2005).

Executive Function. Executive function (EF) is a construct that refers to a class of higher-order cognitive skills deployed during goal-directed behavior. These skills are necessary for multiple aspects of goal-directed behavior, including representing a goal and formulating a plan, selecting an action, and monitoring your behavior to judge whether your plan has been successfully executed (Zelazo, Carlson, & Kesek, 2008). In one conceptualization of EF, Miyake and colleagues (2000; 2012) emphasize the roles of inhibition (intentional override of a prepotent response), working memory (keeping information in mind and manipulating or updating it in response to environmental demands), and shifting (flexibly switching between mental sets). More recently, work in this group has focused on a unity/diversity framework that focuses on a "common EF" factor in addition to working memory and shifting (Friedman, Miyake, Robinson, & Hewitt, 2011; Miyake & Friedman, 2012). The common EF factor accounts for variance in shifting, working memory, and inhibitory control tasks, and represents a more general ability to adaptively engage in goal-oriented behavior. In other words, the ability to actively keep goals in mind (e.g., only pay attention to the central target) and use this information to influence the processing of task-relevant information (e.g., making the central target more salient) as well as guide behavioral output (e.g., slow down to avoid errors). Within this conceptualization, executive attention represents the combination of inhibition and switching to flexibly focus on one element of experience at a time.

An alternative conceptualization of EF, the cognitive complexity and control theory-revised (CCC-r, Zelazo et al., 2003), highlights the hierarchical complexity of the rules children can use to guide their behavior. In this framework, the ability to reflect on one's own rule structure from a higher level of consciousness allows for the flexible switching between mental sets. Zelazo and Cunningham's (2007) iterative-reprocessing model posits affectively laden information ascends through higher levels of consciousness before feeding back to lower-order processes for reevaluation. Automatic processes may represent only a few iterations, whereas more effortful and deliberate processes, such as those necessary to execute complex behaviors within a "hot" context, reflect a greater amount of reprocessing and a subsequent "cooling" of the contextual effect.

"Hot" EF refers to the deployment of these skills in emotionally or motivationally salient contexts (Zelazo & Carlson, 2012). The induction of a heightened emotional state has been shown to interfere with EFs on a task assessing inhibitory control (Lewis et al., 2006). In one of the most famous illustrations of hot EF, Mischel and colleagues performed the "marshmallow task" with preschool-aged children, giving them the option to delay eating a single marshmallow in order to get a second marshmallow at the end of the delay period (Mischel, Shoda, & Rodriguez, 1989). More than a decade later, preschoolers who were better able to delay gratification were rated by parents as having better emotion regulation and attention regulation skills, scored higher on the SAT, and were less likely to engage in recreational drug use (Ayduk et al., 2000). A key element of success on this task is the ability to successfully direct attention away from the tempting object (Mischel et al., 1989). Subsequent research has found that preschoolers who were better at regulating their attention and directing it away from the delay object performed better on a go/nogo task in adolescence (Eigsti et al., 2006). Both cool and hot EF skills are dependent upon prefrontal circuitry, including the ACC, dorsolateral prefrontal cortex (dlPFC), ventrolateral preftontal cortex (vlPFC), and orbitofrontal cortex (OFC). Similar to research findings on neural systems associated with attention networks, PFC development is associated with improvements in executive function across childhood and adolescence (Davidson, Amso, Anderson, & Diamond, 2006).

Neural correlates. When evaluating the neural correlates of executive function using event related potential (ERP) methodology, researchers have focused on several components of interest including the N2, error-related negativity (ERN), and feedback-related negativity (FRN). Each of these components represents a pattern of excitatory post-synaptic potentials averaged across task trials. Continuous electroencephalogram (EEG) data is collected during a computer-based task and is then decomposed into segments that encompass stimulus or response-locked events. The N2 or N200 component is a negative deflection that occurs between 150 and 450ms following stimulus offset over midline frontal channels. This component is related to conflict monitoring, and is evident on tasks that require executive attention (e.g., flanker), as well as tasks that require the inhibition of a prepotent response (e.g., Go/Nogo). The effect of conflict on this component is observed at more anterior sites in younger children, compared with fronto-parietal sites in adults (Abundis-Gutierrez, Checa, Castellanos, & Rueda, 2014). Source localization studies suggest that the ACC is involved in the generation of this response, with evidence that children may recruit a broader network involving occipito-temporal or parietal areas (Jonkman, Sniedt, & Kemner, 2007). However, a recent study utilizing simultaneously recorded EEG and functional magnetic resonance imaging (fMRI) with adults localized conflict processing during target presentation to the pre-supplementary motor area (Iannaccone et al., 2015). In both children and adults, the detection of conflict results in a larger N2 amplitude compared to trials with less conflict (Cragg, Fox, Nation, Reid, & Anderson, 2009; Donkers & van Boxtel, 2004; Larson, Clayson, & Clawson, 2014). Developmental studies of the N2 show larger amplitudes in younger children (Jonkman, 2006; Lamm, Zelazo, & Lewis, 2006), and in children with poorer task performance (Espinet, Anderson, & Zelazo, 2012). Lamm and colleagues (2006) demonstrated that this linear, age-related decrease in amplitude is related to general improvements in executive function rather than merely reflecting enhanced performance on the ERP task. Recent research has confirmed this finding in middle childhood, noting that N2 amplitude predicted performance on a battery of executive function (Brydges, Fox, Reid, & Anderson, 2014).

The feedback-related negativity (FRN) is a negative deflection over midline frontal channels that occurs roughly 150-450ms following performance feedback. Larger amplitudes are observed following feedback that identifies an incorrect response compared to correct responses. While there is some debate in the performance monitoring literature regarding whether the FRN primarily indexes surprise or the weighted valence of a response, both of these processes could plausibly re-orient or enhance selective attention to the target on subsequent trials (Ullsperger, 2014). Thus, the FRN represents a key element of an individuals' ability to evaluate and appropriately adjust their behavior on a moment-to-moment basis. Source localization studies have identified the ACC as a potential generator of this signal (Walsh & Anderson, 2012), which was recently confirmed in a simultaneous fMRI-EEG study that also noted activation of several nodes in the salience network, including the anterior insula (Hauser et al., 2014). In adults, larger FRN amplitudes are associated with improved task performance (Bellebaum & Daum, 2008; van der Helden et al., 2010). Research with highly impulsive, young children noted an exaggerated FRN amplitude compared to controls. Notably, FRN amplitudes were significantly associated with task accuracy only within the impulsive group, suggesting that this amplified signal plays a key role in impulsive children's ability to effectively perform on a task. In other words, children with poorer inhibitory control may rely more on effective performance monitoring to modulate their behavior (Roos, Pears, Bruce, Kim, & Fisher, 2015).

The error-related negativity (ERN) is a negative deflection over midline frontal channels occurring within approximately 150ms of an erroneous response to a stimulus. This component also indexes cognitive conflict, such that the erroneous response conflicts with the correct response selected by the ongoing processing of the target stimulus. Larger amplitudes are observed when the correct response is more strongly activated by the target, which subsequently increases the degree of conflict (Larson et al., 2014; Yeung et al., 2004) For example, increasing the salience of the correct target stimulus on the flanker task by either making the flanking stimuli smaller or farther away from the central target results in larger ERN amplitudes (Danielmeier et al., 2009; Maier et al., 2012). Simultaneous EEG-fMRI research suggests that the ERN is associated with activation in the ACC, rostral cingulate zone, and pre-supplementary motor area (Iannaccone et al., 2015). In typically developing populations, the amplitude of this component increases with age across childhood and adolescence (Tamnes, Walhovd, Torstveit, Sells, & Fjell, 2013). A recent cross-sectional study failed to detect developmental change in the ERN between the ages of 3 and 7 years, suggesting that error monitoring improves at a faster rate during middle childhood and adolescence (Grammer, Carrasco, Gehring, & Morrison, 2014). In adults, larger ERN amplitudes are associated with improved executive function and attentional control (Larson & Clayson, 2011).

Anxiety. Having briefly described attention and executive functions, I turn now to the relations of attention and self-regulation with anxiety. Though less studied than attention orienting, association studies do suggest that self-regulation, particularly executive attention may also play an important role in anxiety. Pacheco-Unguetti and colleagues (2011) found that clinically anxious individuals showed decreased efficiency in the executive network, as well as difficulty disengaging attention from irrelevant distractor stimuli. High levels of trait anxiety have also been shown to predict poorer executive attention (Pacheco-Unguetti, Acosta, Callejas, & Lupianez, 2010). Other researchers have noted increased reflexive orienting to neutral distractors compared to non-anxious participants (Moriya & Tanno, 2009). Indeed, Sylvester and colleagues (2012) argued that the pattern of network dysfunction in anxiety disorders is characterized by increased functioning in brain networks that support reflexive orienting, and decreased functioning in prefrontal networks responsible for cognitive control.

ERP studies provide additional support for the altered functioning of self-regulatory networks in anxious individuals. In light of consistent findings associating larger ERN amplitudes with anxiety in both adults and children, this ERP component has been proposed as a biomarker of risk for anxiety (Hajcak, 2012). Compared to controls, adults with Obsessive Compulsive Disorder (OCD) and General Anxiety Disorder (GAD) demonstrate an exaggerated ERN amplitude (Xiao et al., 2011), suggesting that in addition to indexing response monitoring, it also reflects the extent to which the error is experienced as aversive (Weinberg, Riesel, & Hajcak, 2012). Association studies in children mirror findings in adults, with larger ERN amplitudes found in clinical populations of children suffering from both GAD (Ladoucer, Dahl, Birmaher, Axelson, & Ryan, 2006) and OCD (Hajcak, Franklin, Foa, & Simons, 2008). Among typically developing children and youth, both trait anxiety and internalizing symptoms predict larger ERNs (Lewis & Stieben, 2004; Meyer, Weinberg, Klein, & Hajcak, 2012). Notably, recent work has shown that ERN amplitude relates to anxiety, but not to depressive symptoms, suggesting that this association is unique to anxiety (Bress, Meyer, & Hajcak, 2013). Evidence for the predictive utility of this component is beginning to accumulate, with recent work in behaviorally inhibited children finding that enhanced ERN amplitudes at age 7 predicted social phobia symptoms at age 9 (Lahat et al., 2014). A recent study of 236 healthy 6-year-olds found that larger ERN amplitudes predicted the onset of an anxiety disorder by age 9, even after controlling for anxiety symptoms at age 6 and maternal anxiety symptoms (Meyer, Hajcak, Torpey-Newman, Kujawa, & Klein, 2015).

Self-regulation and executive attention have also been shown to moderate anxiety, suggesting that these higher-order regulatory processes may act as a protective factor. Derryberry and Reed (2002) studied the effect of effortful control, which is a trait measure of self-regulation, and anxiety on attention orienting. When given sufficient time for regulatory processes to come online, individuals with high trait anxiety and high effortful control demonstrated no attention bias to threat. Lonigan and Vasey (2009) replicated these findings in a sample of typically developing children and adolescents. Individuals with high levels of effortful control showed no attention bias to threat, even if they were high on a measure of negative affectivity.

The moderating role of executive attention has also been noted in children with behaviorally inhibited temperament. Children at this temperamental extreme show heightened vigilant and withdrawal behaviors when confronted with novelty, and are at heightened risk for developing anxiety disorders, particularly social anxiety in adolescence (Chronis-Toscano et al., 2009) and adulthood (Biederman et al., 2001; Gladstone, Parker, Mitchell, Wilhelm, & Malhi, 2005). However, only a minority of children initially identified as behaviorally inhibited will go on to display clinically significant symptoms, suggesting the important role of moderating factors in the development of anxiety disorders in this population (Degnan & Fox, 2007). Children who were assessed as highly inhibited at 24 months of age who demonstrated better attention regulation at 48 months were significantly less likely than their peers with poorer attentional control to report problems with anxiety (White et al., 2011).

Data from studies linking anxiety attention regulatory processes suggest that EF and executive attention should be considered as key targets for interventions that aim to improve emotion regulation and anxiety symptoms in children. Self-regulation appears to act as a protective factor, moderating pre-existing risk for anxiety in children and adults. Similar to the body of work investigating attention orienting, training studies that directly manipulate EF and attention will allow researchers to determine causal relationships between these processes and the regulation of negative emotions. Internationally adopted (IA) children are an ideal target population for this work, because of the heightened risk for both anxiety and deficits in self-regulation noted in this population.

Internationally Adopted Children: Evidence of Suitability as a Target Population

Internationally adopted (IA) children experience disruptions in early caregiving relationships and, for those who have experienced institutional care, have often been exposed to severe conditions of deprivation. The conditions surrounding surrender of an infant into foster or institutional care may involve an increased likelihood of prenatal insult, such as malnutrition or exposure to alcohol, which place children at further risk for compromised neural development (Gunnar & Kertes, 2005). Indeed, micronutrient deficiency has been shown to predict deficits in IQ and executive function (EF) independently from duration of institutional deprivation (Doom et al., 2014). The majority of research on IA children has focused on post-institutionalized (PI) children.

The effects of early adversity on neural development are well documented by both structural and functional methodologies. A recent structural MRI study of early adolescents noted that children adopted from institutional care had significantly reduced PFC and hippocampal volumes compared to non-adopted children. While hippocampal volumes were associated with age at removal from the institution, PFC volume was comparably affected in both early and late-adopted children, suggesting that this brain region is particularly susceptible to adverse early experiences in the first year of life (Hodel et al., 2105). Compared to children reared in their birth families, children reared in Romanian orphanages showed smaller grey matter volumes in prefrontal areas including the OFC (McLaughlin et al., 2013). Several studies have documented decreased integrity fractional anisotropy of the uncinate fasciculus, a white matter tract connecting limbic areas to the PFC (Eluvathingal et al., 2006; Govindan, Behen, Helder, Makki, & Chugani, 2010; Hanson et al., 2013). Researchers have also noted global reductions in white matter volume (Eluvathingal et al., 2006; Mehta et al., 2009; Sheridan et al., 2012) and disrupted organization of prefrontal white matter (Behen et al., 2009; Eluvathingal et al., 2006; Govindan et al., 2010; Hanson et al., 2013). PI children have also shown increased amygdala volume (Mehta et al., 2009; Tottenham et al., 2010) as well as increased activation in response to threatening stimuli (Maheu et al., 2010; Tottenham et al., 2011). However, the most recent work in this population has not replicated this structural finding (Hodel et al., 2015).

EEG and ERP studies of PI children echo many of the findings of the MRI literature, with institutional care predicting more immature functioning of neural systems that support self-regulation. In the Bucharest Early Intervention Study, children between 8 and 9 years of age who were randomly selected for placement in foster care had significantly larger ERN amplitudes compared to their peers who remained in institutional care (McDermott, Westerlund, Zeanah, Nelson, & Fox, 2013). In a subsequent study, children in the foster care group who exhibited larger ERNs demonstrated greater academic competence and fewer externalizing problems compared to children in this group with smaller ERNs (McDermott, Troller-Renfree, Vanderwert, Nelson, Zeanah, & Fox, 2013). Research in similarly aged children noted that compared to children reared in their families of origin, PI children had smaller ERNs during a flanker task and smaller N2 amplitudes during a go/nogo paradigm (Loman et al., 2013). Institutional care is also associated with increased levels of low-frequency power and decreased levels of high-frequency power in EEG studies for children still in institutional care or shortly after leaving such care (McLaughlin et al., 2010; Tarullo, Garvin, & Gunnar, 2011), which has been found to partially mediate the relationship between institutional rearing and ADHD symptoms (McLaughlin et al., 2010). It is clear from studies of brain structure and function that even a discrete period of early deprivation is sufficient to compromise neural development, and these effects are also apparent in IA children's self-regulatory capacities.

While data on brain structure and function in IA children consistently demonstrate negative impacts of early deprivation, research regarding IA children's emotion regulation capacities are more mixed. Two large studies and a meta-analysis have failed to find evidence of a link between early deprivation and increased internalizing symptoms during childhood (Gunnar & van Dulmen, 2007; Juffer & van IJzendoorn, 2005; Rutter, Kreppner, & O'Connor, 2001). However, a recent investigation of IA children during middle childhood found that parents of children adopted from institutional as well as from foster care (FC) settings reported higher levels of internalizing symptoms. When the children were asked to report on their own symptoms, PI and not FC children reported higher mean levels of internalizing symptoms, with more PI children reporting a higher frequency of scores above the clinical cutoff (Wiik et al., 2011). This increase in internalizing symptoms is consistent with data from imaging studies showing increased amygdala volume (Mehta et al., 2009; Tottenham et al., 2010), reactivity to threat (Tottenham et al., 2011), and decreased grey matter volume in the OFC, which supports emotion regulation (McLaughlin et al., 2013). Further research using IA children's self-reported symptoms is necessary to further elucidate the nature of this risk, as observer reports are likely less sensitive measures.

The nature of anxiety problems among IA children may remain up for debate, but the presence of difficulties with attention and behavior regulation in this population is undeniable (Merz & McCall, 2011; Nelson, 2007). These deficits are sufficiently common in this population that the English and Romanian Adoptees Study (ERA) has classified it as a deprivation-specific problem (DSP) with more severe impairment associated with longer durations of institutional care (Kreppner, O'Connor, Rutter, & the

English Romanian Adoptees Study, 2001). Following adoption into families, children demonstrate evidence of catch-up in both physical and cognitive development (IQ; Maclean, 2003), but the evidence regarding the positive effects of the adoptive home environment on attention are mixed: some researchers have found that the quality of the home environment predicted long-term improvements in inattention/overactivity (Audet & LeMare, 2011), whereas other research suggests that deficits in attention regulation may not remit (Gunnar, & van Dulmen 2007; Kreppner et al., 2001; Wiik et al., 2011). Catch-up growth in this domain may not become obvious for years following removal from the institutional setting (Stevens et al., 2008). There is evidence to suggest that the lack of a relationship with a consistent, responsive caregiver in institutional settings has a uniquely pernicious effect on the development of self-regulation: in orphanages with appropriately stimulating physical environments and high-quality caregiving by multiple individuals continues to be associated inattention and hyperactivity (Roy, Rutter, & Pickles, 2004). It is no surprise that, given the prevalence and persistence of attention deficits in PI children, the incidence of clinically significant attention problems in this population is elevated, with some samples reporting rates over 40% (Miller, Chan, Tirella, & Perrin, 2009). Importantly, recent work has highlighted the mediating role of decreased PFC cortical thickness and immature patterns of cortical activity in the relationship between institutional care and ADHD symptomatology (McLaughlin et al., 2010, 2013). Sonuga-Barke and Rubia (2008) found that, although the profiles of attention problems in post-institutionalized children (specifically males) were highly similar to comparison cases of typical ADHD, post-institutionalized children appeared to have greater deficits in inhibitory control, but lower levels of conduct problems. The precise nature of attention problems in PI children remains unclear, with evidence for deficits in multiple aspects of relevant regulatory processes, including: inhibitory control, sustained attention, attention regulation, and error monitoring (Loman et al., 2013; McDermott et al., 2013; Pollak et al., 2010; Sonuga-Barke & Rubia, 2008).

Broader investigations of EF in IA children have noted significant deficits present as early as one year following adoption (Hostinar et al., 2013). Similar to problems specific to attention regulation and inhibitory control, these broader deficits appear to persist across middle childhood. Pollak and colleagues (2010) used a battery of cognitive tasks to assess post-institutionalized children's working memory, attention, executive control, and learning abilities. Even though they had been in their adoptive homes for 6 years or more PI children performed more poorly on tests of inhibitory control, visual and auditory attention, and working memory, but not planning or rule learning. The BEIP study repeated this analysis with comparable findings (Bos, Fox, Zeanah & Nelson, 2009). In both of these studies, longer durations of early deprivation predicted more severe EF deficits. In a sample of children adopted later than the two studies previously mentioned, EF impairments were more severe and included deficits in planning, consistent with previous findings that longer durations of institutionalization predict poorer outcomes (Bauer, Hanson, Pierson, Davidson & Pollak, 2009). PI children also show poorer educational achievement, with worse outcomes associated with longer durations of institutional care (Beckett et al., 2007; van IJzendoorn & Juffer, 2006), which likely reflects broader difficulties with EF. Taken together, these studies highlight the negative impact early adversity has on the neural underpinnings of self-regulation, which may put children at further risk for the later development of psychopathology.

Deficits in self-regulation during childhood may carry forward as risk for emotional disorders during the transition to adolescence. Compelling evidence from the ERA study shows that although at age 6 there was no significant difference in emotional difficulties between PI and non-adopted children, by age 11 substantially more PI children were above clinical cutoffs. While most children below cutoffs at age 6 remained so, a subgroup of these children shifted into the clinical range by the second assessment. Notably, the presence of DSPs (including inattention/overactivity), rather than emotional difficulties at age 6 significantly predicted emotional disturbance at both time points (Colvert et al., 2008). At age 15, PI children continued to report heightened emotional difficulties, where the relationship between early deprivation and later emotional problems were mediated by the presence of DSPs in early and middle childhood. While quasi-autism was most strongly associated with later emotional difficulties, there were also positive associations with inattention/overactivity (Sonuga-Barke et al., 2010).

In summary, alterations in the development of brain areas that support self-regulation are well documented in this population. Further, evidence for altered neural development is bolstered by deficits in self-regulation that are apparent early in development and persist across the childhood years. There is also emerging evidence that these early self-regulation deficits may be concurrently accompanied by increased rates of anxiety symptoms and these may also feed forward to clinically significant problems with emotion regulation during adolescence. The nature of deficits noted in this population makes IA children an ideal population for testing the relation between attention and anxiety in an intervention model. Interventions that target attention and EF should be contrasted with interventions that target general self-regulation, including emotion regulation, in order to provide a stringent test of causal relations between attention regulation and the regulation of negative emotions.

Training Self-Regulation

Multiple approaches have been suggested to improve self-regulation. This review focuses on two types of training: general EF training, accomplished through classroom curricula or computer-based practice, and contemplative practice, which practices EF in the context of meditative activities but also directly trains emotion regulation.

EF Training. Empirical support is growing for the effectiveness of classroom-based approaches to improving EF in children. Tools of the Mind, which is a preschool curriculum based on Vygotsky's theory of cognitive development (Vygotsky, 1978), utilizes tools like pretend play, encouraging self-directed speech, and scaffolding in the form of visual reminders. A randomized, controlled trial of this preschool curriculum found that children in Tools classrooms performed significantly better on an inhibitory control task as well as a flanker task, especially following a rule reversal (Diamond, Barnett, Thomas, & Munro, 2007). Montessori programs emphasize a culture of self-control in the classroom and where children are able to freely choose which learning materials to explore and long periods of focus are encouraged. Research comparing children chosen by lottery to enroll in Montessori preschool to a control group of unselected lottery students noted significant improvements in EF in addition to reading and math (Lillard & Else-Quest, 2005). Another adjunct to curricula, the Promoting Alternative Thinking Strategies (PATHS) program explicitly emphasizes conscious self-control strategies like self-directed speech and generating explicit plans for regulating emotion during moments of challenge. Children in middle childhood significantly improved on a measure of inhibitory control, which mediated the relationship between intervention status and fewer internalizing and externalizing behaviors one year later (Riggs, Greenberg, Kusche, & Pentz, 2006).

Several of the previously mentioned programs focus exclusively on the preschool period. While research has convincingly demonstrated the potential long-term impact of high-quality preschool for high-risk populations (e.g., Reynolds, Temple, White, Ou, & Robertson, 2011), the research and development of programs designed to benefit a wider range of ages is necessary. The Rush NeuroBehavioral Center (RNBC) EF Curriculum contains modules that extend from kindergarten through 12th grade. A preliminary investigation included children in grades four through eight, and found that students who adhered more strongly to the program (e.g., using their planner) achieved higher grades in reading and math and had higher rates of homework completion (Leon, 2008, as cited by Otero et al., 2014). While the generalization to academic functioning is promising, more rigorous studies of this intervention are needed. Pay Attention! is an individually-delivered intervention that consists of 16 sessions with a trained practitioner. The program focuses on multiple aspects of attention using both auditory and visual stimuli. As training progresses, games become more difficult with the introduction of distractors (e.g., distracting noises played when a child is listening for a specific word) or with simultaneous activities. A randomized, controlled trial in 7 to 15-year-olds with ADHD found significant improvement on behavioral measures of attention and planning as well as improvements in symptomatology by both parent and clinician report (Tamm et al., 2013). The inherent flexibility of this program allows for maximally effective administration across age and skill levels, which is a major challenge to implementing interventions in a classroom.

Computerized cognitive training programs are among the most widely studied, and are notable for their treatment integrity because the programs remove the possibility of human error on the part of instructors. This type of training is also appealing from the standpoint of implementations because of their potential cost-effectiveness and ability to adapt to the skill level of individual participants (Otero, Barker, & Naglieri, 2014). CogMed working memory training is a five-week, computerized training protocol that has been the best studied in this area, with two recent meta-analytic reviews supporting its efficacy for the improvement of working memory. However, Melby-lervag and Hulme (2013) failed to find consistent support for claims that these trainings transfer effectively to other aspects of EF, such as inhibition, or to measures of academic functioning. A meta-analysis of these programs for children with ADHD also noted improvements of moderate magnitude for working memory, but no evidence of transfer to performance on other cognitive tests or measures of academic functioning (Rapport, Orban, Kofler, & Friedman, 2013). This suggests that although working memory is an important component of EF, focusing training efforts on inhibition and shifting may yield more generalizable improvements in self-regulation.

Initial evidence for the effects of training on the function of the executive attention network comes from a study by Rueda and colleagues (2005). In this study, five days of computerized training with typically developing children aged 4-6 years. The training program used games that challenged executive attention in addition to general EF skills with games that required attentional focus, inhibition, memory, planning, and shifting as difficulty increased. Both groups of children improved from pre- to post-test on the child ANT, but these behavioral improvements were largest for the younger group. Among four-year-olds, only the trained children showed larger N2 amplitudes on incongruent trials compared to congruent ones at the same anterior site as the six-year-olds. For the six-year-olds, training produced a more posterior effect, similar to that seen in adults. Training was also related to improvements on an intelligence test, which suggests near transfer of improved common EF.

Subsequent research by this group has also examined the persistence of improvements following training as well as the transfer of improvements to behavioral measures of hot EF, including a gambling task and delay of gratification. In this study, five-year-olds completed ten sessions of computerized training similar to the program discussed above. Immediately following training, the difference between congruent and incongruent N2 amplitudes increased significantly, and the latency of the component was shorter in trained children. Further, trained children showed this effect at a more posterior site compared to controls. These effects were maintained when children were tested two months after training. Unlike the previous study, there was no significant effect of training on behavioral performance during the child ANT. The previous finding of transfer of training effects to fluid intelligence was replicated in this study, and the effects here remained significant at follow-up. This study also found evidence for the transfer of training to hot EF, noting that while children in the control group got worse at delay of gratification during subsequent testing sessions, trained children did not. Children who received training also made significantly more advantageous choices on a gambling test at two months post-training (Rueda, Checa, & Combita, 2012). The results from these two studies are of particular importance because improving function in the neural networks that support executive attention appears to generalize to improvements in broader areas of self-regulation in young children.

Similar research in adults used ERP to examine the effect of three days of computer-based training with the Simon task and an emotional go/nogo on flanker performance. They found significant effects of near transfer to the flanker task, with trained participants showing faster RTs and enhanced accuracy on incongruent trials at posttest. In addition, N2 amplitude decreased for incongruent trials only (Millner et al., 2012). These results are promising in light of limited evidence for transfer of training tasks (Melby-Lervag & Hulme, 2013; Rapport et al., 2013), but should be interpreted with caution due to the lack of a control group.

Contemplative Practice. In recent years, contemplative practice has become of particular interest to researchers and clinicians seeking to improve self-regulation skills in both typically developing and at-risk populations. The secular practice of mindfulness refers to a state of non-judgmental awareness of one's present experience (Kabat-Zinn, 2003). This emphasis on a lack of judgment when observing the present allows individuals to experience thoughts and emotional states, or external stimuli without interference. By doing so, the individual creates ample space and time to mobilize appropriate resources when action (in the form of problem solving or regulation) becomes necessary (Teper, Segal, & Inzlicht, 2013). Training this type of awareness involves both the orienting and executive components of attention; common exercises require individuals to briefly focus their attention (usually to a specific physical sensation) before disengaging and shifting attentional focus to a new stimulus. Focused meditation requires the sustained deployment of executive attention, coupled with shifting back to the original focus following periods of distraction. Emotions provide an additional point of attentional focus, with practice aimed at awareness of emotional experience without allowing it to overwhelm regulatory resources. Contemplative practice encourages iterative reprocessing of emotions, which serves as an avenue for regulating their experience and expression.

Research in adults has repeatedly shown that mindfulness meditation and related practices lead to improvements in a vast array of areas, including reductions in internalizing symptoms, functioning of the orienting and executive attention networks, inhibitory control, emotion regulation, and cognitive flexibility (Baer, 2003; Holzel et al., 2011; Heeren, Van Broeck, & Philippot, 2009; Ortner, Kilner, & Zelazo, 2007), with much emphasis placed on the regulation of anxiety. A randomized, controlled trial of mindfulness training found that seven days of regular mindfulness practice among naïve adults significantly reduced self-reported symptoms of anxiety compared to controls (Chen, Xang, Wang, & Zhang, 2013). Another brief training study noted significant decreases in elements of negative mood (e.g, tension) for individuals who engaged in mindfulness meditation. Notably, this group showed larger decreases compared to both a sham meditation condition that emphasized calm breathing and an active control that emphasized calm sitting (Zeidan, Johnson, Gordon, & Goolkasian, 2010). Research by Carmody & Baer (2008) suggests that in adults, there is a linear negative relationship between amount of mindfulness practice and self-reported symptoms of anxiety; adults who reported greater amounts of home practice reported fewer symptoms following training. Individuals with severe anxiety symptoms at baseline may be more likely to experience a significant benefit from mindfulness training (Schreiner & Malcom, 2008). Although only a few examples are highlighted here, the contention that contemplative practice leads to reductions in symptoms of anxiety is supported by meta-analytic work (e.g., Khoury et al., 2013), and accumulating work suggests that emotion regulation may be a key mediating mechanism underlying this improvement (Holzel et al., 2011; Van Dam, Hobkirk, Sheppard, Aviles-Andrews, & Earleywine, 2013).

Research in adults has also informed our understanding of the effects of contemplative practice on the neural underpinnings of self-regulation. Expert meditators demonstrate greater activation in the rostral ACC compared to controls while engaging in focused attention meditation during both neutral and affectively charged conditions (Gard et al., 2010; Holzel, 2007). Compelling evidence for the efficacy of training the executive attention networks comes from a series of randomized controlled trials of integrative body-mind training (IBMT), which demonstrated improvements in executive attention and emotion regulation, as well as increased ACC activity and improved ACC-striatal connectivity compared to an active control of relaxation training (Tang, Posner, & Rothbart, 2014). In a sample of meditation-naïve adults, engaging in a single mindfulness exercise was sufficient to decrease the amplitude of the Pe ERP component, which is associated with the affective and motivational salience of errors, although there was no change in the ERN (Larsen, Steffen, & Primosch, 2013). Individuals who score higher on measures of dispositional mindfulness show a stronger inhibitory association between the PFC and amygdala (Creswell, Way, Eisenberger, & Lieberman, 2007), and a study of individuals with social anxiety found that eight weeks of mindfulness training significantly reduced amygdala activation during an affective regulation task compared to baseline (Goldin & Gross, 2010). Interestingly, expert meditators show *enhanced* rather than down-regulated neural processing of aversive stimuli, suggesting that with expertise, regulatory processes become automatized and do not require the same degree of effortful processing (Holzel et al., 2011).

In light of the body of work supporting mindfulness as a means of improving self-regulation in adults, Zelazo and Lyons (2012) argue that the practice of mindfulness is an active process or reflection. Thus, in line with the iterative reprocessing model discussed earlier, mindfulness should facilitate the use of both "top-down," prefrontally-mediated control mechanisms used while engaging in reprocessing and also decrease the influence of "bottom-up" interference.

Converging evidence from studies utilizing self- and other-report measures in children suggests that mindfulness-based training programs may effectively improve self-regulation. A recent meta-analysis of mindfulness-based programs in school settings across grades 1-12 noted significant, large effects of mindfulness on cognitive performance in controlled studies (Zenner, Hermleben-Kurtz, & Walach, 2014), but studies using objective behavioral measures of students' performance yield less consistent evidence. For example, Recent work with elementary school children provides promising evidence that mindfulness training leads to improvements in parent and teacher-reported behavioral regulation and EF, particularly among children with larger initial EF difficulties (Flook et al., 2010). Follow-up research in a preschool sample yielded a similar pattern of results for the teacher reports; students in the intervention group showed improvements in ratings of social competence, particularly when they demonstrated poorer EF at baseline. However, there were no significant effects on behavioral measures of cool or hot EF (Flook et al., 2014). A recent study of slightly older children in a school setting did find effects of mindfulness training on a flanker task as well as an inhibitory control task (Schonert-Reichl et al., 2015). Much of the research on mindfulness in children involves training low-risk, typically developing samples, but there is also emerging evidence that these types of practice may be effective at improving attention and emotion regulation skills in high-risk populations.

Semple and colleagues (2010) conducted a randomized, controlled trial of mindfulness-based cognitive therapy for children (MBCT-C) in a sample of 9 to 13-year-old children referred by a clinic's remedial reading program. Treatment was associated with significant reductions in parent-reported attention problems, which was maintained at a three-month follow-up. This reduction in attention problems also accounted for 46% of the variability in behavior problems. In a sub-group of children who demonstrated clinical levels of anxiety at pre-test, there was a significant reduction in symptoms after the intervention. However, there were no changes in anxiety symptoms relative to controls in the treatment group as a whole. A preliminary study using a very small group of 8-year-old boys with a diagnosis of ADHD, utilized objective observer reports of classroom behavior for each case over time. Following individual mindfulness training, percentage of classroom time spent on-task increased. Parent and teacher reports indicated significant decreases in hyperactivity, but not attentional focus (Carboni, Roach, & Fredrick, 2013). A feasibility study by Zylowska and colleagues (2008) in a small sample of adolescents with ADHD noted significant improvements in behavioral measures of EF following an 8-week mindfulness training program. Adolescents showed significant improvements in executive attention, inhibitory control, and set shifting but not in working memory. Behavioral improvements were accompanied by improvement of self-reported ADHD symptoms. While promising, it is important to note that neither the work by Carboni et al. (2013) or Zylowska et a. (2008) utilized a control group; although evidence is converging from studies using a variety of assessments in children and adolescents with self-regulation difficulties, larger sample sizes and more rigorous methodology are required to support causal claims that mindfulness training leads to improvement in self-regulation.

Despite strong evidence that these practices promote cognitive function and well-being in adults, critiques of this research in children point out that enthusiasm for MM-based training outstrips the scientific merit of much of the available literature (Greenberg & Harris, 2012). Methods of both intervention and assessment are highly variable, and even converging evidence at this stage should be interpreted with caution. Reviews of studies examining contemplative training in children and youths suggest that these interventions may lead to improvements in emotion regulation and academic competence, but a lack of active control groups and objective measures diminishes confidence in these findings (Birdee et al., 2009; Black et al., 2008; Burke, 2009; Galantino, Galbavy, & Quinn, 2008; Greenberg & Harris, 2012). For example, a recent large study of a school-based mindfulness program of over 400 children failed to employ a control group and relied exclusively on reports from teachers who also participated in the intervention as an outcome measure (Black & Fernando, 2014). A meta-analysis of mindfulness-based stress reduction (MBSR) training in adults noted that effect sizes for studies employing active controls were smaller, but not significantly different from effect sizes for studies using wait-list controls (Grosman, Nieman, Schmidt, & Walach, 2004), which was recently echoed by a meta-analysis of mindfulness interventions in schools, such that effect sizes for observational and controlled studies were nearly identical (*g*s = 0.40 and 0.41, respectively; Zenner et al., 2014). Zoogman and colleagues (2015) noted smaller effect sizes for studies that employed active controls (*del*=0.227). However, as evidence accumulates that contemplative practice can induce change in self-regulation among children and youth, researchers must also consider the *relative* efficacy of this type of training. Despite a current cultural push to include contemplative practice as part of a standard school curriculum, it remains unclear whether this type of training is optimal for improving self-regulation, particularly among students who may already be struggling in this domain.

Summary

The neural networks that support the development of attention and attention regulation undergo rapid development during the first years of life. In infancy, the ability to shift attention away from a distressing stimulus represents one of the earliest forms of emotion regulation, and many years of research have documented the ongoing links between attention and emotion across the lifespan. Executive attention, which develops most rapidly during the preschool years, is part of the broader construct of self-regulation, which encompasses the regulation of attention, cognition, behavior, and emotion. In this framework, executive attention recruits executive functions including working memory, inhibition, and shifting to carry out complex behavior. Effortful control, the trait analogue of EF, and executive attention act as protective factors for individuals at risk for anxiety. Executive attention and EF may also be causally related to anxiety, though no studies to date have examined this association with an intervention model. In order to test these relations, training EF and executive attention should be compared to an intervention that simultaneously trains cognitive, behavior, and emotion regulation skills.

Internationally adopted children display a pattern of self-regulation difficulties that make than an ideal target population to investigate this question. These children, particularly if they have experienced social deprivation in the form of orphanage-based care, experience deficits in attention regulation that are present shortly after adoption and can persist through the childhood years. Evidence regarding a higher incidence of anxiety symptoms during middle childhood in IA children remains mixed. However, longitudinal research suggests that children who were struggling with self-regulation during childhood experience heightened risk for the development of emotional disorders during the transition to adolescence. Comparing EF training to broader self-regulation training in a population with deficits in both of these areas is necessary to rigorously test its capacity to transfer effects to broader areas of self-regulation, including emotion regulation and anxiety symptoms.

Multiple studies have successfully demonstrated that EF can be trained across the lifespan in typically developing and clinical populations. Classroom curricula that focus on the use of EF and provide strategic scaffolding of these skills have demonstrated improvement in early and middle childhood. Additionally, computer-based training programs have led to improvements in executive attention and hot EF skills in addition to changes in the amplitude of the N2. However, the evidence for the ability of computer-based training to transfer to broader self-regulation skills remains extremely limited. Contemplative practice trains EF as well as emotion regulation, and has inspired a rapidly growing body of research. Mindfulness-based practices in adults have yielded consistent effects on the improvement of self-regulation present at the level of behavior, brain structure, connectivity, and peripheral regulatory systems. Work in children shows promise, with positive impacts on self-regulation noted even in studies of children with ADHD. However, a major concern with this literature arises from consistent findings that are often observed between studies with major methodological flaws, such as reliance on potentially biased reporting and a lack of active (or any) control groups. Additionally, no research study to date has compared mindfulness-based training to another intervention designed to improve self-regulation; this comparison is necessary in order to determine whether training self-regulation in the context of mindful awareness or training self-regulation through focal practice results in the broader generalization of these skills.

The Current Study

The current study attempts to address several gaps in the literature reviewed above by comparing executive function training to mindfulness-based training in a randomized, controlled trial. Using a pre-post design with an additional follow-up, this study will be able to effectively track change within and between groups. In theory, both trainings focus on self-regulatory skills, but mindfulness-based training is unique in its explicit focus on emotion regulation strategies. Thus, the mindfulness group will act as an active control for testing whether training "cool" attention and EF skills and their potential for transfer to emotion regulation. The use of objective behavioral measures as well as parent and teacher report will provide insight into the transfer of skills to other contexts. Further, the addition of ERP during computerized EF tasks will allow the direct assessment of changes in the function of the neural networks described above, with the aim of a better understanding of each intervention's mechanism of change.

Aim 1. Assess the extent to which mindfulness and executive function training programs lead to changes in neural correlates and behavioral measures of cool EF, including executive attention and inhibitory control. I hypothesize that both trainings should lead to improvements in executive attention, with concomitant decreases in the N2 amplitude during the flanker and block 1 of the emotion induction go/nogo task. Mindfulness training should uniquely result in increases of ERN and FRN amplitude because of the emphasis on self-monitoring in this program. The EF group should uniquely improve on inhibitory control, demonstrating smaller N2 amplitudes on correct nogo trials because of this training's opportunities for focal practice of this skill.

Aim 2. Assess the extent to which mindfulness and executive function training programs lead to changes in neural correlates and behavioral measures of hot EF, including dinky toys, delay of gratification, and block 3 of the emotion induction go/nogo. I hypothesize that only the EF group will improve on the dinky toys inhibitory control task due to likely near transfer of skills practiced during training. However, I predict that both training groups will show improvement on delay of gratification and on inhibitory control under conditions of high emotional arousal. Additionally, both training groups should show decreases in N2 amplitude during the final block of the go/nogo.

Aim 3. Examine whether experimenter, parent, and teacher ratings of self-regulation are improved by the training conditions. I hypothesize that children in both training groups should show improvements in self-regulation, particularly in ratings of attentional control, emotion regulation, and anxiety symptoms. However, because of the greater focus on emotion regulation in the mindfulness training, I expect that the mindfulness group should show greater improvements in anxiety and emotion regulation.

Exploratory Aim 4. Determine if individual differences in children at baseline or intervention dosage contribute to relative improvement on self-regulation within each of the intervention groups. I hypothesize that increased dosage will predict a greater degree of improvement.

Method

Participants

During the summers of 2013 and 2014, 96 internationally adopted (IA) children and their families completed this study. Mean age of participants was 7.86 years (SD=1.50). Fifty-eight were female (60.4%) and 38 were male (39.6%). Children were adopted from the following regions: 17.7% Eastern Europe, 38.5% Southeast Asia, 7.3% South Asia, 29.17% Latin America, 6.3% Africa, and 1% Caribbean. Age at adoption ranged from 3 to 60 months (M=15.27, SD=12.04), with 69.8% of children spending at least some time in institutional care. Children's adoptive homes were highly resourced, with 86.5% reporting living in a two-parent household and 83% of primary parents reported attaining a bachelor's degree or higher. Median annual income was $125,000 to $150,000.

Fourteen (14.5 %) participants reported a current diagnosis of ADHD at baseline, 8 reported a diagnosed anxiety disorder, and one child's parent reported a diagnosis of depression. Forty-one parents (42.7%) reported that their child is receiving special education services in school, with 10 children currently receiving mental health services. Parent reports of children's behavior on the Strengths and Difficulties Questionnaire

(SDQ; Goodman et al., 1997) show 30.2% of the sample within the clinical range for ADHD symptoms and 20.8% in the clinical range for emotional distress. Available norms for this measure show that in children aged 4-7 and 8-10 years old, roughly 10% score in the clinical range for parent reported ADHD symptoms and emotional difficulties (www.sdqinfo.org). Although the rate of diagnoses in this sample does not suggest increased risk, examinations of parent reported behaviors show elevated risk for problems with self-regulation. Due to ethical considerations, children's current treatment protocols were not interfered with. Families were only asked that if their child was taking medication that might impact their behavior (e.g., methylphenidate), to ensure that they took it (or not) the same way on the day of the testing sessions. In this way we were able to avoid potential confounds related to the scheduling of stimulant medication administration.

Participants were primarily recruited by phone from a registry of families maintained by the Minnesota International Adoption Project. Recruitment flyers were also placed in a research building on the University of Minnesota Campus. All registry families had at least one internationally adopted (IA) child and self-identified as willing to be contacted for research participation. Because the training programs were not designed to support children with extreme behavioral difficulties, children with fetal alcohol syndrome (FAS), autism spectrum disorders (ASD), pervasive developmental disorder (PDD), or severe cognitive impairment were excluded from the study to minimize the risk of the child's distress. In order to test the ability of the mindfulness training to teach children new techniques, children were also excluded from participation if families reported extensive experience with martial arts that included meditative components or yoga. Extensive experience was defined as continuous participation in weekly classes during the previous year. From the initial pool of 464 internationally adopted children aged 6-10 years who lived within a 50 mile radius of the University of Minnesota, recruiters were able to make contact with 320 families. Twenty–two children met exclusion criteria for this study. One hundred and seventeen children were eligible and their parents agreed to participate.

Of those agreeing to participate, one hundred and seven children completed the pretesting session. One child was excluded following testing because of an autism diagnosis that was undisclosed during recruitment. An additional nine children withdrew from the study before post-test. Three children withdrew because they did not like the training classes, four cited logistical difficulties related to the commute, and two children passively declined. Only one of the children who withdrew had been randomized to the control group. Another child's data had to be dropped from analyses because of substantial changes in psychiatric medication during the course of the study, resulting in a final sample of 96. Children who did not complete the study were significantly more anxious than completers $t(103)=-2.86$, $p<.01$, but did not differ on age or parent-reported ADHD symptoms. Withdrawal from the study did not significantly differ across groups $\chi^2=2.33$, *n.s.*

Families were compensated with a $15 Target gift card for attending each laboratory testing session and a $10 gift card for completing the online follow-up. All procedures and materials presented here have been granted approval by the University of Minnesota Institutional Review Board.

Randomization

Following the end of the pretesting period, participants were randomized to group. Given the relatively small sample size, participants were stratified by parent-reported ADHD symptoms and by primary type of pre-adoption care (institution or foster care) prior to random assignment in order to promote equivalent distribution of high-risk children across the conditions. They were then randomly assigned to the MT, EF, or no intervention (NI) group. The final distribution of the groups was as follows: MT=33 (22 girls), EF=32 (17 girls), NI=31 (19 girls). Sex was distributed equally across groups χ^2=1.26, n.s.

Training

The mindfulness training (MT) and EF training groups participated in 12 total hours of training, split into hour-long classes that take place twice per week. Classes included a group of 5-7 children, a lead instructor, and up to two assistant teachers. Assistant instructors served as models for activities and provided individualized support for children with more severe behavior regulation issues. In addition to attending classes, families in both groups were asked to complete home practice activities designed to increase program dosage and improve transfer of learned skills to broader domains of functioning. Home practice activities are brief, mirror the progression of the training curricula, and are designed to capitalize on pre-existing family routines (e.g., bedtime, chores, meals).

The MT curriculum involves a variety of very short mindfulness and relaxation practices adapted for school-aged children (see Appendix A; Johnson, Forston, Gunnar,

& Zelazo, 2011). Children are encouraged to understand mindfulness as "paying attention to right now," and a variety of activities encourage them to be present across multiple sensory modalities. Daily body scans create an additional focus on self-monitoring and non-judgmental awareness of (even unpleasant) physical sensations and emotions. Each class ends with a guided meditation activity ("belly buddies") in which children lie down and use the weight of a stuffed animal on their bellies to direct their focus to their breathing. These guided activities increased in length over the course of the intervention, lasting up to five minutes by the end of the training. Towards the end of the curriculum, emphasis is placed on the use of breathing as an emotion and behavior regulation strategy. Homework activities progressed from reinforcing basic skills (e.g., belly breathing) to parent scaffolding of children's self-regulation with mindful breathing.

The EF curriculum focuses on child-friendly games that specifically address inhibitory control, attention, and cognitive flexibility (see Appendix B). As the curriculum progresses, games become increasingly challenging with additional working memory demands and flexible rule switching. Towards the end of the curriculum, emphasis is placed on using reflection skills to identify problems and flexibly generating solutions to meet changing situational demands.

The current investigator, a graduate student collaborator, a trained post-baccalaureate volunteer, and a trained graduate student volunteer served as the primary instructors for the intervention classes. During the pilot phase of this project, the lead investigators were trained by one of the authors of the original curricula to ensure consistency of delivery. The other two primary instructors "apprenticed" as an assistant teacher in both of the training programs during the prior summer. Each of the primary instructors had a background in child psychology and in the mindfulness literature. One of the instructors was a certified yoga instructor and two were practicing child therapists (under the supervision of a licensed psychologist). Each class has at least one assistant instructor who is an advanced graduate student in clinical psychology. An additional assistant instructor was an advanced undergraduate student with extensive experience working with children on behavioral management in a classroom setting. To prevent instructor bias, lead instructors were balanced across class time and type, and each class was videotaped and coded for teacher engagement by independent observers. There was no significant difference between the EF and MT groups on teacher engagement $t(8)=-.71$, n.s.

Class attendance, homework assignment completion, and children's engagement during lessons were recorded. For each of the 11 at-home assignments, parents reported how often the activities were completed on a 4-point scale (0=not completed, 1=completed once, 2=completed 2-3 times, 3=completed more than 3 times). During every lesson, intervention teachers rated each child's engagement with class activities on a 5-point scale from 0 (absent or removed from class for disruptive behavior) to 5 (consistently engaged and on-task; actively avoids distractions.) Homework and engagement scores were summed across the twelve lessons to create dosage scores.

Procedure

Participants completed pre- and post-testing within a three-week window immediately prior to training, and immediately following the training period. Each testing session lasted for about 90 minutes. The current investigator, graduate student collaborator, and trained undergraduates served as experimenters. Each child was tested by a different experimenter at each session, and all experimenters were blind to condition. The testing session included behavioral tasks that assessed different aspects of EF: executive attention, inhibitory control, and delay of gratification. The tasks described in detail below were collected as part of a larger battery that also includes tasks related to socioemotional competence (e.g., theory of mind, prosocial skills); however, those tasks were beyond the scope of the current work. During the testing session, parents completed questionnaires about their child's self-regulation abilities as well as their physical and mental health.

Following arrival at the testing location, written consent and assent were obtained and families received compensation. The testing session began with the application of the EEG net followed by the Color Flanker and emotion induction go/nogo tasks. Children got a brief break after the computerized tasks before continuing with the behavioral assessment. Delay of gratification was administered at the end of the testing session.

Four months after the end of the training period, parents were contacted via e-mail with a copy of an online survey to fill out and an additional link to forward to their child's primary teacher. Teachers were not informed of the purpose of the study.

Measures

Behavioral Measures of EF

Attention. Sustained and executive attention were measured with the Color Flanker Task (McDermott et al., 2007). In this computerized task, children are presented with a row of five red and blue circles. Participants must respond to the central target by indicating its color with a button press while inhibiting responses to congruent (same color) or incongruent (opposite color) flanking stimuli. The task consists of three blocks of 60 trials (180 total), with equal numbers of each trial type presented in a pseudorandom order. Depending on total accuracy during 24 practice trials, children played a version of the game with 250ms, 400ms, 550ms, or 700ms target duration. After each response, children were presented with feedback in the form of a smile or a frown face.

Inhibitory Control. Inhibitory control was directly assessed with two different tasks. “Hot” inhibitory control was assessed with the Dinky Toys task. In this task, the experimenter instructs the child to sit with both hands in his or her lap. The experimenter then presents a box of attractive small toys. The child is instructed to use his or her words, instead of hands, to indicate the toy he or she would like to keep. The child’s responses are scored live on a scale ranging from 0 (hands do not move from lap, uses words only) to 5 (uninhibited toy grab, digs extensively in bin). This game was presented three times over the course of the experimental session, and final scores reflect a mean of the three experimenter ratings.

“Cool” inhibitory control was also assessed during the first block of the computerized Emotion Induction Go/Nogo task (Lewis et al., 2006). This portion of the task consists of 200 total trials with 66 nogo trials. Stimuli consist of a pair of similar letters (e.g., x and y) presented one at a time on the screen. Children are instructed to press a button every time they see a letter, except when that letter is repeated. Stimulus duration is dynamically adjusted by task performance to maintain a nogo error rate of 50% ± 10%. Correct responses are rewarded with points and error responses are followed by feedback in the form of a red bar at the bottom of the screen. A screen with the child’s accumulated points appears every 20 trials, which uses color and noise cues to alert children to gains and losses.

Hot EF. Hot EF was directly assessed with two different tasks. In the third block of the Emotion Induction Go/Nogo task (Lewis et al., 2006), children complete a block of the task that is identical to Block 1 (see above) except for the presence of emotional arousal. Prior to reading task instructions, experimenters told participants that a high number of points was necessary to win a more desirable prize. As mentioned above, in Block 1, children accumulate points for correct responses. During Block 2, which consists of 150 trials (40 nogo), a change in the scoring algorithm results in the loss of all earned points, resulting in the induction of (often negative) emotional arousal. During block 3, the scoring algorithm returns to normal and children are able to win back their points to get the "big" prize.

The computerized delay of gratification task consists of 25 test trials in which children are told they can press the little star to receive one point, or wait to press the big star and receive five points. Children are instructed that a high number of points is necessary to win the "big" prize. During each trial, the little star remains on screen for the duration of the 30-second delay period. To minimize overt inattention as a regulatory strategy, the big star target only remains onscreen for 1,000ms. Clicks on the little star are accompanied by a "clunk" sound, whereas clicks on the big star are accompanied by a cash register sound to continually emphasize the discrepant point value to participants. In order to ensure understanding, children completed five practice trials with an experimenter, during which they were encouraged to wait for the big star and reminded of the point value of each of their responses. Task duration ranges with delay performance, but can last up to 15 minutes. The outcome measure for this task is the average delay time per trial.

Observer Reports of EF

Preschool Self-Regulation Assessment (PSRA; Smith-Donald et al., 2007). The PSRA is a standardized assessor report that consists of 28 items probing children's attention, emotions, and behavior across the entirety of the testing session. The attention scale consists of five items that assess children's ability remain focused on the experimental tasks, and the inhibitory control scale consists of six items that address behaviors related to general impulsivity. Scores for each scale were averaged with higher scores reflecting better regulation.

MacArthur Health and Behavior Questionnaire (HBQ; Essex et al., 2002). The HBQ is a 140-item parent report questionnaire that assesses the child's mental health, physical health, and academic and social functioning. At each session, parents were asked to report on their child's behavior within the past several weeks. Only the inattention and impulsivity subscales were included as parent reports of EF. These scales consist of six and nine items, respectively, and higher scores reflect greater problems in these domains.

Parent, Teacher and Observer Reports of Emotion Regulation

Anxiety. Children's anxiety was measured by parent reports of anxious behaviors on the overanxious subscale of the HBQ. The depression scale was also examined to determine whether any impacts of training were specific to anxiety or more general to other internalizing problems.

Emotion Regulation. Measures of emotion regulation were obtained from blind experimenters, parents, and blind teachers. On the PSRA (Smith-Donald et al., 2007), experimenters coded children's ability to regulate arousal across the testing session on a 4-point likert-style scale, with higher scores reflecting greater regulation. The intensity and duration of children's expression of anger, worry/sadness, and positive affect were also coded. Intensity was multiplied by duration to create a weighted measure of emotional expression, with higher scores indicating more expression. Two experimenters rated approximately 20% of testing sessions to calculate interrater reliability on this measure, and all Kappa values were .80 or greater.

Parents and teachers completed the Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997) a 24-item questionnaire designed to investigate children's experience of negative or unstable mood, as well as their ability to regulate their emotions over the course of the previous week. Teacher report for this measure is available only at the four-month follow-up.

Demographics and Baseline Functioning

Health and Resources Questionnaire. (HRQ) Demographic survey including family information, education services, pre-adoption history, and post-placement history.

Strengths and Difficulties Questionnaire. (SDQ; Goodman, 1997) Contains 25 items that assess emotional symptoms, peer relationship problems, hyperactivity/inattention, conduct problems, and prosocial behavior. It also includes an impact supplement (Goodman, 1999) that asks the parent to report whether they believe the child has difficulties in the above areas, and then assesses chronicity, distress, burden to others, and social impairment. This measure was used to determine which percentage of the sample fell into the clinical range for ADHD and emotional symptoms.

NIH Toolbox: Vocabulary. This measure of receptive vocabulary is administered in a computerized adaptive format. The participant is presented with an audio recording of a word and four photographic images on the computer screen and is asked to select the picture that most closely matches the meaning of the word. This test takes approximately 4 minutes to administer and is recommended for ages 3-85. Because of the language-based nature of the training curricula, this measure was used in exploratory analyses to determine whether baseline verbal ability was related to improvement.

EEG/ERP Data Acquisition and Processing

Following consent and assent procedures, trained experimenters applied a 128 electrode Geodesic Sensor Net to the child's head and adjusted electrodes until all impedances were below 100 kΩ. An additional impedance check took place at the end of the flanker task and additional adjustments were made as needed. The EEG net was not applied to children with documented, severe sensory integration issues. Additionally, experimenters were trained to remove the net if it became overly distracting or distressing for the child.

Continuous EEG was recorded using Netstation software while the child played the Color Flanker and Emotion Induction Go/Nogo. On the Flanker task, only data from trials where a response was made were included, as non-responses likely reflected lapses of attention. On the Go/Nogo, correct nogo trials that were not preceded or followed by correct go trials were removed in order to account for attentional lapses. Data were collected at a sampling rate of 500 Hz and referenced to Cz. Data were filtered using a .01-30Hz bandpass filter prior to initial baseline correction and segmentation. For the Flanker task, stimulus-locked and feedback-locked segments spanned –400 to 600ms post-stimulus and response-locked segments spanned -400ms to 250ms. All segments on the Go/Nogo spanned -400 to 1000ms post-stimulus or response. An automated artifact detection program was used to remove channels with EMG or movement-related artifact or segments containing eye blinks. All data files were visually inspected by trained research assistants to verify the effectiveness of the automated program and manual edits were made as needed. Segments containing more than 15 bad channels were removed. Following artifact detection, bad channels were replaced with imputed waveforms, ERP averages were created for each individual subject, and waveforms were re-referenced to the average of all channels. Waveforms for stimulus-locked and feedback-locked components were baseline corrected using a window from -200ms to the stimulus offset. For response-locked components, the baseline correction used a window from -300ms to -100ms prior to the response. A difference wave was computed for feedback trials by subtracting the average waveform of positive feedback trials from negative feedback trials. Waveforms were visually inspected to ensure that potential latency differences between conditions did not introduce artifact. Data were extracted from three midline frontal channels: 6 (CFz), 11 (Fz), and 16 (AFz). Windows for component extraction were defined as follows: N2=250-400ms post-stimulus, ERN=0-100ms post-response, FRN=250-400ms post-feedback stimulus. The adaptive mean (average amplitude extending for 25ms on either side of the minimum value) was extracted for data analysis.

The vast majority of children wore the EEG net during flanker data collection; no children refused during pretest and three refused at post. For the go/nogo, three children refused at pretest and 6 refused at post. Hardware failure resulted in the loss of an additional three children’s flanker data and ten children’s go/nogo ERP data. The majority of data lost prior to artifact scoring occurred because of behavioral performance below validity thresholds (see Results section for criteria). Flanker ERP data from 15 children (15.6%) were excluded because of behavioral performance and go/nogo ERP data from 41 children (42%) were excluded because of behavioral performance. Following flanker artifact scoring, 56% of stimulus-locked trials, 66% of response-locked trials were retained, and 36% of feedback-locked trials were retained for the flanker task. This corresponded to an average of 38 stimulus-locked, 10 response-locked, and 13 feedback-locked trials. Following go/nogo artifact scoring, fewer than 30 participants met the minimum criteria of eight good trials. Because of the very limited ERP data available for this task, only behavioral data will be considered further.

Data Analysis Plan

In order to account for limited statistical power, pretest scores on each measure were subtracted from posttest values to generate difference scores. These scores were entered as the dependent variable for subsequent analyses. Difference scores were analyzed using one-way Analyses of Covariance (ANCOVA) models with intervention group as the between-subjects factor. Each analysis included planned simple contrasts comparing intervention groups to the NI control condition. Child sex was initially examined as a potential covariate but was not related to any of the dependent variables included in these analyses. For each dependent measure, only children who provided valid data and who did not perform at ceiling during pretest were included. Because the analytic subsample varies across tasks, information regarding the representativeness of the subgroup is provided in the results for each measure below. Subgroups of included vs. excluded children were compared on age, as well as parent reports of inattention, impulsivity, anxiety symptoms, and emotion regulation from the HBQ and ERC. Means and standard deviations for all measures are presented in Tables 1 and 2.

Results

Training Descriptives

Mean attendance in the MT group was 10.33 (*SD*=1.19) classes and the EF group attended a mean of 9.28 out of the 12 (*SD*=1.49) classes. This difference was statistically significant $t(63)=3.16$, $p<.01$. There was no significant difference between the two training groups on home activity compliance (MT: $M=13.18$, $SD=3.72$; EF: $M=13.28$, $SD=4.83$) $t(63)=-.09$, *n.s.* In the MT group, children's mean engagement with in-class activities was 46.03 (*SD*=6.92) and the mean rating for the EF group was 40.22 (*SD*=7.91). This difference was statistically significant $t(63)=3.16$, $p<.01$. These data suggest that families exhibited greater "buy-in" or engagement with the training program if randomized to the MT group.

Neural Correlates of EF: Color Flanker

Inclusion criteria for all Flanker analyses included a validity criterion (minimum of 65% accuracy on congruent trials at both testing sessions) and equivalent EEG net experience at both sessions (refusal, partial wear, full wear) to account for changes in task demands during EEG/ERP collection. Analyses of ERP components additionally required a minimum of eight trials included in the average ERP waveform for each subject at each testing session.

N2. 65 children were included in the following analyses (MT=23, EF=26, NI=16). This subgroup did not significantly differ from excluded children on age or parent-reported self-regulation at pretest (all *p*'s >.10). The pattern of behavioral results remained similar after excluding additional cases. Using the average of the montage, a univariate ANCOVA that covaried age, flanker task version, and number of trials, there was no significant effect of group on pre-post change in N2 amplitude for either congruent $F(2,59)=.82$, *n.s,*, $\eta^2=.03$. or incongruent trials $F(2,59)=.02$, *n.s,*, $\eta^2<.01$. No planned contrasts were significant. In summary, there was no effect of training on N2 amplitude during an executive attention task (see Appendix C).

FRN. 31 children were included in the following analyses (MT=15, EF=10, NI=6). This subgroup did not significantly differ from excluded children on age or any measure of parent-reported self-regulation. Using the average of the montage, a univariate ANCOVA covarying age, flanker task version, and number of trials revealed no significant difference between the three groups on pre-post change in FRN amplitude $F(2, 25)=.10$, *n.s.*, $\eta^2=.01$. In summary, there was no effect of training on the change in FRN amplitude during an executive attention tasks, suggesting that children's ability to effectively discriminate between positive and negative feedback was not improved by either intervention (see Appendix D).

ERN. 36 children were included in the following analyses (MT=17, EF=12, NI=7). This subgroup exclusively differed from excluded children on the emotion regulation subscale of the ERC $t(94)=-2.09$, $p<.05$; however, it is important to note here that the two groups did not differ on parent reported anxiety. The pattern of behavioral results in this subsample is consistent with the findings in the larger sample (see below). Due to the smaller number of errors during congruent trials, only errors during incongruent trials are examined here. Using the average of the montage, a univariate

ANCOVA covarying age, flanker task version, and number of trials revealed a significant effect of group on pre-post change in ERN amplitude $F(2, 30)=3.50$, $p<.05$, $\eta^2=.19$. Planned contrasts revealed that the MT and EF groups were significantly different from each other (p<.05), but neither group was significantly different from the NI group. For the EF group, ERN amplitude became more negative from pre- to post-test, whereas the MT group's ERN amplitude became more positive (see Figure 1). To investigate whether this decrease in amplitude among the MT group was related to concomitant decreases in anxiety, paired samples t-tests were conducted within each group. Only the MT group showed a significant decrease in the overanxious subscale of the HBQ $t(16)=2.77$, $p<.05$; change in the EF group $t(11)=.28$ and the NI group $t(6)=.40$ were not significant.

Behavioral Measures of EF

Attention. The following analyses included 81 children (MT=26, EF=30, NI=25; see inclusion criteria above). Independent samples t-tests revealed that excluded children were significantly younger than those included in this analysis $t(94)=-2.71$, $p<.01$, but the subgroups did not differ on parent-report measures of attention, impulsivity, or emotion regulation at pretest (all *p*'s > .5).

In order to determine whether incongruent trials produced interference (the expected "flanker effect"), a 2 (session) x 2 (trial type) repeated measures ANOVA revealed significant main effects of both session $F(1,80)=5.19$, $p<.05$ and trial type $F(1,80)=330.2$, $p<.001$ on accuracy. An identical pattern of results was found for reaction time (session: $F(1,80=16.84)$, $p<.001$, trial type: $F(1,80)=278.18$, $p<.001$). Overall, children improved significantly from pre- to post-test and there was a significant flanker effect with incongruent trials producing a greater degree of interference.

Difference scores were included in an ANCOVA model that covaried age and flanker task version. There was no significant effect of group on change in Flanker interference (RT on incongruent trials - RT on congruent trials) $F(2,76)=.25$, *n.s,*, $\eta^2=.01$. or on change in accuracy on congruent trials $F(2, 76)=1.04$, *n.s.*, $\eta^2=.03$. There was a marginally significant effect of group on change in accuracy on incongruent trials $F(2,76)=2.65$, $p=.08$, $\eta^2=.07$. Planned contrasts revealed that only the EF group improved on this measure of executive attention compared to controls ($p<.05$; Figure 2).

Inhibitory Control.

Dinky Toys. Children who performed at ceiling during pretest were not included in this analysis, leaving a subsample of 43 children (MT=14, EF=14, NI=15). Included children did not differ from excluded children on age or any index of parent-reported self-regulation (all *p*'s>.10). There was a marginally significant effect of group on change in dinky toy performance $F(2,39)=3.02$, $p=.06$, $\eta^2=.13$, with simple contrasts revealing that only the difference between the EF and NI groups reached significance ($p<.05$; Figure 3).

Emotion Induction Go/Nogo Block 1. Inclusion criteria for these analyses included a validity criterion (greater than 65% accuracy on Block 1 Go trials at both testing session) and equivalent EEG net experience across both testing sessions. 55 children were included in these analyses (MT=16, EF=18, NI=21). Children included in these analyses were significantly older than the excluded subgroup $t(94)=-4.08$, $p<.001$, and parents reported the included group as more inattentive, but this remained at trend level $t(94)=-1.71$, $p=.09$.

A univariate ANCOVA including age as a covariate revealed no significant effect of group on Go trial accuracy during Block 1 $F(2,51)=2.05$, *n.s.*, $\eta^2=07$, however the planned contrast between the MT and NI group on this measure was marginally significant ($p=.05$) such that children in the MT group decreased in accuracy compared to controls. There was no significant effect of group on pre-post change in reaction time for Go trials $F(2,51)=.30$, *n.s.*, $\eta^2=.01$, Nogo accuracy $F(2,51)=1.61$, *n.s.*, $\eta^2=.06$, or on the change in the maximum number of points earned $F(2,51)=.77$, *n.s.*, $\eta^2=.03$. There was no effect of intervention group on cool inhibitory control assessed during Block 1.

Hot EF.

Emotion Induction Go/Nogo Block 3. Information regarding this analytic subsample is presented above. The emotion induction procedure was confirmed with a 2 (session) x 3 (block) x 2 (trial type) repeated measures ANOVA on accuracy. There were significant main effects of session ($F(1,53)=10.11$, $p<.01$), block ($F(2,106)=420.85$, $p<.001$), and trial type ($F(1,53)=11.19$, $p<.001$), with accuracy decreasing during the emotion induction block and recovering during the final block. Similar to the flanker task, children were less accurate on nogo trials and all children performed better at post-test.

A univariate ANCOVA including age as a covariate revealed no significant effect of group on pre-post change in Go trial accuracy during Block 3 $F(2,50)=.01$, *n.s.*, $\eta^2<.001$ or reaction time for Go trials $F(2,51)=.30$, *n.s.*, $\eta^2=.01$. Additionally, there was no effect of group on pre-post change in Nogo accuracy $F(2,51)=.79$, *n.s.*, $\eta^2=.03$, or maximum points earned $F(2,50)=1.00$, *n.s.*, $\eta^2=.04$. In summary, there was no effect of either training program on inhibitory control skills under conditions of heightened emotional arousal.

Delay of Gratification. Children who performed at ceiling during pretest were not included in this analysis, leaving a subsample of 78 children (MT=28, EF=26, NI=24). This subgroup was significantly younger than excluded children $t(94)=2.40$, $p<.05$ A univariate ANCOVA including age as a covariate revealed no effect of group on change in mean wait time $F(2, 74)=.75$, *n.s.*, $\eta^2=.02$.

Observer Reports of EF

The entire available sample was analyzed for measures of emotion regulation collected during testing sessions. All analyses used univariate ANCOVA models with age included as a covariate.

Attention. There was no significant effect of group on the change in experimenter $F(2,92)=.18$, *n.s.*, $\eta^2<.01$, or parent ratings of attention $F(2,92)=1.29$, *n.s.*, $\eta^2=.03$.

Inhibitory Control. There was no significant effect of group on the change in experimenter $F(2,92)=1.03$, *n.s.*, $\eta^2=.02$, or parent-rated impulsivity $F(2,90)=1.60$, *n.s.*, $\eta^2=.03$.

Parent, Teacher and Observer Reports of Emotion Regulation

Reports at Testing.

The entire available sample was analyzed for measures of emotion regulation collected during testing sessions. All analyses used univariate ANCOVA models with age included as a covariate.

Anxiety. Group significantly affected the pre-post change on parent-rated over anxious behaviors $F(2,91)=3.25$, $p<.05$, $\eta^2=.07$. Planned contrasts revealed that the two intervention groups differed significantly from each other, with the MT group showing a greater decrease compared to the EF group ($p<.05$). There was no effect of group on pre-post change in the depression subscale $F(2,90)=.55$, *n.s.*, $\eta^2=.01$, suggesting that MT training exclusively affected parent reports of children's anxiety, rather than internalizing symptoms more generally (Figure 4).

Emotion Regulation. There was no effect of group on the change in experimenter rated regulation of arousal $F(2,92)=1.11$, *n.s.*, $\eta^2=.02$. Further, there was no significant effect of group on pre-post change in the expression of worry or sadness $F(2,90)=.06$, *n.s.*, $\eta^2<.01$, or the expression of positive affect $F(2,92)=1.19$, *n.s.*, $\eta^2=.03$. Analysis of anger expression difference scores yielded no significant effect of group in the overall model $F(2,92)=1.49$, *n.s.*, $\eta^2=.03$, however the planned simple contrast between the MT and NI groups reached the trend level ($p=.09$), with the MT group showing a larger decrease on this measure. There was no significant effect of group on pre-post change in either the emotion regulation subscale $F(2,91)=.83$, *n.s.*, $\eta^2<.01$, or the negativity/lability subscale $F(2,88)=.59$, *n.s.*, $\eta^2=.01$.

Emotion Regulation at Follow-Up.

Parent Report. 78 parents completed the ERC in the online follow-up. Thirteen families reported that they continued to use activities from the trainings: 5 reported continued use of breathing activities, 2 continued to use a bedtime routine, 5 reported using multiple activities after the end of the training period, and 1 family reported that they continued to help their child find emotional sensations in the body. Notably, all of these families participated in the MT intervention. Four of these families reported that their child had begun a regular yoga practice since the end of the training period and these children were removed from analyses. The final sample for these analyses included 28 children in the MT group, 22 children in the EF group, and 24 children in the NI group. Included children were significantly younger $t(94)=-2.31$, $p=.05$, but did not differ from excluded children on any other measure of parent-reported self-regulation. Difference scores were used as the dependent variable and were calculated by subtracting pretest scores from follow-up reports.

There was no significant effect on either the lability/negativity $F(2,70)=.06$, *n.s.*, $\eta^2<.01$, or the emotion regulation subscale $F(2,70)=1.17$, *n.s.*, $\eta^2=.03$, suggesting that there were no long-term effects of training on parents' perceptions of children's emotion regulation skills.

Teacher Report. 55 teachers completed the ERC in the online follow-up (MT=17, EF=15, NI=19). Children whose parents reported regular yoga practice were not included in these analyses. Included children did not differ from excluded children on age or any measures of parent-reported self-regulation. Because teacher report is only available at a single time point, subscale scores rather than difference scores are used as the dependent variable.

The overall ANCOVA model found no significant effect of group on teacher's ratings on the emotion regulation subscale $F(2,47)=1.95$, *n.s.*, $\eta^2=.08$. However, planned contrasts revealed a marginally significant effect for the MT group, such that these children received higher ratings compared to the NI group ($p=.07$). There was no effect of group on teachers' ratings on the negativity/lability subscale of this measure $F(2,47)=.96$, *n.s.*, $\eta^2=.04$ (Figure 5).

Predicting Change: Child vs. Dosage Effects

This set of exploratory analyses aims to consider the independent effects of individual differences as well as intervention dosage on children's improvement in several domains of self-regulatory skills.

Data Reduction. In order to assess change across broader domains of self-regulation, difference scores for accuracy on both the flanker and go/no-go, maximum points achieved in each block of go/nogo, difference scores for dinky toys, delay of gratification, and experimenter ratings of attention, impulsivity, and regulation were entered into a principal components analysis using a varimax rotation. In order to avoid potential bias, parent reports were not included because they were not blind to condition. The factor analysis yielded four components with an eigenvalue >1, with no items loading simultaneously onto multiple factors. Rotated factor scores are available in Table 3. The four components consisted of: attention, cool inhibitory control, experimenter rated regulation, and hot EF, and accounted for a total of 82.3% of the variance. The attention factor consisted of flanker accuracy scores for both congruent and incongruent trials. The cool inhibitory control factor included block 1 scores from the go/nogo. The experimenter rated regulation factor consisted of change on dinky toys (reverse weighted) and the three experimenter ratings from the PSRA. The hot executive function factor included accuracy scores from block 3 of the go/no-go as well as mean wait time during delay of gratification, reflecting a broader degree of EF skills deployed in affective (and often aversive) contexts. Because of task-dependent missing data, this analysis represents a subset of the sample with complete data on all measures. In order to maximize power PCA data were used to inform the aggregation of data into four composites that map on to the factor structure. Difference scores were then standardized and averaged to create four composite variables, with higher scores in each of these variables reflecting a larger degree of improvement.

Regression Analyses. Hierarchical regression analyses were conducted within each intervention group to assess the degree to which child variables and intervention dosage contributed to improvements in the four domains listed above. Age, sex, and verbal ability were entered into block 1; parent reported over anxious behavior and ADHD symptoms were entered into block 2; and class attendance, homework completion, and teacher rated engagement were entered into block 3.

Executive Function Training. Results for the attention and hot EF composites can be found in tables 4 and 5, respectively. Improvement on attention was related to fewer parent-reported ADHD symptoms at baseline t=-2.17, p<.05 and increased class attendance t=2.03, p=.05. Interestingly, poorer teacher rated engagement predicted improvements on attention as well t=-2.24, p<.05. An identical pattern of results emerged for the hot EF composite. Improvement on hot EF was predicted by fewer parent rated ADHD symptoms t=-2.86, p<.01, better class attendance t=1.89, p=.07, and poorer teacher rated engagement t=-2.41, p<.05. Teacher engagement and parent reported ADHD symptoms are significantly negatively correlated in this subgroup r(31)=-.31, p<.05. Neither cool inhibitory control nor experimenter rated regulation were related to any of the predictors in the model (all p's >.10).

Mindfulness Training. Results for the attention and hot EF composites can be found in Tables 6 and 7, respectively. Older children (t=3.20, p<.01) and children with better baseline verbal ability (t=1.89, p=.08) showed greater improvements on the attention composite, although the relationship with verbal ability was marginally significant. Only teacher rated engagement was related to improvements in hot EF $t=-2.14$, $p<.05$. The negative relation here suggests that children with poorer self-regulation during the intervention classes benefitted more from the training. Neither cool inhibitory control nor experimenter rated regulation were related to any of the predictors in the model (all *p*'s >.10).

Discussion

The current study used a randomized, controlled design to examine the effect of two types of attention training, mindfulness and executive function training, on self-regulation and anxiety. Ninety-six children between the ages of 6 and 10 years were randomly assigned to the MT, EF, or NI group and self-regulation was measured with behavioral, neural, and other-report measures immediately pre- and post-testing. Self-regulation was again assessed via parent and teacher report at a 4-month follow-up. Both interventions consisted of 12 hours of total training, which is in line with similar research in this age group (Shapiro et al., 2015). Of the eleven tests of self-regulation included in this study, five showed significant or marginally significant effects of training on behavioral measures of EF, neural correlates of EF, and reports of emotion regulation. Overall, the two interventions had dissociable effects, with EF training affecting attention and inhibitory control processes, and MT training affecting anxiety and emotion regulation. Examinations of neural correlates suggested that both interventions may be equally effective in altering differential aspects of error-related processing.

Turning first to the ERN findings, contrary to hypotheses, examination of the ERN component during the Flanker task yielded differential effects of the two training programs. It was hypothesized that the MT curriculum would lead to larger ERNs and subsequently improved task performance because of the curriculum's increased degree of continuous self-monitoring through body scans, sensory awareness games, and meditation practices. However, rather than noting an increased ERN amplitude, children in this group demonstrated smaller, less negative ERNs. This appears to be related to enhanced regulation of anxiety as a result of completing the MT curriculum. Analysis of parent reports of anxiety in both the ERN subsample and the entire sample demonstrate that the MT group had lower scores on anxiety following training. Thus, the decrease in ERN amplitude likely reflects a decrease in the aversive experience of error for children in MT training (Weinberg et al., 2012). Similar findings were noted in adults following a single exposure to mindfulness prior to a flanker task, although the difference was found in the Pe, which is also associated with the affective salience of errors (Larson et al., 2013). During MT training, children were explicitly trained in breathing-based emotion regulation strategies, but they were also exposed to a practice of non-reactivity. For example, during body scans and meditation exercises children were encouraged to notice physical and emotional sensations that might have been unpleasant (e.g., mosquito bites, feeling worried) and to then just "sit" with those feelings. These practices happened at the beginning and end of every class, providing students with numerous opportunities to engage with potentially unpleasant feelings with minimal judgment. While the MT group experienced a decrease in ERN amplitude, the EF group experienced an increase in ERN amplitude, which, when considered in light of their improved behavioral performance on this task, supports the literature linking larger ERNs to improved attentional control (Larson & Clayson, 2011). While this finding is exciting, it is also extremely preliminary. The small sub-sample included here was rated as significantly worse at regulating emotions by their parents at pretest, but were no different from excluded children on any other measure of anxiety or emotion dysregulation; this may suggest that MT training is most helpful for children who already experience some difficulty regulating their emotions. It is also important to take the contrasts into account: given the very small magnitude of this change, neither training group differed significantly from controls.

Contrary to hypotheses, only the EF group significantly improved their performance on a measure of executive attention compared to controls. While the MT group also demonstrated an increase in accuracy on incongruent trials, the magnitude of this effect did not significantly differ from the NI condition. This is particularly surprising given that it appears that the MT intervention benefitted from significantly better buy-in from participants: attendance rates were higher, children demonstrated greater engagement (more time spent on-task) during MT classes, and only families randomized to this condition continued to use activities from the intervention curriculum. An element of the classes that may have better supported this skill in the EF curriculum was the team play nature of the attention focusing games. For example, during a game of "memory," the children took turns flipping over cards placed face down on the floor in an attempt to find a match. In order to maximize the opportunity for success in this context, closely attending to classmates' performance was imperative. While sensory-based attention focusing exercises were a core element of the MT curriculum, children were engaging with task stimuli on a more individual level, which may have permitted more distractions. It is also possible that a much higher intervention dosage is necessary in order to see the effects of MT training on behavioral measures of executive attention.

As hypothesized, only the EF group significantly improved on a hot measure of inhibitory control, the dinky toys task. After training, children in this group committed fewer rule violations when told to use their words instead of their hands when choosing an attractive prize from a box. Inhibitory control was a direct focus of the EF curriculum, with one-third of each class devoted to “stopping our bodies” games, such as Simon Says, Red Light/ Green Light, and Bear/Dragon. Each of these games requires that children attend to a specific cue that signals then to inhibit a prepotent response. Mindfulness activities also required the exercise of inhibitory control skills, such as keeping your body still while lying down for breath-focused attention activities and focusing on a non-obvious sensory element of an object. For example, during mindful tasting, students listen for the sounds a raisin makes and find a variety of colors (gray, purple, black, brown, blue) in the skin instead of generating an automatic response that would impair more detailed focus. However, performance on the dinky toys task likely represents far transfer for this group. This pattern of results supports the contention that the strongest effects of training lie in skills that are directly practiced (Dahlin et al., 2008; Diamond, 2012) and echoes results from adult research demonstrating limited transfer of training individual EF skills (Hsu, Novick, & Jaeggi, 2014). While recent research has reported transfer of mindfulness training to behavioral measure of inhibitory control (Schonert-Reichl et al., 2015), the intervention dosage was much larger than the current study’s. Thus, our findings support the argument that while mindfulness may aid in improving inhibitory control during middle childhood, in the short-term, the direct practice of those skills is more effective. It is important to note that this analysis did exclude children who performed at ceiling during pretesting. However, it is unlikely that this introduced any bias as this subgroup was representative of the larger sample based on age and parent-reported self-regulation.

Contrary to hypotheses, there was no evidence of transfer of improvements in attention to gains in emotion regulation among children randomized to EF training. This was surprising given research demonstrating that executive attention moderates the risk for developing anxiety in a high-risk sample (White et al., 2011), a growing body of literature demonstrating far transfer of attention bias modification training to reductions in clinical symptoms (Eldar et al., 2012; Schmidt et al., 2009; Watters et al., 2013), and a recent training study that noted transfer of improvements in executive attention to performance on affective tasks (Rueda et al., 2012). Experimenter, parent, and teacher report data also suggest that only the MT intervention improves emotion regulation, though the analyses for experimenter and teacher report remained at trend level. Compared to the NI group, only the MT group was rated by experimenters as displaying a decrease in displays of anger and frustration across the entirety of the laboratory testing session. These displays were almost universally in direct response to errors or perceived task failure on the flanker task or emotion induction go/nogo. This may be driven by errors becoming less emotionally salient at post-test, as suggested by the ERP data, although the effect size here was small. Parent report from the testing sessions also indicates a significant decrease for the MT in over anxious behavior compared to the EF group, which more directly mirrors the effects seen in ERP data. Similar to the ERP finding, neither group differed from the NI condition, so these results should be interpreted with caution. Four months after the intervention period, teachers who were blind to the purpose of the study gave children in the MT group higher ratings of emotion regulation compared to the NI group. Although other-report measures of children's self-regulation are not ideal and reported effects were marginal, the consistency of this finding across multiple measures and informants—two of which were blind to the child's intervention group status—lends some confidence to the argument that MT interventions can improve the regulation of negative emotion in a group of children at heightened risk for the development of emotional difficulties. The maintenance of these effects are likely attributed to the MT group's reported ongoing mindfulness practice—almost 40% of participants in this condition reported continuing to use at least one activity or game learned in class at the follow-up. This contention is supported by meta-analytic evidence demonstrating that longer duration of practice is associated with greater gains (Zenner et al., 2014).

An exploratory analysis of potential predictors of improvement within each intervention group yielded further insights about which children likely benefit the most from each type of training. Within the MT group, older children and children with better verbal ability showed greater improvement in attention. The nature of the MT intervention requires a great deal of language-based communication: teachers verbally describe unfamiliar tasks and require students to verbally report on physical sensations and emotional experiences. Guided relaxation practices rely on verbal cues from the teacher and each exercise is accompanied by a class discussion on their experience and how we can apply practices to the real world. In short, effective participation in MT training requires verbal skill. Older children likely saw more benefit in this area as a result of enhanced self-monitoring capabilities that allowed them to more effectively engage with the various mindfulness practices (Grammer et al., 2014). In the domain of hot EF, children in the MT group who were rated as less engaged showed greater improvement. Because engagement ratings captured children's ability to remain on-task, this suggests that children who struggled to regulate their behavior more generally benefitted the most on this outcome, similar to findings from Flook and colleagues (2010, 2014) that children with poorer baseline EF showed the greatest improvements.

The pattern of predictors of improvement for children in the EF group was identical for both attention and hot EF outcomes. In this group, better class attendance, fewer baseline ADHD symptoms, and poorer teacher-rated engagement predicted improvement. The effect of attendance on improvement in this group alone suggests a dose-dependent relationship for the efficacy of direct skill training. No participants in this condition reported continuing to play games from class after the end of the training period, which may explain the failure of improvements in EF to persist at follow-up. Notably, parent ratings of ADHD and teacher engagement ratings were negatively correlated in this training group, potentially suggesting that children with fewer ADHD symptoms at baseline may have experienced the training games as easy and were thus more prone to distractibility during classes. Alternatively, parents may be underreporting children's difficulty with attention regulation and inhibitory control. If the former is true, this pattern suggests that children may need a stronger base of self-regulation skills in order to benefit from a relatively small dosage of focal practice; this type and duration of training may not be ideal for children who experience more substantial self-regulation challenges.

There was no significant effect of training on either the N2 or the FRN component during the flanker task. The lack of effect on the N2 was surprising in light of previous studies eliciting training effects on this component with a smaller intervention dosage (Espinet et al., 2013; Larsen et al., 2013; Millner et al., 2012; Rueda et al., 2005, 2012). However, important differences between our sample and methods may account for the lack of effect here. Previous research on EF and MT training and changes in ERP utilized typically developing samples who were younger and older than the mean age of children in the current study. Second, those trainings focused on individual children using computerized tasks, although Espinet and colleagues (2013) provided reflection training with a live experimenter during the computerized task. The current study trained children in a classroom setting, which is an inherently hot context that involves greater bottom-up interference from distractions or emotionally arousing events. In this sense, EF was likely much more successfully deployed during computer-based training, which may explain the stronger effects seen at the level of neural activity in prefrontally mediated control networks. It is also possible that in middle childhood, the neural networks that generate the N2 are less plastic compared to those that generate the ERN (Grammer et al., 2014), which would explain why our findings were restricted to change in this component.

There was no significant effect of training on behavioral performance during the emotion induction go/nogo or the delay of gratification task. This is likely due to the high level of task difficulty, particularly for children who struggle with attention regulation and inhibitory control. For the emotion induction go/nogo, although the task utilized a self-adjusting stimulus duration intended to increase task difficulty as performance improved, the fast presentation times led many children to skip trials in an attempt to better focus their attention. These errors of omission, although part of a regulatory strategy, likely introduced significant noise into the data. Further, the amount of frustration and anxiety experienced during this task led to multiple instances where experimenters discontinued the game due to children's distress. Even for those who did persist, many children were likely challenged beyond the scope of their regulatory skills.

We also failed to find effects of either training program on delay of gratification. Similar to the go/nogo task, the delay of gratification task used here may have overly challenged children's regulatory skills. The short presentation time of the big stars, while intended to maintain task engagement, likely made it impossible for children to use effective delay strategies like shifting their attention away from the hot stimulus (Eigsti et al., 2006; Mischel et al., 1989). Other training studies have also failed to note changes on this measure (e.g., Flook et al., 2014; Raver et al., 2011). Rueda and colleagues (2012) noted that their training group maintained stable scores on this measure over time while the control group worsened, resulting in a group difference. While that finding may be the result of improved self-regulatory strategies that prevented a similar decline in the treatment group, the decrease in scores among controls may have occurred for unrelated reasons

Limitations

A major limitation of this study is the lack of generalizability of the sample. While the use of IA children allows for a more stringent test of these trainings in children at risk for difficulty with both attention and emotion regulation, we are unable to extend these findings to lower risk populations. There is also limited generalizability to other high risk samples; non-IA children who experience a similar degree of prenatal or early life risk are more likely to remain in stressful, under-resourced environments that compound their early risks. The high burden and nature of this study likely created a large sampling bias, such that parents with children struggling with self-regulation to a greater degree or parents who were more motivated to change their children's behavior were more likely to participate. The high burden of this study likely excluded families who were less organized and lacked scheduling flexibility. Thus, these results may not effectively generalize even within the IA population. While subject retention was excellent, with fewer than 10% of participants withdrawing from the study before post-testing, 20% of the remaining families did not complete the longitudinal follow-up and only roughly 60% of teachers completed online survey materials. As such, children with complete data may exclusively represent the most motivated or organized families. However, analyses of children with and without follow-up data suggest that they may have differed from each other in age only.

Compared to typically developing samples (e.g., Abundis-Gutierrez et al., 2014), a relatively small proportion of ERP data was retained after artifact scoring. Due noted issues with self-regulation in this sample, children had a difficult time remaining still while wearing the EEG net and often tensed the muscles of their body and face while preparing to make a response. Error trials were particularly affected by movement, with many children flinching and frowning upon commission of errors, propagating EMG artifact through the midline frontal channels. Because PI children are more likely to demonstrate difficulties with sensory processing (Wilbarger, Gunnar, Schneider, & Pollak, 2010), EEG/ERP data collection is particularly challenging in this population. Similar findings must be replicated in other high- and low-risk populations in order to gain confidence in these findings.

While the large age range in this study allowed us to do a preliminary assessment of whether age predicted improvements for the two intervention groups, it is also a limitation. Future studies using larger samples of children within restricted age ranges is necessary to effectively determine whether younger and older children respond differently to the training programs. The broad range of children's skill level in the training classrooms may have made equivalent administration of the trainings across age groups impossible, however teachers and assistants made every effort to identify students who were struggling with various activities and provide them with additional support. The age range also presented measurement challenges, with older children more likely to perform at ceiling. Larger sample sizes with restricted age ranges will allow for better measurement of self-regulatory skill and increased statistical power will make intent-to-treat analyses plausible. An additional limitation of this study is the roles of the primary investigators as teachers of the interventions. Independent coders rated teacher engagement as equivalent across the two training conditions, but the nature of the research study may have resulted in a style of teaching or level of motivation that is not commonly observed in intervention settings.

The nature of the measures used in this study also present a significant limitation. The children who failed to provide valid data (due to poor task understanding or ceiling performance) varied across tasks, which precluded corrections for multiple statistical tests. In the future, more flexible measures that can accommodate a wider range of ability will allow for the maximal retention of subjects across measures and correction for multiple analyses.

Conclusions and Future Directions

Even in light of these limitations, this study provides an important contribution to our understanding of the relative efficacy of mindfulness and executive function-based training. The use of ERP methodology also lent an insight into the differential mechanisms underlying the immediately observed behavioral improvements in both training conditions. When studied in comparison to wait-list controls or “active” conditions that primarily control for amount of time spent in the intervention, both EF and mindfulness training have demonstrated potential to improve attention and emotion regulation. However, in a sample of IA children who are more likely to experience current difficulties with self-regulation and remain at heightened risk for the developing of internalizing problems during the transition to puberty, these interventions have differential effects. EF training produced significant improvements in executive attention and hot inhibitory control, which was likely supported by observed changes in the ERN indicating improved conflict processing and error monitoring. On the other hand, MT training led to improvements in emotion regulation, with decreases in parent-reported anxiety symptoms and blind experimenter-rated displays of frustration and anger during testing. These behavioral changes were accompanied by a decrease in ERN amplitude, which has been associated in other studies with decreased symptoms of anxiety and less negative affect. As ERN amplitude has also been associated with the degree to which errors are experienced as aversive, this result suggests that MT training primarily functions by decreasing bottom-up interference on self-regulation, at least initially. A striking finding in this study is that these improvements in emotion regulation appeared to generalize to observable classroom behavior in the MT group, who was rated by teachers as having better emotion regulation skills compared to controls. This finding is accompanied by parent reports that only children in the MT group continued to use activities and practices from the training. This suggests that improvements in EF and emotion regulation are possible in this population, but continued practice of self-regulation skills is required to maintain improvements.

To our knowledge, this is the first study to directly contrast mindfulness and EF training using a methodologically rigorous design that spanned multiple levels of analysis. As such, replication of these findings is necessary. Future studies should replicate this design in larger samples of children within restricted age ranges to determine whether patterns of improvement differ across childhood and adolescence. Future research should also systematically vary the duration of these interventions and the length of longitudinal follow-up time to determine whether these behavioral and neural effects strengthen with improved training, and also to test how well these improvements persist following the end of training. An additional line of research should examine whether training parents to regularly participate in mindfulness and executive function games with their children effectively improves children's self-regulation. This particular avenue holds tremendous promise for the ability to deliver very high doses of training in a cost-effective way. Initial training with parents could be supplemented with online-based support networks to maximize fidelity and minimize the cost of expert interventionists. With this approach, training could be made available to children whose families are unable to meet the scheduling and commuting burdens inherent to any multi-session intervention that takes place outside the home.

This study has direct implications for researchers, practitioners, educators, and parents. For children who are coping primarily with internalizing symptoms, mindfulness may be particularly helpful to ameliorate these symptoms. EF training techniques appear more appropriate if improvements in attention and inhibitory control, rather than emotion regulation, are the primary focus of interest. It comes as no surprise that combining these two trainings may lead to optimal improvements in broader areas of self-regulation. An important takeaway from our results is the finding that basic EF skills can effectively be trained with simple games, even among older children. Although the preschool years are often characterized as a sensitive period for the development of EF (Zelazo et al., 2008), continued practice of these skills throughout childhood is necessary for their optimal functioning. A recent cultural movement has seen the implementation of mindfulness-based practices cropping up in schools, but these findings should encourage educators to include explicit EF training as well, in order to maximize potential benefits for self-regulation.

In conclusion, although there was no evidence to support the hypothesis that training executive attention and EF transfer to improvements in anxiety and emotion regulation, the findings of the current study show promise for the utility of MT and EF training for improving emotion regulation and executive function, respectively. Despite a relatively small sample size and a short training period of twelve hours, significant, dissociable intervention effects were seen at the level of children's brain activity and behavior across multiple informants. This study provides an important contribution to the literature by using a rigorous design to test the relative efficacy of two related trainings. These preliminary results require replication, and further research is needed to titrate the optimum dosage of these trainings and determine for whom they are most effective.

Table 1.

Means and standard deviations of laboratory measures at pre and post-testing.

	MT			EF			NI		
		Pre	Post		Pre	Post		Pre	Post
	N	*M* (SD)	*M* (SD)	*N*	*M* (SD)	*M* (SD)	*N*	*M* (SD)	*M* (SD)
Flanker Acc Cong	26	.85 (.10)	.87 (.08)	30	.89 (.08)	.91 (.09)	25	.89 (.10)	.89 (.10)
Flanker Acc Incong	26	.72 (.12)	.75 (.10)	30	.78 (.12)	.83 (.10)	25	.79 (.11)	.79 (.12)
Flank Effect	26	52.85 (44.64)	51.10 (5.46)	30	56.32 (37.13)	50.37 (39.81)	25	53.78 (29.93)	57.94 (37.20)
N2 Cong (µv)	23	-4.83 (3.63)	-5.79 (4.03)	26	-5.64 (4.97)	-5.89 (4.53)	16	-4.39 (3.58)	-6.42 (5.71)
N2 Incong (µv)	23	-5.50 (3.55)	-6.07 (3.72)	26	-6.79 (6.23)	-7.66 (4.75)	16	-5.82 (3.88)	-6.72 (4.20)
ERN (µv)	17	-2.00 (3.61)	-.59 (3.75)	12	-1.51 (3.02)	-3.29 (3.64)	7	-1.76 (2.06)	-1.02 (1.46)
FRN (µv)	15	-.45 (3.79)	-2.06 (2.91)	10	-.75 (4.34)	-3.24 (2.72)	6	-1.02 (3.56)	-3.57 (3.64)
GNG B1 Go Acc	16	0.87 (.08)	.80 (.06)	18	.80 (.08)	.76 (.07)	21	.83 (.08)	.82 (.07)
GNG B1 Go RT (ms)	16	414.06 (55.82)	337.35 (55.84)	18	375.63 (69.48)	308.23 (48.10)	21	382.22 (48.41)	321.55 (55.15)
GNG B1 NG Acc	16	.44 (.11)	.55 (.08)	18	.54 (.08)	.60 (.09)	21	.54 (.05)	.60 (.06)
GNG B1 Max Pts	16	2169.38 (672.56)	2712.5 (446.56)	18	2622.5 (318.28)	2969.44 (436.67)	21	2640.95 (275.90)	3016.90 (303.37)
GNG B3 Go Acc	16	.84 (.10)	.86 (.06)	18	.78 (.07)	.80 (.10)	21	.83 (.09)	.85 (.09)
GNG B3 Go RT (ms)	16	361.04 (66.45)	330.99 (53.18)	18	328.91 (58.08)	290.14 (33.69)	21	346.31 (56.30)	319.83 (52.89)
GNG B3 NG Acc	16	.51 (.08)	.56 (.10)	18	.57 (.08)	.58 (.08)	21	.52 (.13)	.53 (.11)
GNG B3 Max Pts	16	2535.00 (367.51)	2842.50 (552.65)	18	2703.89 (570.31)	2933.61 (355.58)	21	2681.75 (396.96)	2658.33 (721.59)
Dinky Toys	14	1.40 (1.00)	.70 (.81)	14	1.49 (.73)	.43 (.85)	15	1.40 (.89)	1.13 (1.42)
Delay of Gratification (s)	28	15.87 (9.75)	21.56 (7.40)	26	13.27 (9.64)	17.53 (9.67)	24	14.94 (8.23)	18.58 (8.79)

Table 2.

Means and standard deviations of observer reports (experimenter, parent, and teacher) of children's self-regulation at pretest, posttest, and longitudinal follow-up.

		MT				EF				NI		
		Pre	Post	4mo		Pre	Post	4mo		Pre	Post	4mo
	N	*M* (SD)	*M* (SD)		*N*	*M* (SD)	*M* (SD)		*N*	*M* (SD)	*M* (SD)	
Experimenter												
Attention	33	2.51 (.49)	2.40 (.54)	-	32	2.57 (.48)	2.53 (.46)	-	31	2.54 (.51)	2.48 (.66)	-
Impulsivity	33	2.48 (.54)	2.43 (.55)	-	32	2.69 (.38)	2.49 (.46)	-	31	2.62 (.56)	2.53 (.60)	-
Arousal Regulation	33	1.64 (.78)	1.91 (.72)	-	32	1.91 (.78)	1.94 (.72)	-	31	1.94 (.85)	1.84 (.93)	-
Anger	33	1.58 (1.25)	1.27 (1.42)	-	32	1.22 (1.41)	1.28 (1.30)	-	31	1.29 (1.55)	1.65 (2.24)	-
Worry/ Sadness	33	.94 (1.03)	.91 (1.20)	-	32	.87 (1.23)	.84 (1.17)	-	31	1.26 (1.63)	1.32 (2.00)	-
Positive	33	2.39 (2.89)	2.39 (2.42)	-	32	3.72 (2.73)	3.91 (2.91)	-	31	3.58 (3.22)	4.58 (3.18)	-
Parent												
Attention	33	.80 (.41)	.68 (.46)	-	32	.91 (.50)	.91 (.44)	-	31	1.04 (.51)	.92 (.61)	-
Impulsivity	33	.89 (.46)	.79 (.44)	-	32	.89 (.44)	.91 (.42)	-	31	.85 (.45)	.80 (.55)	-
Anxiety	33	.55 (.29)	.23 (.24)	-	32	.52 (.26)	.45 (.36)	-	31	.53 (.31)	.37 (.40)	-
Emotion Regulation	33	3.38 (.29)	3.42 (.28)	3.52 (.36)[a]	32	3.13 (.40)	3.19 (.39)	3.40 (.41)[b]	31	3.35 (.32)	3.38 (.30)	3.53 (.31)[c]
Negativity/ Lability	33	1.88 (.39)	1.82 (.36)	1.80 (.35)[a]	32	2.06 (.47)	1.97 (.36)	1.97 (.47)[b]	31	1.83 (.43)	1.76 (.44)	1.84 (.36)[c]
Teacher												
Emotion Regulation	17	-	-	3.47 (.35)	15	-	-	3.34 (.41)	19	-	-	3.53 (.33)
Negativity/ Lability	17	-	-	1.84 (.35)	15	-	-	1.96 (.42)	19	-	-	1.83 (.37)

[a] *N*=28, [b] *N*=22, [c] *N*=24

Table 3.

Factor structure of behavioral and experimenter report measures of self-regulation at testing.

Measure (Difference Score)	Component			
	Attention	Cool Inhibitory Control	Exp Rated Regulation	Hot EF
Flanker Acc Cong	.869			
Flanker Acc Incong	.912			
GNG B1 NG Acc		.859		
GNG B1 Max Pts		.936		
Dinky Toys			-.662	
PSRA Attention			.768	
PSRA Impulsivity			.814	
PSRA Arousal Reg			.701	
GNG B3 NG Acc				.935
GNG B3 Max Pts				.796
Delay of Gratification				.684

Note: Extraction Method: Principal Component Analysis, Rotation Method: Varimax

Table 4.

Hierarchical regression predicting scores on the attention composite for children randomized to EF training.

	B	SE *B*	β	R^2	*F* for Δ R^2
Step 1				.09	*F*(3,26)=.83
Age	.10	.12	.16		
Sex	-.32	.3	-.21		
Vocab	.00	0	.12		
Step 2				.12	*F*(2, 24)=.48
Age	.07	.13	.11		
Sex	-.39	.32	.25		
Vocab	.00	.01	.11		
Anxiety	-.04	.65	-.01		
ADHD	-.35	.37	-.20		
Step 3				.30	*F*(3,21)=1.76
Age	.19	.17	.31		
Sex	-.30	.32	-.19		
Vocab	.00	.01	.08		
Anxiety	-.29	.64	-.09		
ADHD	**-1.02**	**.47**	**-.58***		
Attendance	**.47**	**.23**	**.89**^		
Homework	-.01	0.04	-.09		
Engagement	**-.11**	**0.05**	**-1.06***		

**p*<.05, ^*p*=.05

Table 5.

Hierarchical regression predicting scores on the hot EF composite for children randomized to EF training.

	B	SE *B*	β	R^2	*F* for Δ R^2
Step 1				.07	$F(3,27)=.67$
Age	-.02	.11	-.03		
Sex	-.25	.29	-.17		
Vocab	-.01	.01	-.22		
Step 2				.23	$F(2,25)=2.63$❖
Age	-.09	.11	-.16		
Sex	-.22	.25	-.15		
Vocab	.00	.01	-.11		
Anxiety	1.09	.57	-.37		
ADHD	-.57	.33	-.33		
Step 3	-.01			.44	$F(3,22)=2.67$❖
Age	-.15	.15	-.02		
Sex	-.01	.27	-.10		
Vocab	-.01	.01	-.17		
Anxiety	.75	.54	.26		
ADHD	**-1.14**	.40	**-.67****		
Attendance	**.37**	.19	**.72**❖		
Homework	-.03	.04	-.20		
Engagement	**-.10**	**.04**	**-.99***		

❖$p<.10$, *$p<.05$, **$p<.01$

Table 6.

Hierarchical regression predicting scores on the attention composite for children randomized to MT training.

	B	SE *B*	β	R^2	*F* for Δ R^2
Step 1				.30	***F*(3,22)=3.18***
Age	**.24**	**.11**	**.23***		
Sex	.05	.35	.02		
Vocab	.01	.01	.24		
Step 2				.41	*F*(2,20)=1.75
Age	**.24**	**.10**	**.42***		
Sex	.03	.34	.02		
Vocab	.01	.01	.21		
Anxiety	**1.03**	**.55**	**.32**❖		
ADHD	.01	.41	.00		
Step 3				.58	*F*(3,17)=2.31
Age	**.33**	**.10**	**.58****		
Sex	-.18	.34	-.09		
Vocab	**.02**	**.01**	**.33**❖		
Anxiety	.84	.52	.26		
ADHD	-.21	.40	-.09		
Attendance	.24	.18	.31		
Homework	.00	.04	-.01		
Engagement	.03	.03	.24		

❖$p<.10$, *$p<.05$, **$p<.01$

Table 7.

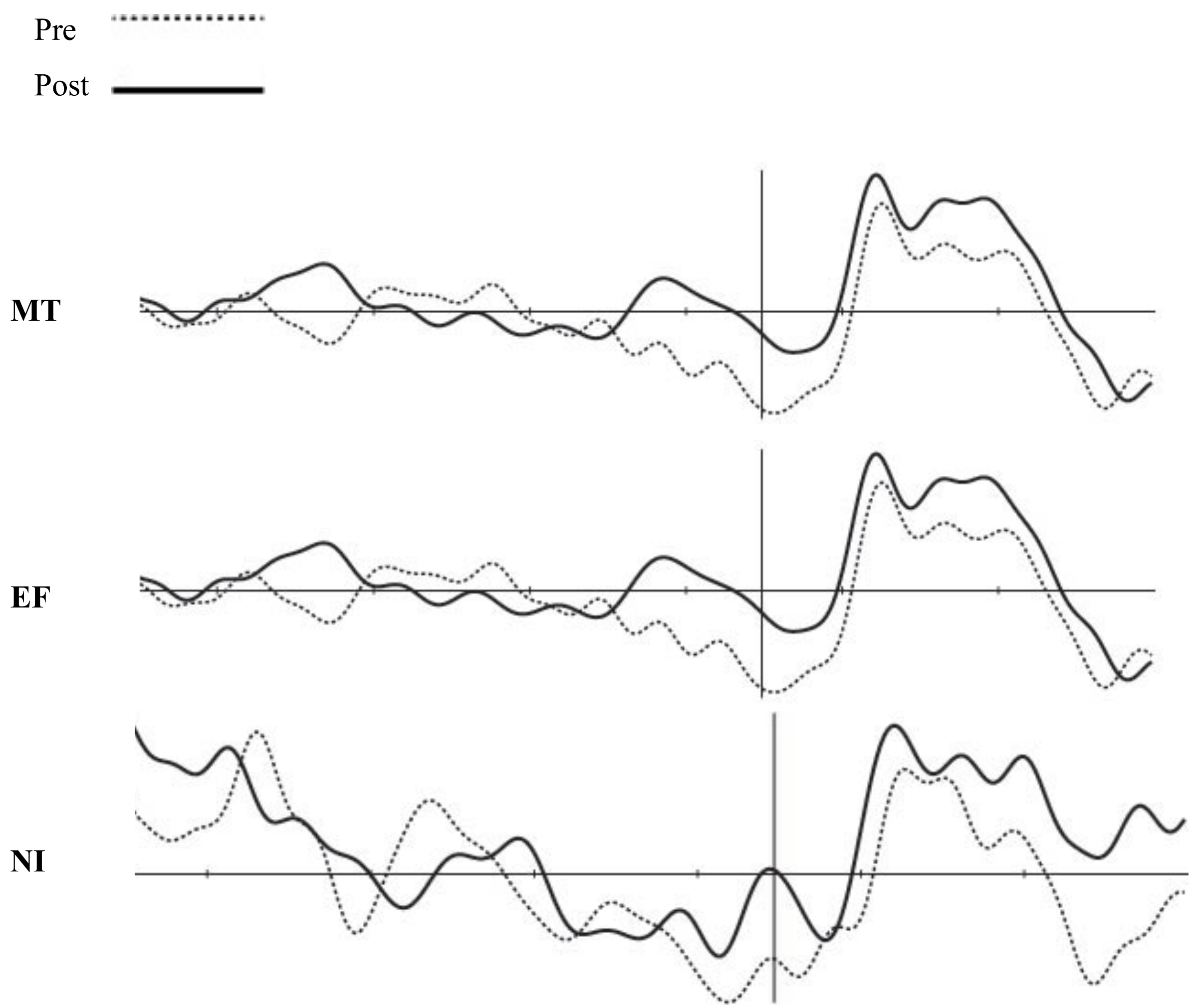
Hierarchical regression predicting scores on the hot EF composite for children randomized to MT training.

	B	SE *B*	β	R^2	*F* for Δ R^2
Step 1				0.06	*F*(3,29)=.64
Age	.07	.07	.19		
Sex	-.21	.24	-.16		
Vocab	.00	.01	.05		
Step 2				0.08	*F*(2,27)=.77
Age	.08	.08	.20		
Sex	-.21	.25	-.16		
Vocab	.00	.01	.06		
Anxiety	-.29	.41	-.13		
ADHD	.00	.31	.00		
Step 3				0.29	*F*(3,24)=.23
Age	.08	.08	.22		
Sex	.00	.27	.00		
Vocab	.00	.01	-.05		
Anxiety	-.08	.41	-.03		
ADHD	.07	.31	.05		
Attendance	.18	.14	.33		
Homework	.00	.04	.01		
Engagement	**-.05**	**.03**	**-.58***		

*p<.05

Figure 1.

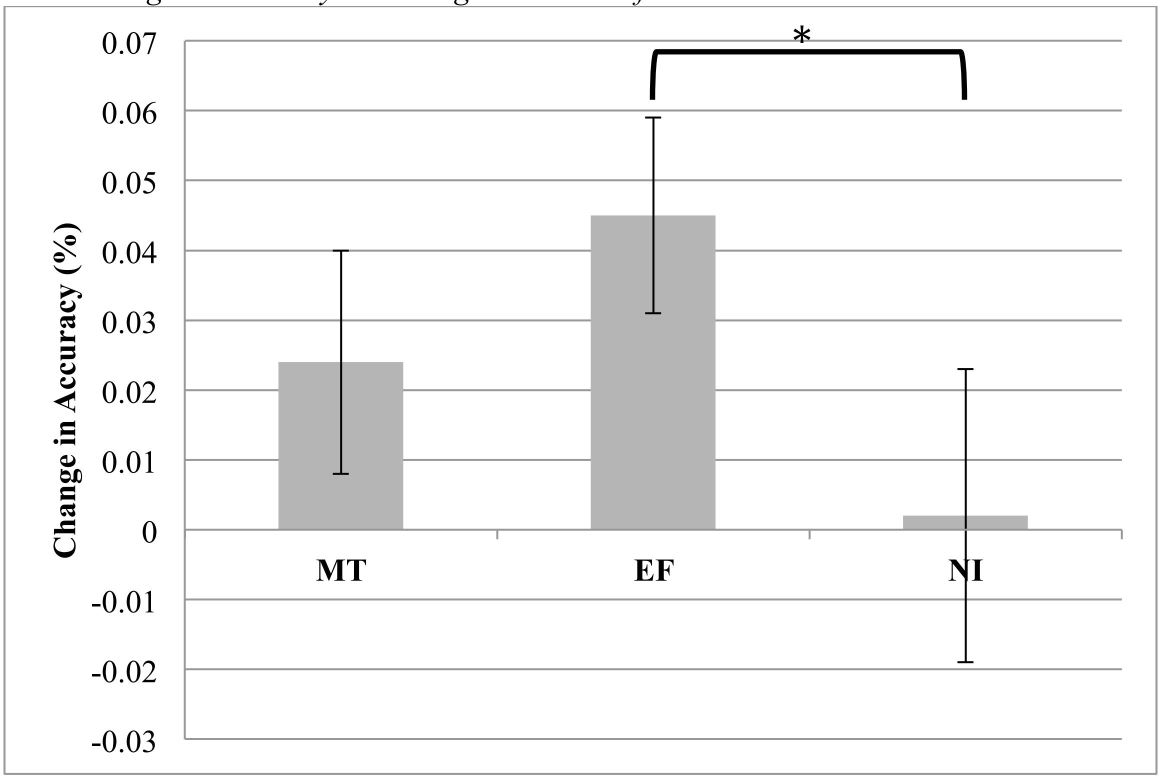
Grand averaged waveforms of the error-related negativity (ERN) for each group at site Fz.



Note: MT=mindfulness training, EF=executive function training, NI=no intervention

Figure 2.

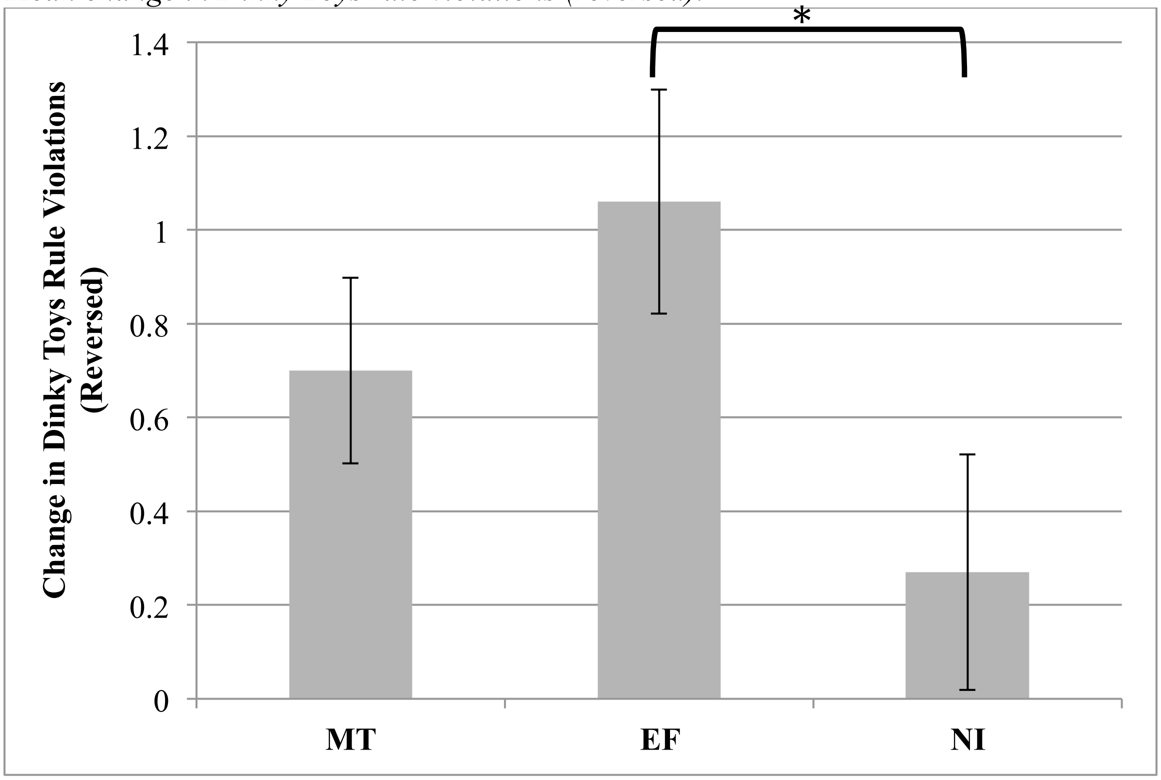
Mean change in accuracy on incongruent trials of the Flanker task.



Note: MT=mindfulness training, EF=executive function training, NI=no intervention

Figure 3.

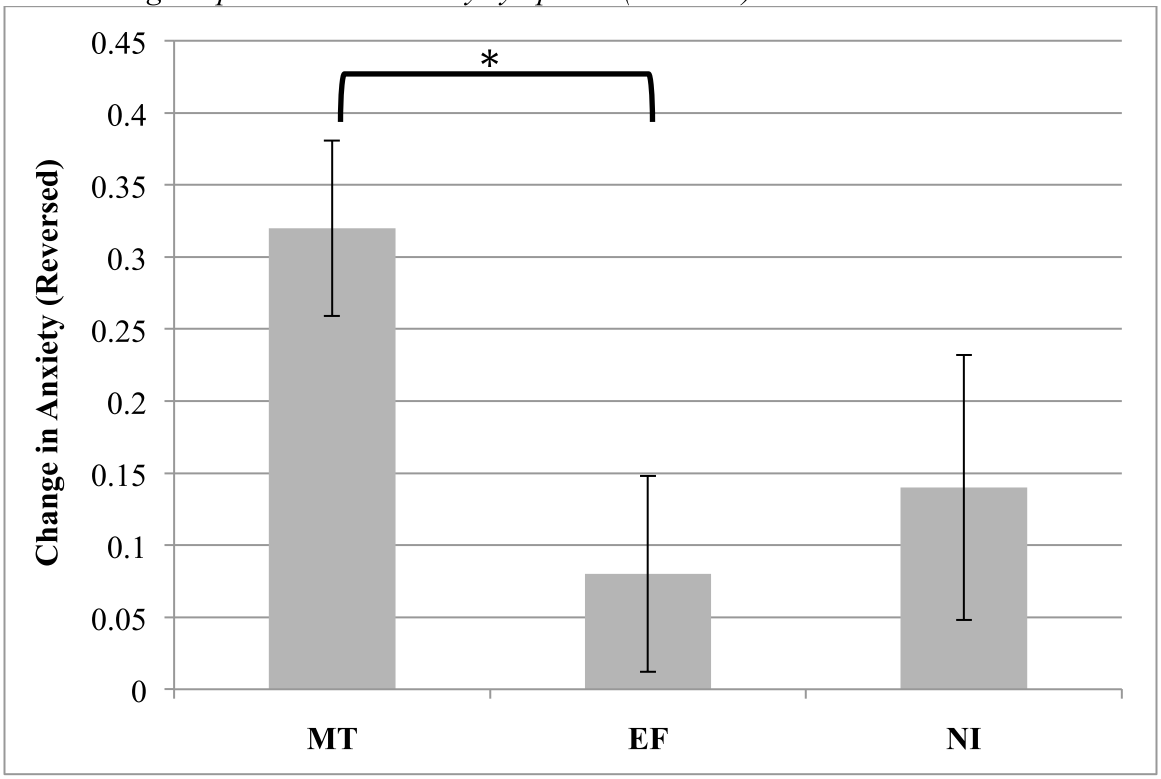
Mean change in Dinky Toys rule violations (reversed).



Note: MT=mindfulness training, EF=executive function training, NI=no intervention

Figure 4.

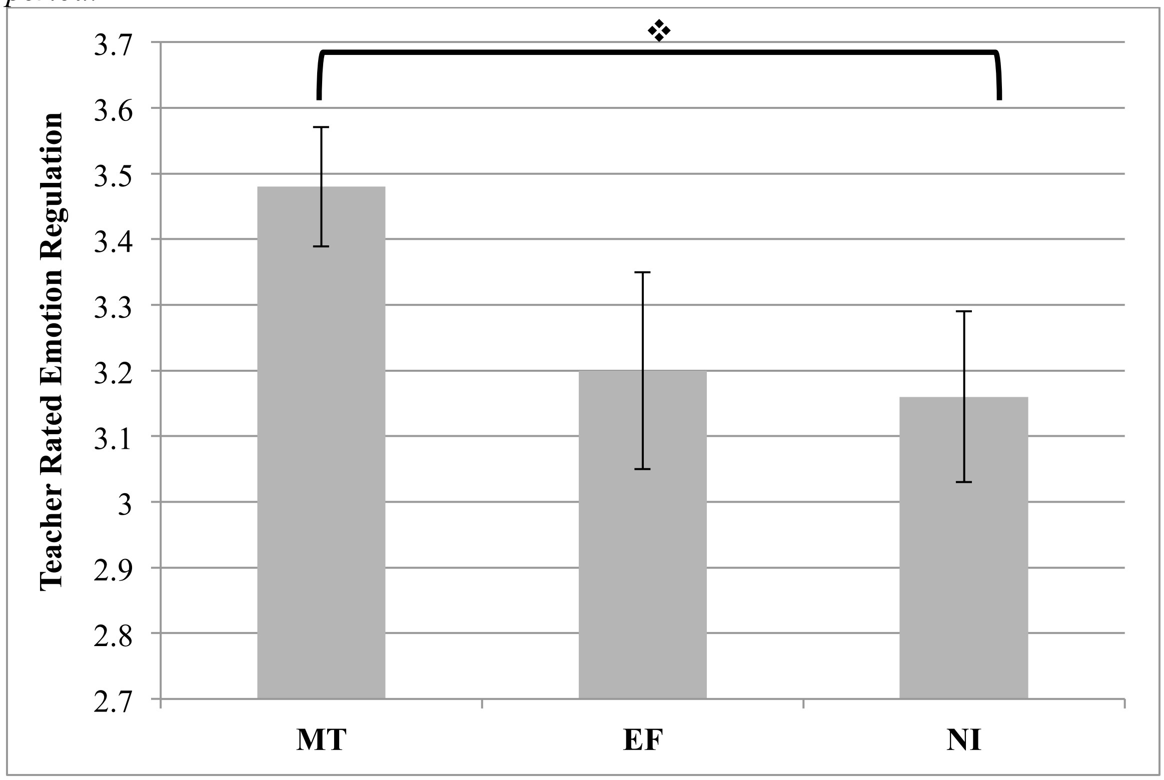
Mean change in parent-rated anxiety symptoms (reversed).



Note: MT=mindfulness training, EF=executive function training, NI=no intervention

Figure 5.

Mean teacher ratings of emotion regulation four months after the end of the training period.



Note: MT=mindfulness training, EF=executive function training, NI=no intervention

References

Abundis-Gutiérrez, A., Checa, P., Castellanos, C., & Rueda, M. R. (2014). Electrophysiological correlates of attention networks in childhood and early adulthood. *Neuropsychologica, 57,* 78-92. doi: 10.1016/j.neuropsychologia.2014.02.013

Amir, N., Beard, C., Burns, M., & Bomyea, J. (2009). Attention modification program in individuals with generalized anxiety disorder. *Journal of Abnormal Psychology, 118,* 28-33. doi: 10.1037/a0012589

Audet, K., & LeMare, L. (2011). Mitigating effects of the adoptive caregiving environment on inattention/ overactivity in children adopted from Romanian orphanages. *International Journal of Behavioral Development, 35*, 107–115. doi: 10.1177/0165025410373313

Ayduk, O., Mendoza-Denton, R., Mischel, W., Downey, G., Peake, P. K., & Rodriguez, M. (2000). Regulating the interpersonal self: Stra- tegic self-regulation for coping with rejection sensitivity. *Journal of Personality and Social Psychology, 79*, 776–792.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenberg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin, 133,* 1-24. doi: 10.1037/0033-2909.133.1.1

Bar-Haim, Y., Morag, I., & Glickman, S. (2011). Training anxious children to disengage attention from threat: A randomized controlled trial. *Journal of Child Psychology and Psychiatry, 52,* 861-869. doi: 10.1111/j.1469-7610.2011.02368.x

Baer, R. A. (2003). Mindfulness training as a clinical intervention: A conceptual and empirical review. *Clinical Psychology: Science and Practice*, *10*(2), 125–143. doi:10.1093/clipsy/bpg015

Bauer, P. M., Hanson, J. L., Pierson, R. K., Davidson, R. J., & Pollak, S. D. (2009) Cerebellar Volume and Cognitive Functioning in Children Who Experienced Early Deprivation, *Biological Psychiatry, 66*, 110-106. doi: 10.1016/j.biopsych.2009.06.014

Beard, C., Sawyer, A. T., & Hofmann, S. G., (2012). Efficacy of attention bias modification using threat and appetitive stimuli: A meta-analytic review. *Behavior Therapy, 43,* 724-740. doi: 10.1016/j.beth.2012.01.002

Beckett, C., Maughan, B., Rutter, M., Castle, J., Colvert, E., Groothues, C., … Sonuga-Barke, E. J. S. (2007). Scholastic Attainment Following Severe Early Institutional Deprivation: A Study of Children Adopted from Romania. *Journal of Abnormal Child Psychology, 35,* 1063-1073. doi: 10.1007/s10802-007-9155-y

Behen, M. E., Muzik, O., Saporta, A. S. D., Wilson, B. J., Hua, J., & Chugani, H. T. (2009). Abnormal fronto-striatal connectivity in children with histories of early deprivation: a diffusion tensor imaging study. *Brain Imaging and Behavior, 3,* 292–297. doi: 10. 1007/s11682-009-9071-6

Bellebaum, C. and Daum, I. (2008), Learning-related changes in reward expectancy are reflected in the feedback-related negativity. *European Journal of Neuroscience, 27*, 1823–1835. doi: 10.1111/j.1460-9568.2008.06138.x

Biederman, J., Hirshfeld-Becker, D.R., Rosenbaum, J.F., Herot, C., Friedman, D., Snidman, N., ..., Faraone, S.V. (2001). Further evidence of association between behavioral inhibition and social anxiety in children. *American Journal of Psychiatry, 158,* 1673–1679. doi: 10.1176/appi.ajp.158.10.1673

Birdee, G. S., Yeh, G. Y., Wayne, P. M., Phillips, R. S., Davis, R. B., & Gardiner, P. (2009). Clinical applications of yoga for the pediatric population: A systematic review. *Academic Pediatrics, 9,* 212–220. doi: 10.1016/j.acap.2009.04.002

Black, D. S., Milam, J., & Sussman, S. (2008). Sitting-meditation interventions among youth: A review of treatment efficacy. *Pediatrics, 124,* 532–541. doi: 10.1542/peds.2008-3434

Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. *Annual Reviews of Psychology, 66,* 711-31. doi: 10.1146/annurev-psych-010814-015221

Bos, K. J., Fox, N., Zeanah, C. H., & Nelson, C. A. (2009). Effects of early psychosocial deprivation on the development of memory and executive function. *Front Behav Neurosci, 3*, 16. doi: 10.3389/neuro.08.016.2009

Jennifer N. Bress , Alexandria Meyer & Greg Hajcak (2015) Differentiating anxiety and depression in children and adolescents: Evidence from event-related brain potentials, *Journal of Clinical Child & Adolescent Psychology, 44,* 238-249, doi: 10.1080/15374416.2013.814544

Brydges, C. R., Fox, A. M., Reid, C. L., & Anderson, M. (2014). Predictive validity of the N2 and P3 ERP components to executive functioning in children: a latent-variable analysis. *Frontiers in Human Neuroscience, 8,* 1-10. 10.3389/fnhum.2014.00080

Bunge, S. A., Dudukovic, N. M., Thomason, M. E., Vaidya, C. J., & Gabrielli, J. D. E. (2002). Immature frontal lobe contributions to cognitive control in children: Evidence from fMRI. *Neuron, 33,* 301-311. doi: 10.1016/S0896-6273(01)00583-9

Bunge, S. A., Hazeltine, E., Scanlon, M. D., Rosen, A. C., & Gabrielli, J. D. E. (2002). Dissociable contributions of prefrontal and parietal cortices to response selection. *NeuroImage, 3,* 1562-1571. doi: 10.1006/nimg.2002.1252

Burke, C. A. (2009). Mindfulness-Based Approaches with Children and Adolescents: A Preliminary Review of Current Research in an Emergent Field. *Journal of Child and Family Studies*, *19*(2), 133–144. doi:10.1007/s10826-009-9282-x

Carboni, J. A., Roach, A. T., & Fredrick, L. D. (2013). Impact of mindfulness training on the behavior of elementary school students with attention deficit hyperactive disorder. *Research in Human Development*, *10*(3), 234–251.

Carmody, J. & Baer (2008). Relationships between mindfulness practice and levels of mindfulness, medical and psychological symptoms and well-being in a mindfulness-based stress reduction program. *Journal of Behavioral Medicine, 31,* 23-33. doi: 10.1007/s10865-007-9130-7

Chen, Y., Yang, X., Wang, L., & Zhang, X. (2013). A randomized controlled trial of the effects of brief mindfulness meditation on anxiety symptoms and systolic blood pressure in Chinese nursing students. *Nurse Education Today, 33,* 1166-1172. doi: 10.1016/j.nedt.2012.11.014

Chronis-Tuscano, A., Degnan, K.A., Pine, D.S., Pérez-Edgar, K., Henderson, H., Diaz, Y., ..., Fox, N.A. (2009). Stable early maternal report of behavioral inhibition predicts lifetime social anxiety disorder in adolescence. *Journal of the American Academy of Child and Adolescent Psychiatry, 48,* 928–935. doi: 10.1097/CHI.0b013e3181ae09df

Columbo, J. (2001). The development of visual attention in infancy, *Annual Review of Psychology, 52,* 337-367. doi: 10.1146/annurev.psych.52.1.337

Colvert, E., Rutter, M., Beckett, C., Castle, J., Groothues, C., Hawkins, A., … Sonuga-Barke, E. J. S. (2008). Emotional difficulties in early adolescence following severe early deprivation: Findings from the English and Romanian adoptees study. *Development and Psychopathology, 20,* 547-567. doi: 10.1017/S0954579408000278

Corbetta, M., Kincade, J. M., Ollinger, J. M., McAvoy, M. P., & Shulman, G. L. (2000). Voluntary orienting is dissociated from target detection in human posterior parietal cortex. *Nature Neuroscience, 3,* 292–297. doi: 10.1038/73009

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*, 201–215. doi: 10.1038/nrn755

Cragg, L., Fox, A., Nation, K., Reid, C., and Anderson, M. (2009). Neural correlates of successful and partial inhibitions in children: an ERP study. *Dev. Psychobiol.* 51, 533–543. doi: 10.1002/dev.20391

Creswell, J. D., Way, B. M., Eisenberger, N. I., & Lieberman, M. D. (2007). Neural correlates of dispositional mindfulness during affect labeling. *Psychosomatic Medicine, 69,* 560–565.

Cunningham, W. A., & Zelazo, P. D. (2007). Attitudes and evaluations: A social cognitive neuroscience perspective. *Trends in Cognitive Sciences, 11,* 97-104. doi: 10.1016/j.tics.2006.12.005

Dahlin, E., Neely, A. S., Larsson, A., Bäckman, L., and Nyberg, L. (2008). Transfer of learning after updating training mediated by the striatum. *Science, 320,* 1510–1512. doi: 10.1126/science.1155466

Danielmeier, C., Wessel, J.R., Steinhauser, M., Ullsperger, M., 2009. Modulation of the error-related negativity by response conflict. *Psychophysiology, 46,* 1288–1298. doi: 10.1111/j.1469-8986.2009.00860.x

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologica, 44,* 2037-2078. doi: 10.1016/j.neuropsychologia.2006.02.006

Degnan, K. A., & Fox, N. A. (2007). Behavioral inhibition and anxiety disorders: Multiple levels of a resilience process. *Development and Psychopathology, 19,* 729–746. doi: 10.1017/S0954579407000363

Derryberry, D., & Reed, M. A. (2002). Anxiety-related attentional biases and their regulations by attentional control. Journal of Abnormal Psychology, 111, 225–236. doi: 10.1037/0021-843X.111.2.225

Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool Program Improves Cognitive Control. *Science*, *318*(5855), 1387–1388.

Donkers, F. C. L., & van Boxtel, G. J. M. (2004). The N2 in go/no-go tasks reflects conflict monitoring not response inhibition. *Brain and Cognition, 56,* 165-176. doi:10.1016/j.bandc.2004.04.005

Doom, J. R., Gunnar, M. R., Georgieff, M. K., Kroupina, M. G., Frenn, K., Fuglestad, A. J. and Carlson, S. M. (2014), Beyond Stimulus Deprivation: Iron Deficiency and Cognitive Deficits in Postinstitutionalized Children. Child Development. doi: 10.1111/cdev.12231

Eigsti, I., Zayas, V., Mischel, W., Shoda, Y., Ayduk, O., Dadlani, M. B., … Casey, B. J. (2006). Predicting cognitive control from preschool to late adolescence and young adulthood. *Psychological Science, 17,* 478-484. doi: 10.1111/j.1467-9280.2006.01732.x

Eldar, S., Apter, A., Lotan, D., Perez-Edgar, K., Naim, R., Fox, N. A., … Bar-Haim, Y. (2012). Attention bias modification treatment for pediatric anxiety disorders: A randomized controlled trial. *American Journal of Psychiatry, 169,* 213-220. doi: 10.1176/appi.ajp.2011.11060886

Eldar, S., Ricon, T., & Bar-Haim, Y. (2008). Plasticity in attention: Implications for stress response in children. *Behaviour Research and Therapy, 46,* 450-461. doi: 10.1016/j.brat.2008.01.012

Eluvathingal, T. J., Chugani, H. T., Behen, M. E., Juhász, C., Muzik, O., Maqbool, M., & Makki, M. (2006). Abnormal brain connectivity in children after early severe socioemotional deprivation: a diffusion tensor imaging study. *Pediatrics, 117,* 2093–2100. doi: 10.1542/peds. 2005-1727.

Espinet, S. D., Anderson, J. E., & Zelazo, P. D. (2012). N2 amplitude as a neural marker of executive function in young children: An ERP study of children who switch versus perseverate on the Dimensional Change Card Sort. *Developmental Cognitive Neuroscience, 2S,* S49-S58. doi: 10.1016/j.dcn.2011.12.002

Essex, M. J., Boyce, W. T., Goldstein, L. H., Armstrong, J. M., Kraemer, H. C., & Kupfer, D. J. (2002). The confluence of mental, physical, social, and academic difficulties in middle childhood. II: Developing the MacArthur Health and Behavior Questionnaire. *Journal of the American Academy of Child & Adolescent Psychiatry, 41*, 588-603.

Fan, J., Gu, X., Guise, K. G., Liu, X., Fossella, J., Wang, H., & Posner, M. I. (2009). Testing the behavioral interaction and integration of attentional networks. *Brain and Cognition, 70,* 209-220. doi: 10.1016/j.bandc.2009.02.002

Friedman, N. P., Miyake, A., Robinson, J. L., & Hewitt, J. K. (2011). Developmental trajectories in toddlers' self-restraint predict individual differences in executive functions 14 years later: A behavioral genetic analysis. *Developmental Psychology, 47*, 1410–1430.

Flook, L., Goldberg, S. B., Pinger, L., & Davidson, R. J. (2015). Promoting prosocial behavior and self-regulatory skills in preschool children through a mindfulness-based kindness curriculum. *Developmental Psychology, 51,* 44-51. doi: 10.1037/a0038256

Flook, L., Smalley, S. L., Kitil, M. J., Galla, B. M., Kaiser-Greenland, S., Locke, J., Ishijima, E., et al. (2010). Effects of mindful awareness practices on executive functions in elementary school children. *Journal of Applied School Psychology*, *26*(1), 70–95. doi:10.1080/15377900903379125

Galantino, M. L., Galbavy, R., & Quinn, L. (2008). Therapeutic effects of yoga for children: A systematic review of the literature. *Pediatric Physical Therapy, 20,* 66–80. doi: 10.1097/PEP.0b013e31815f1208

Gard, T., Hölzel, B. K., Sack, A. T., Hempel, H., Lazar, S. W., Vaitl, D., & Ott, U. (2012). Pain attenuation through mindfulness is associated with decreased cognitive control and Increased sensory processing in the brain. *Cerebral Cortex, 22,* 2692-2702. doi: 10.1093/cercor/bhr352

Gerardi-Caulton, G. (2000). Sensitivity to spatial conflict and the development of self-regulation in children 24–36 months of age. Developmental Science, 3/4, 397–404. doi: 10.1111/1467-7687.00134

Gladstone, G.L., Parker, G.B., Mitchell, P.B., Wilhelm, K.A. & Malhi, G.S. (2005). Relationship between self reported childhood behavioral inhibition and lifetime anxiety disorders in a clinical sample. *Depression and Anxiety, 22,* 103–113. doi: 10.1002/da.20082

Goldin, P. R., & Gross, J. J. (2010). Effects of mindfulness-based stress reduction (MBSR) on emotion regulation in social anxiety disorder. *Emotion, 10,* 83–91. doi: 10.1037/a0018441

Goodman R. (1997) "The Strengths and Difficulties Questionnaire: A Research Note." *Journal of Child Psychology and Psychiatry, 38,* 581-586.

Goodman, R. (1999). The extended version of the Strengths and Difficulties Questionnaire as a guide to child psychiatric caseness and consequent burden.*Journal of Child Psychology and Psychiatry, 40*, 791-799.

Govindan, R. M., Behen, M. E., Helder, E., Makki, M. I., & Chugani, H. T. (2010). Altered water diffusivity in cortical association tracts in children with early deprivation identified with tract-based spatial statistics (TBSS). *Cerebral Cortex, 20,* 561–569. doi: 10.1093/cercor/bhp122.

Grammer, J. K., Carrasco, M., Gehring, W. J., & Morrison, F. J. (2014). Age-related changes in error processing in young children: A school-based investigation. *Developmental Cognitive Neuroscience, 9,* 93-105. doi: 10.1016/j.dcn.2014.02.001

Greenberg, M. T., & Harris, A. R. (2011). Nurturing Mindfulness in Children and Youth: Current State of Research. *Child Development Perspectives*, *0*(0), 1–6. doi:10.1111/j.1750-8606.2011.00215.x

Grossman, P., Niemann, L., Schmidt, S., & Walach, H. (2004). Mindfulness-based stress reduction and health benefits: A meta-analysis. *Journal of Psychosomatic Research, 57,* 35–43. doi: 10.1016/S0022-3999(03)00573-7

Gunnar, M. R., & Kertes, D. A. (2005) Prenatal and postnatal risks to neurobiological development in internationally adopted children. In D.M. Brodzinsky & J. Palacios (Eds.), *Psychological Issues in Adoption* (pp.47-65). London: Praeger.

Gunnar, M. R., van Dulmen, M. H., & the International Adoption Project Team. (2007). Behavior problems in post-institutionalized internationally-adopted children. *Development & Psychopathology, 19,* 129-148. doi: 10.1017/s0954579407070071

Hanson, J. L., Adluru, N., Chung, M. K., Alexander, A. L., Davidson, R. J., & Pollak, S.D. (2013). Early neglect is associated with alterations in white matter integrity and cognitive functioning. *Child Development, 84,* 1566–1578. doi: 10.1111/cdev.12069.

Hajcak, G. (2012). What we've learned from mistakes. *Current Directions in Psychological Science, 21,* 101–106. doi: 10.1177/ 0963721412436809

Hajcak, G., Franklin, M. E., Foa, E. B., & Simons, R. F. (2008). Increased error-related brain activity in pediatric obsessive-compulsive disorder before and after treatment. *The American Journal of Psychiatry, 165,* 116–123. doi: 10.1176/appi.ajp.2007.07010143

Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J. C., Fox, N. A., Leibenluft, E., … Pine, D. S. (2010). Attention bias modification treatment: A meta-analysis toward the establishment of novel treatment for anxiety. *Biological Psychiatry, 68,* 982-990. doi: 10.1016/j.biopsych.2010.07.021

Harman, C., Rothbart, M. K., & Posner, M. I. (1997). Distress and attention interactions in early infancy. *Motivation and Emotion, 21,* 27-43.

Hauser, T. U., Iannaccone, R., Stämpfli, P., Drechsler, R., Brandeis, D., Walitza, S., & Brem, S. (2014). The feedback-related negativity (FRN) revisited: New insights into the localization, meaning and network organization. *Neuroimage, 84,* 159-168. doi: 10.1016/j.neuroimage.2013.08.028

Heeren, A., Van Broeck, N., & Philippot, P. (2009). The effects of mindfulness on executive processes and autobiographical memory specificity. *Behaviour research and therapy*, *47*(5), 403-409. doi: 10.1016/j.brat.2009.01.017

Hodel, A. S., Hunt, R. H., Cowell, R. A., van den Heuvel, S. E., Gunnar, M. R., & Thomas, K. M. (2015). Duration of early adversity and structural brain development in post-institutionalized adolescents. *Neuroimage, 105,* 112-119. doi: 10.1016/j.neuroimage.2014.10.020.

Holzel, B. K., Lazar, S. W., Gard, T., Schuman-Olivier, Z., Vago, D. R., & Ott, U. (2011). How does mindfulness meditation work? Proposing mechanisms of action from a conceptual and neural perspective. *Perspectives on Psychological Science*, *6*(6), 537-559. doi:10.1177/1745691611419671

Hostinar, C. E., Stellern, S. A., Schaefer, C., Carlson, S. M., & Gunnar, M. R. (2013). Associations between early life adversity and executive function in children adopted internationally from orphanages. *PNAS, S2,* 17208-17212. doi: 10.1073/pnas.1121246109

Hsu, N. S., Novick, J. M., & Jaeggi, S. M. (2014). The development and malleability of executive control abilities. *Frontiers in Behavioral Neuroscience, 8,* 221. doi: 10.3389/fnbeh.2014.00221

Iannaccone, R., Hauser, T. U., Staempfli, P., Walitza, S., Brandeis, D., & Brem, S. (2015). Conflict monitoring and error processing: New insights from simultaneous EEG-fMRI. *Neuroimage, 105,* 395-407. doi: 10.1016/j.neuroimage.2014.10.028

Johnson, A., Forston, J., Gunnar, M.R., & Zelazo, P. D., (2011). A Randomized Controlled Trial of Mindfulness Meditation Training in Preschool Children.

Poster presented to the Biennial Meeting of the Society for Research in Child Development.

Jonkman, L. M. (2006). The development of preparation, conflict monitoring and inhibition from early childhood to young adulthood; a Go/Nogo ERP study. *Brain Res., 1097*, 181–193. doi: 10.1016/j.brainres.2006.04.064

Jonkman, L. M., Sniedt, F. L., & Kemner, C. (2007). Source localization of the nogo-N2: A developmental study. *Clinical Neurophysiology, 118,* 1069-1077. doi: 10.1016/j.clinph.2007.01.017

Juffer, F., & van IJzendoorn, M. H. (2005). Behavior problems and mental health referrals of international adoptees: A Meta-analysis. *Journal of the American Medical Association, 293,* 2501-2515. doi: 10.1001/jama.293.20.2501

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context : Past, present, and future. *Clinical Psychology: Science and Practice*, *10*(2), 144-156. doi:10.1093/clipsy/bpg016

Kerns, J. G., Cohen, J. D., MacDonald, A. W., Cho, R. Y., Stenger, V. A., & Carter, C. S. (2004). Anterior cingulate conflict monitoring and adjustments in control. *Science, 303,* 1023-1026. doi: 10.1126/science.1089910Konrad, K., Neufang, S., Thiel, C. M., Specht, K., Hanisch, C., Fan, J. … Fink, G. R. (2005). Development of attentional networks: An fMRI study with children and adults. *NeuroImage, 28,* 429-439. doi: 10.1016/j.neuroimage.2005.06.065

Khoury, B., Lecomte, T., Fortin, G., Masse, M., Therien, P., Bouchard, V., & Hofmann, S. G. (2013). Mindfulness-based therapy: a comprehensive meta-analysis. *Clinical Psychology Review, 33,* 763–771. doi:10.1016/j.cpr.2013.05.005.

Kreppner, J. M., O'Connor, T. G., Rutter, M., & English Romanian Adoptees Study, T. (2001). Can inattention/overactivity be an institutional deprivation syndrome? *Journal of Abnormal Child Psychology, 29*(6), 513-528. doi: 10.1023/a:1012229209190

Ladouceur, C. D., Dahl, R. E., Birmaher, B., Axelson, D. A., & Ryan, N. D. (2006). Increased error-related negativity (ERN) in childhood anxiety disorders: ERP and source localization. *Journal of Child Psychology and Psychiatry, 47,* 1073–1082. doi: 10.1111/j.1469-7610.2006.01654.x

Lahat, A., Lamm, C., Chronis-Tuscano, A., Pine, D. S., Henderson, H. A., & Fox, N. A. (2014). Early behavioral inhibition and increased error monitoring predict later social phobia symptoms in childhood. *Journal of the American Academy of Child & Adolescent Psychiatry, 53,* 447– 455. doi: 10.1016/j.jaac.2013.12.019

Lamm, C., Zelazo, P. D., & Lewis, M. D. (2006). Neural correlates of cognitive control in childhood and adolescence: Disentangling the contributions of age and executive function. *Neuropsychologica, 44,* 2139-2148. doi: 10.1016/j.neuropsychologia.2005.10.013

Larson, M.J., Clayson, P.E., 2011. The relationship between cognitive performance and electrophysiological indices of performance monitoring. *Cognitive, Affective, & Behavioral Neuroscience, 11,* 159–171. doi: 10.3758/s13415-010-0018-6

Larson, M. J., Clayson, P. E., & Clawson, A. (2014). Making sense of all the conflict: A theoretical review and critique of conflict-related ERPs. *International Journal of Psychophysiology, 93,* 283-297. doi: 10.1016/j.ijpsycho.2014.06.007

Larson, M. J., Steffen, P. R., & Primosch, M. (2013). The impact of a brief mindfulness meditation intervention on cognitive control and error-related performance monitoring. *Frontiers in Human Neuroscience, 7,* 308. doi: 10.3389/fnhum.2013.00308

Lewis, M. D., Lamm, C., Segalowitz, S. J., Stieben, J., & Zelazo, P. D. (2006). Neurophysiological correlates of emotion regulation in children and adolescents. Journal of cognitive neuroscience, 18(3), 430–43. doi:10.1162/089892906775990633

Lewis, M. D., & Stieben, J. (2004). Emotion Regulation in the Brain: Conceptual Issues and Directions for Developmental Research. *Child Development, 75,* 371-376.

Lillard, A., & Else-quest, N. (2006). The Early Years: Evaluating Montessori Education. *Science*, *313*(5795), 1893–1894.

Loman, M. M., Johnson, A. E., Westerlund, A., Pollak, S. D., Nelson, C. A., & Gunnar, M. R. (2013). The effect of early deprivation on executive attention in middle childhood. *Journal of Child Psychology and Psychiatry, 54,* 37-45.

Lonigan, C. J., Vasey, M. W., Phillips, B. M., & Hazen, R. A. (2004). Temperament, anxiety, and the processing of threat-relevant stimuli. *Journal of Clinical Child & Adolescent Psychology, 33,* 8-20. doi: 10.1207/S15374424JCCP3301_2

Maier, M. E., di Pellegrino, G. and Steinhauser, M. (2012), Enhanced error-related negativity on flanker errors: Error expectancy or error significance?. *Psychophysiology, 49*, 899–908. doi: 10.1111/j.1469-8986.2012.01373.x

MacLean, K. (2003). The impact of institutionalization on child development. *Development and Psychopathology,* 15, 853–884. doi: 10.1017.S0954579403000415

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., & Holker, L. (2002). Selective attention and emotional vulnerability: Assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology, 111,* 107–123. doi: 10.1037/0021-843X.111.1.107

Maheu, F. S., Dozier, M., Guyer, A. E., Mandell, D., Peloso, E., Poeth, K., … Ernst, M. (2010). A preliminary study of medial temporal lobe function in youths with a history of caregiver deprivation and emotional neglect. *Cognition, Affect, and Behavioral Neuroscience, 19,* 34-49. doi: 10.3758/CABN.10.1.34

Mathews, A., & MacLeod, C. (2002). Induced processing biases have causal effects on anxiety. *Cognition & Emotion, 16,* 331–354. doi: 10.1080/02699930143000518

Matsumoto, K., & Tanaka, K. (2004). Conflict and cognitive control. *Science, 303,* 969-970. doi: 10.1126/science.1094733

Maoz, K., Abend, R., Fox, N. A., Pine, D. S., & Bar-Haim, Y. (2013). Subliminal attention bias modification training in socially anxious individuals. *Frontiers in Human Neuroscience, 7,* 1-12. doi: 10.3389/fnhum.2013.00389

McDermott, J. M., Perez-Edgar, K., & Fox, N. A. (2007). Variations of the flanker paradigm: Assessing selective attention in young children. *Behavior Research Methods, 39*, 62-70.

McDermott, J. M., Troller-Renfree, S., Vanderwert, R., Nelson, C. A., Zeanah, C. H., & Fox, N. A. (2013). Psychosocial deprivation, executive functions, and the emergence of socio-emotional behavior problems. *Frontiers in Human Neuroscience.* doi:10.3389/fnhum.2013.00167

McDermott, J. M., Westerlund, A., Zeanah, C. H., Nelson, C., A., & Fox, N. A. (2012). Early adversity and neural correlates of executive function: Implications for academic adjustment. *Developmental Cognitive Neuroscience, 2S,* S59-S66. doi: 10.1016/j.dcn.2011.09.008

McLaughlin, K. A., Fox, N. A., Zeanah, C. H., Sheridan, M. A., Marshall, P., & Nelson, C. a. (2010). Delayed maturation in brain electrical activity partially explains the association between early environmental deprivation and symptoms of attention-deficit/hyperactivity disorder. *Biological Psychiatry, 68*(4), 329–36. doi:10.1016/j.biopsych.2010.04.005

McLaughlin, K. A., Sheridan, M. A., Winter, W., Fox, N. A., Zeanah, C. H., Nelson, C. A., (2014). Widespread reductions in cortical thickness following severe early-life deprivation: a neurodevelopmental pathway to attention-deficit/hyperactivity disorder. Biological Psychiatry, 76, 629-38. doi: 10.1016/j.biopsych.2013.08.016.

Mehta, M. A., Golembo, N. I., Nosarti, C., Colvert, E., Mota, A., Williams, S. C. R., & Sonuga-Barke, E. J. S. (2009). Amygdala, hippocampal and corpus callosum size following severe early institutional deprivation: the English and Romanian Adoptees study pilot. *Journal of Child Psychology and Psychiatry, 50,* 943–951. doi: 10.1111/j.1469-7610.2009. 02084.x.

Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology, 29,* 270–291. doi: 10.1037/a0028228

Merz, E. C. and McCall, R. B. (2011), Parent ratings of executive functioning in children adopted from psychosocially depriving institutions. *Journal of Child Psychology and Psychiatry, 52,* 537–546. doi: 10.1111/j.1469-7610.2010.02335.x

Meyer, A., Hajcak, G., Torpey-Newman, D. C., Kujawa, A., & Klein, D. N. (2015). Enhanced Error-Related Brain Activity in Children Predicts the Onset of Anxiety

Disorders Between the Ages of 6 and 9. *Journal of Abnormal Psychology*. Advance online publication. doi: 10.1037/abn0000044

Meyer, A., Weinberg, A., Klein, D. N., & Hajcak, G. (2012). The devel- opment of the error-related negativity (ERN) and its relationship with anxiety: Evidence from 8 to 13-year-olds. *Developmental Cognitive Neuroscience, 2,* 152–161. doi: 10.1016/j.dcn.2011.09.005

Mezzacappa, E. (2004), Alerting, Orienting, and Executive Attention: Developmental Properties and Sociodemographic Correlates in an Epidemiological Sample of Young, Urban Children. *Child Development, 75,* 1373–1386. doi: 10.1111/j.1467-8624.2004.00746.x

Miller, L., Chan, W., Tirella, L., & Perrin, E. (2009). Outcomes of children adopted from Eastern Europe. *International Journal of Behavioral Development, 33,* 289-298. Doi: 10.1177/0165025408098026

Millner, A. J., Jaroszewski, A. C., Chamarthi, H., & Pizzagalli, D. A. (2012). Behavioral and electrophysiological correlates of training-induced cognitive control improvements. *Neuroimage, 63,* 742-753. doi:10.1016/j.neuroimage.2012.07.032

Mischel, W., Shoda, Y., & Rodriguez, M. L. (1989). Delay of gratifica- tion in children. *Science, 244,* 933–938.

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21,* 8-14. doi: 10.1177/0963721411429458

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49–100.

Moriya, J., & Tanno, Y. (2009). Competition between endogenous and exogenous attention to nonemotional stimuli in social anxiety. *Emotion, 9,* 739-743. doi: 10.1037/a0016817

Nelson, C. A., Zeanah, C. H., Fox, N. A., Marshall, P. J., Smyke, A. T., & Guthrie, D. (2007). Cognitive recovery in socially deprived young children: the Bucharest

Early Intervention Project. *Science, 318*(5858), 1937-1940. doi: 10.1126/science.1143921

Otero, T. M., Barker, L. A., & Naglieri, J. A. (2014). Executive function treatment and intervention in schools. *Applied Neuropsychology: Child, 3,* 205-214. doi: 10.1080/21622965.2014.897903

Pacheco-Unguetti, A. P., Acosta, A., Marques, E., & Lupianez, L. (2011). Alterations of the attentional networks in patients with anxiety disorders. *Journal of Anxiety Disorders, 25,* 888-895. doi: 10.1016/j.janxdis.2011.04.010

Pacheco-Unguetti, A. P., Acosta, A., Callejas, A., & Lupianez, J. (2010). Attention and anxiety: Different attentional functioning under state and trait anxiety. *Psychological Science, 21,* 298-304. doi: 10.1177/0956797609359624

Pollak, S. D., Nelson, C. A., Schlaak, M. F., Roeber, B. J., Wewerka, S. S., Wiik, K. L., et al. (2010). Neurodevelopmental Effects of Early Deprivation in Postinstitutionalized Children. *Child Development, 81*(1), 224-236. doi: 10.1111/j.1467-8624.2009.01391.x

Posner, M. I. (2008). Measuring alertness. *Annals of the New York Academy of Sciences, 1129,* 193-199. doi: 10.1196/annals.1417.011

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. Annual Review of Neuroscience, 13, 25–42. doi: 10.1146/annurev.neuro.13.1.25

Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as models for the integration of psychological science. *Annual Review of Psychology, 58,* 1-23. doi: 10.1146/annurev.psych.58.110405.085516

Posner, M. I., & Rothbart, M. K. (1998). Attention, self-regulation, and consciousness. *Philosophical Transactions of the Royal Society of London, B, 353*: 1915-1927.

Posner, M. I., & Rothbart, M. K. (2009). Toward a physical basis of attention and self-regulation. *Phys Life Rev, 6,* 103-120. doi: 10.1016/j.plrev.2009.02.001

Posner, M. I., Walker, J. A., Friedrich, F. J., & Rafal, R. D. (1984). Effects of parietal injury on covert orienting of attention. *Journal of Neuroscience, 4,* 1863-74.

Rapport, M. D., Orban, S. a, Kofler, M. J., & Friedman, L. M. (2013). Do programs designed to train working memory, other executive functions, and attention benefit children with ADHD? A meta-analytic review of cognitive, academic, and behavioral outcomes. *Clinical psychology review*, *33*(8), 1237–52. doi:10.1016/j.cpr.2013.08.005

Reynolds, A. J., Temple, J. A., White, B. A. B., Ou, S.-R. &
Robertson, D. L. (2011). Age 26 Cost–Benefit Analysis of the Child-Parent Center Early Education Program. *Child Development, 82,* 379–404. doi: 10.1111/j.1467-8624.2010.01563.x

Ridderinkhof, K. R., & van der Stelt, O. (2000). Attention and selection in the growing child: Views derived from developmental psychophysiology. *Biological Psychology, 54,* 55-106. doi: 10.1016/S0301-0511(00)00053-3

Riggs, N. R., Greenberg, M. T., Kusché, C. A., & Pentz, M. A. (2006). The mediational role of neurocognition in the behavioral outcomes of a social-emotional prevention program in elementary school students: effects of the PATHS Curriculum. *Prevention Science*, *7*(1), 91–102. doi:10.1007/s11121-005-0022-1

Rothbart, M. K., Ellis, L. K., Rueda, M. R., & Posner, M. I. (2003). Developing mechanisms of temperamental effortful control. *Journal of Personality*, *71*, 1113–1144. doi: 10.1111/1467-6494.7106009

Rothbart, M. K., Sheese, B. E., Rueda, M. R., & Posner, M. I. (2011). Developing mechanisms of self-regulation in early life. *Emotion Review, 3,* 207-213. doi: 10.1177/1754073910387943

Roos, L. E., Pears, K., Bruce, J., Kim, H. K., & Fisher, P. A. (2015). Impulsivity and the association between the feedback-related negativity and performance on an inhibitory control task in young at-risk children. *Psychophysiology, 52,* 704-713. doi: 10.1111/psyp.12389

Roy, P., Rutter, M., & Pickles, A. (2004). Institutional care: associations between overactivity and lack of selectivity in social relationships. *Journal of child psychology and psychiatry, and allied disciplines*, *45*(4), 866–73. doi:10.1111/j.1469-7610.2004.00278.x

Rueda, M. R., Checa, P., & Cómbita, L. M. (2012). Enhanced efficiency of the executive attention network after training in preschool children: Immediate changes and effects after two months. *Developmental Cognitive Neuroscience, 2S,* S192-S204. doi: 10.1016/j.dcn.2011.09.004

Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Lercari, L. P., & Posner, M. I. (2004). Development of attentional networks in childhood. *Neuropsychologia, 42,* 1029-1040. doi: 10.1016/j.neuropsychologia.2003.12.012

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2005). The development of executive attention: Contributions to the emergence of self-regulation. *Developmental Neuropsychology, 28,* 573-594. doi: 10.1207/s15326942dn2802_2

Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L., & Posner, M. I. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(41), 14931–6. doi:10.1073/pnas.0506897102

Rutter, M. L., Kreppner, J. M., O'Conner, T. G., & the English and Romanian Adoptees (ERA) Study Team. (2001). Specificity and heterogeneity in children's responses to profound institutional privation. *British Journal of Psychiatry, 179,* 97-103. doi: 10.1192/bjp.179.2.97

Schmidt, N. B., Richey, A., Buckner, J. D., & Timpano, K. r. (2009). Attention training for generalized social anxiety disorder. *Journal of Abnormal Psychology, 118,* 5-14. doi: 10.1037/a0013643

Schonert-Reichl, K. A., Oberle, E., Lawlor, M. S., Abbott, D., Thomson, K., Oberlander, T. F., & Diamond, A. (2015). Enhancing cognitive and social–emotional development through a simple-to-administer mindfulness-based school program for elementary school children: A randomized controlled trial. *Developmental Psychology, 51,* 52-66. doi: 10.1037/a0038454

Schreiner, I. & Malcom, J. P. (2008). The benefits of mindfulness meditation: Changes in emotional states of depression, anxiety, and stress. *Behaviour Change, 3,* 156-168. doi: 10.1375/bech.25.3.156

Semple, R. J., Lee, J., Rosa, D., & Miller, L. F. (2010). A randomized trial of mindfulness-based cognitive therapy for children: Promoting mindful attention to enhance social-emotional resiliency in children. *Journal of Child and Family Studies*, *19*, 218–229. doi:10.1007/s10826-009-9301-y

Shapiro, S. L., Lyons, K. E., Miller, R. C., Butler, B., Vieten, C., & Zelazo, P. D. (2015). Contemplation in the classroom: A new direction for improving childhood education. *Educational Psychology Review, 27,* 1-30. doi: 10.1007/s10648-014-9265-3

Sheridan, M. A., Fox, N. A., Zeanah, C. H., McLaughlin, K. A., & Nelson, C. A. (2012). Variation in neural development as a result of exposure to institutionalization early in childhood. *Proceedings of the National Academy of Sciences of the United States of America, 109,* 12927–12932. doi: 10.1073/pnas.1200041109.

Shields, A., & Cicchetti, D. (1997). Emotion regulation among school-age children: The development and validation of a new criterion Q-sort scale. Developmental Psychology, 33, 906–917.

Smith-Donald, R., Raver, C. C., Hayes, T., & Richardson, B. (2007). Preliminary construct and concurrent validity of the Preschool Self-Regulation Assessment (PSRA) for field-based research. *Early Childhood Research Quarterly, 22,* 173-187.

Sonuga-Barke, E. J. S., & Rubia, K. (2008). Inattentive/overactive children with histories of profound institutional deprivation compared with standard ADHD cases: a brief report. *Child Care Health and Development, 34*(5), 596-602. doi: 10.1111/j.1365-2214.2008.00863.x

Sonuga-Barke, E. J., Schlotz, W., & Kreppner, J. (2010). V. Differentiating developmental trajectories for conduct, emotion, and peer problems following early deprivation. *Monographs of the Society for Research in Child Development, 75,* 102-124. doi: 10.1111/j.1540-5834.2010.00552.x

Stevens, S. E., Sonuga-Barke, E. J. S., Kreppner, J. M., Beckett, C., Castle, J., Colvert, E., Groothues, C., et al. (2008). Inattention/overactivity following early severe institutional deprivation: presentation and associations in early adolescence.

Journal of abnormal child psychology, *36*(3), 385–98. doi:10.1007/s10802-007-9185-5

Suway, J. G., White, L. K., Vanderwert, R. E., Bar-Haim, Y., Pine, D. S., & Fox, N. A. (2013). Modification of threat-processing in non-anxious individuals: A preliminary behavioral and ERP study. *Journal of Behavior Therapy and Experimental Psychiatry, 44,* 285-292. doi: 10.1016/j.jbtep.2012.11.006

Sylvester, C. M., Corbetta, M., Raichle, M. E., Rodebaugh, T. L., Schlaggar, B. L., Sheline, Y. I., … Lenze, E. J. (2012). Functional network dysfunction in anxiety and anxiety disorders. *Trends in Neurosciences, 35,* 527-535. doi: 10.1016/j.tins.2012.04.012

Tamm, L., Epstein, J. N., Peugh, J. L., Nakonezny, P. A., & Hughes, C. W. (2013). Preliminary data suggesting the efficacy of attention training for school-aged children with ADHD. *Developmental Cognitive Neuroscience, 4,* 16-28. doi: 10.1016/j.dcn.2012.11.004

Tamnes, C. K., Walhovd, K. B., Torstveit, M., Sells, V. T., & Fjell, A. M. (2013). Performance monitoring in children and adolescents: a review of developmental changes in the error-related negativity and brain maturation. *Developmental Cognitive Neuroscience, 6,* 1-13. doi: 10.1016/j.dcn.2013.05.001.

Tang, Y., Posner, M. I., & Rothbart, M. K. (2014). Meditation improves self-regulation over the life span. *Annals of the New York Academy of Sciences, 1307,* 104-111. doi: 10.1111/nyas.12227

Tarullo, A. R., Garvin, M. C., & Gunnar, M. R. (2011). Atypical EEG power correlates with indiscriminately friendly behavior in internationally adopted children. *Developmental Psychology*, *47*(2), 417–31. doi:10.1037/a0021363

Teper, R., Segal, L. V., & Inzlicht, M. (2013). Inside the mindful mind: How mindfulness enhances emotion regulation through improvements in executive control. *Current Directions in Psychological Science, 22,* 449-454. doi: 10.1177/0963721413495869

Tottenham, N., Hare, T. A., Quinn, B. T., McCarry, T. W., Nurse, M., Gilhooly, T., & Casey, B. J. (2010). Prolonged institutional rearing is associated with atypically large amygdala vol- ume and difficulties in emotion regulation. *Developmental Science, 13,* 46–61. doi: 10.1111/j.1467-7687.2009.00852.x.

Tottenham, N., Hare, T. A., Millner, A., Gilhooly, T., Zevin, J. D., & Casey, B. J. (2011). Elevated amygdala response to faces following early deprivation. *Developmental Science, 14,* 190-204. doi: 10.1111/j.1467-7687.2010.00971.x

Ullsperger, M., Fischer, A. G., Nigbur, R., & Endrass, T. (2014). Neural mechanisms and temporal dynamics of performance monitoring. *Trends in Cognitive Sciences, 18,* 259-267. doi: 0.1016/j.tics.2014.02.009

van der Helden, J., Boksem, M. A., & Blom, J. H. (2010). The importance of failure: Feedback-related negativity predicts motor learning effi- ciency. *Cerebral Cortex*, *20*, 1596–1603. doi: 10.1093/cercor/bhp224

van Veen, V., & Carter, C. S. (2002). The timing of action-monitoring processes in the anterior cingulate cortex. *Journal of Cognitive Neuroscience, 14,* 593–602. doi: 10.1162/08989290260045837

Vygotsky, L. S. (1978) *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Walsh, M.M. and Anderson, J.R. (2012) Learning from experience: event-related potential correlates of reward processing, neural adaptation, and behavioral choice. *Neuroscience and Biobehavioral Reviews, 36,* 1870–1884. doi: 10.1016/j.neubiorev.2012.05.008

Waters, A. M., Pittaway, M., Mogg, K., Bradley, B. P., & Pine, D. S. (2013). Attention training towards positive stimuli in clinically anxious children. *Developmental Cognitive Neuroscience, 4,* 77-84. doi: 10.1016/j.dcn.2012.09.004

Weinberg, A., Riesel, A., & Hajcak, G. (2012). Integrating multiple per- spectives on error-related brain activity: The ERN as a neural indicator of trait defensive reactivity. *Motivation and Emotion, 36,* 84 –100. doi: 10.1007/s11031-011-9269-y

White, L.K., McDermott, J.M., Degnan, K.A., Henderson, H.A. & Fox, N.A. (2011). Behavioral inhibition and anxiety: the moderating roles of inhibitory control and attention shifting. *Journal of Abnormal Child Psychology. 39,* 735–747. doi: 10.1007/s10802-011-9490-x

Wiik, K. L., Loman, M. M., Van Ryzin, M. J., Armstrong, J. M., Essex, M. J., Pollak, S. D., & Gunnar, M. R. (2011). Behavioral and emotional symptoms of post-institutionalized children in middle childhood. *Journal of Child Psychology and Psychiatry, 52,* 56-63. doi: 10.1111/j.1469-7610.2010.02294.x

Wilbarger, J., Gunnar, M., Schneider, M., & Pollak, S. (2010). Sensory processing in internationally adopted, post-institutionalized children. *Journal of Child Psychology and Psychiatry, 51,* 1105-1114. doi:10.1111/j.1469-7610.2010.02255.x

Xiao, Z., Wang, J., Zhang, M., Li, H., Tang, Y., Wang, Y., . . . Fromson, J. A. (2011). Error-related negativity abnormalities in generalized anx- iety disorder and obsessive-compulsive disorder. *Progress in Neuro- Psychopharmacology & Biological Psychiatry, 35,* 265–272. doi: 10.1016/j.pnpbp.2010.11.022

Yeung, N., Botvinick, M. M., Cohen, J. D., 2004. The neural basis of error detection: conflict monitoring and the error-related negativity. *Psychological Review, 111,* 931–959. doi: 10.1037/0033-295X.111.4.931

Zeidan, F., Johnson, S. K., Gordon, N. S., & Goolkasian, P. (2010). Effects of brief and sham mindfulness on mood and cardiovascular variables. *The Journal of Alternative and Complementary Medicine, 16,* 867-873. doi: 10.1089/acm.2009.0321

Zelazo, P. D., & Carlson, S. M. (2012). Hot and cool executive function in childhood and adolescence: Development and Plasticity. *Child Development Perspectives, 6,* 354-360. doi: 10.1111/j.1750-8606.2012.00246.x

Zelazo, P. D., Carlson, S. M., and Kesek, A. (2008). Development of executive function in childhood. In C. A. Nelson, & M. Luciana (Eds.), *Handbook of developmental cognitive neuroscience, 2nd ed*. (pp. 553-574). Cambridge, MA: MIT Press.

Zelazo, P. D., & Lyons, K. E. (2012). The potential benefits of mindfulness training in early childhood: A developmental social cognitive neuroscience perspective. *Child Development Perspectives, 6,* 154-160. doi: 10.1111/j.1750-8606.2012.00241.x

Zelazo, P. D., Müller, U., Frye, D., Marcovitch, S., Argitis, G., Boseovski, J., … Sutherland, A. (2003). The development of executive function in early childhood. *Monographs of the Society for Research in Child Development, 68,* vii-137. doi: 10.1111/j.1540-5834.2003.06803001.x

Zenner, C., Herrnleben-Kurz, S., & Walach, H. (2014). Mindfulness-based interventions in schools—a systematic review and meta-analysis. *Frontiers in Psychology, 5,* 603. doi: doi: 10.3389/fpsyg.2014.00603

Zoogman, S., Goldberg, S. B. Hoyt, W. T., & Miller, L. (2015). Mindfulness interventions with youth: A meta-analysis. *Mindfulness, 6,* 290-302. doi: 10.1007/s12671-013-0260-4

Zylowska, L., Ackerman, D. L., Yang, M. H., Futrell, J. L., Horton, N. L., Hale, T. S., Pataki, C., et al. (2008). Mindfulness meditation training in adults and adolescents with ADHD: a feasibility study. *Journal of Attention Disorders*, *11*(6), 737–46. doi:10.1177/1087054707308502

Appendix A

Outline of Mindfulness Training Curriculum

Week	Topic/ Objective	Example Activities
1	Getting to know our breath	• Lungs/Breath Diagram: Learn about where our breath goes in our bodies • Parachute Breathing: All of the children hold onto a parachute and lift it as they inhale slowly and deeply, then let it fall as they slowly exhale. • Pinwheel Breathing: practice taking short and long breaths, taking note of the calm, relaxed feelings during slow breathing • Rocking the Beanie to Sleep: Practice deep belly breathing with a beanie toy on belly. • Starfish Stretch: Lie down and as you inhale, stretch all limbs out from the center of the body, relax on the exhale.
2	Getting to know our bodies and feelings	• Tic Toc: sit cross-legged and rock side-to-side to a drumbeat, practice listening to the drum and matching its pace • Body Scan: practice being aware of different sensations in each region of the body • Mindfulness Journals: practice being mindful of feelings and emotions, color/decorate a blank outline of a person to describe feelings • Hopping Game: practice mindful breathing and listening for a cue to hop forward at the same time as other students in line • Friendly Wishes: practice mindful breathing while sending positive, friendly wishes to ourselves, friends, family, and the whole world
3	Mindful Seeing and Hearing	• Shape hunt: practice mindfully observing surroundings, find shapes in classroom (e.g., the table is a square) • Sounds right: match plastic easter eggs filled with different object by sound only (e.g., salt, paperclips)
4	Mindful Touch, Smell, and Taste	• Behind My Back: practice identifying familiar objects behind the back, using touch only • Focus on Smell: practice identifying objects in opaque canisters by smell, being mindful of what these smells make us think, remember, and feel • The Mindful Raisin: practice mindfully observing a raisin's appearance and texture and noticing how it feels to eat it
5	Breathing, Listening, Feelings, and Thoughts	• Read "Moody Cow Meditates" • Deep Body Scans with Mindfulness Journaling • Baking Soda in Water: add baking soda to a clear bowl of water and get wiggly and "jazzed up," practice slow mindful breathing as baking soda settles and water becomes clear again
6	Breathing, Listening, Feelings, and Thoughts	• Snow Globe: shake a snow globe and practice mindful breathing and awareness while the snow settles • Make your Own Snow Globe: final activity, parents welcome to join

Appendix B

Outline of Executive Function Training Curriculum

Each class consists of inhibitory control games, selective attention games, and cognitive flexibility/ imagination games.

Inhibitory Control Games

Objective: be able to stop oneself from performing actions that one is not supposed to do, understand that rules can change and be able to change behavior to adhere to new rules.

- Sample Activities
  - Head-Shoulders-Knees-and-Toes (classic children's song): during each verse, the name of a body part is omitted. Children must remember not to say the name of the body part even though they are pointing to it.
  - Red Light, Green Light: game in which children move after they hear "Green light!" and freeze when they hear "Red light!"
  - Simon Says: children perform an action only after the leader precedes the command with "Simon says…"
  - Bear/Dragon: puppet twist on Simon Says. Children perform an action only if the friendly bear tells them to do it. A more complex variation involves switching the rule halfway through so that children only respond to the dragon.
  - Freeze Dance: children dance (matching pace to the music, which shifts from fast to slow) while the music is playing, have to freeze in place when it stops.

Selective Attention Games

Objective: Be able to focus attention on relevant information to achieve specific goals. Be able to keep in mind information in order to achieve a goal.

- Sample Activities
  - Sound Bingo: Each child has a card with 4 animals on it, when they hear an animal sound they place a marker on the matching picture.
  - Blink!: sort cards by a different characteristic (color, shape, or number)
  - Familiar Figures: Children match a card with a picture of an animal on it to one of three photos of animals that look similar to each other.
  - Matching/ Memory Game: Children will be shown 3-6 (depending on the week) picture cards that will then be placed on a board face down. Each child gets a turn selecting a card from a deck, and trying to match it to the card on the board.

- Spot the Difference: Children have to spot all of the subtle differences between two pictures

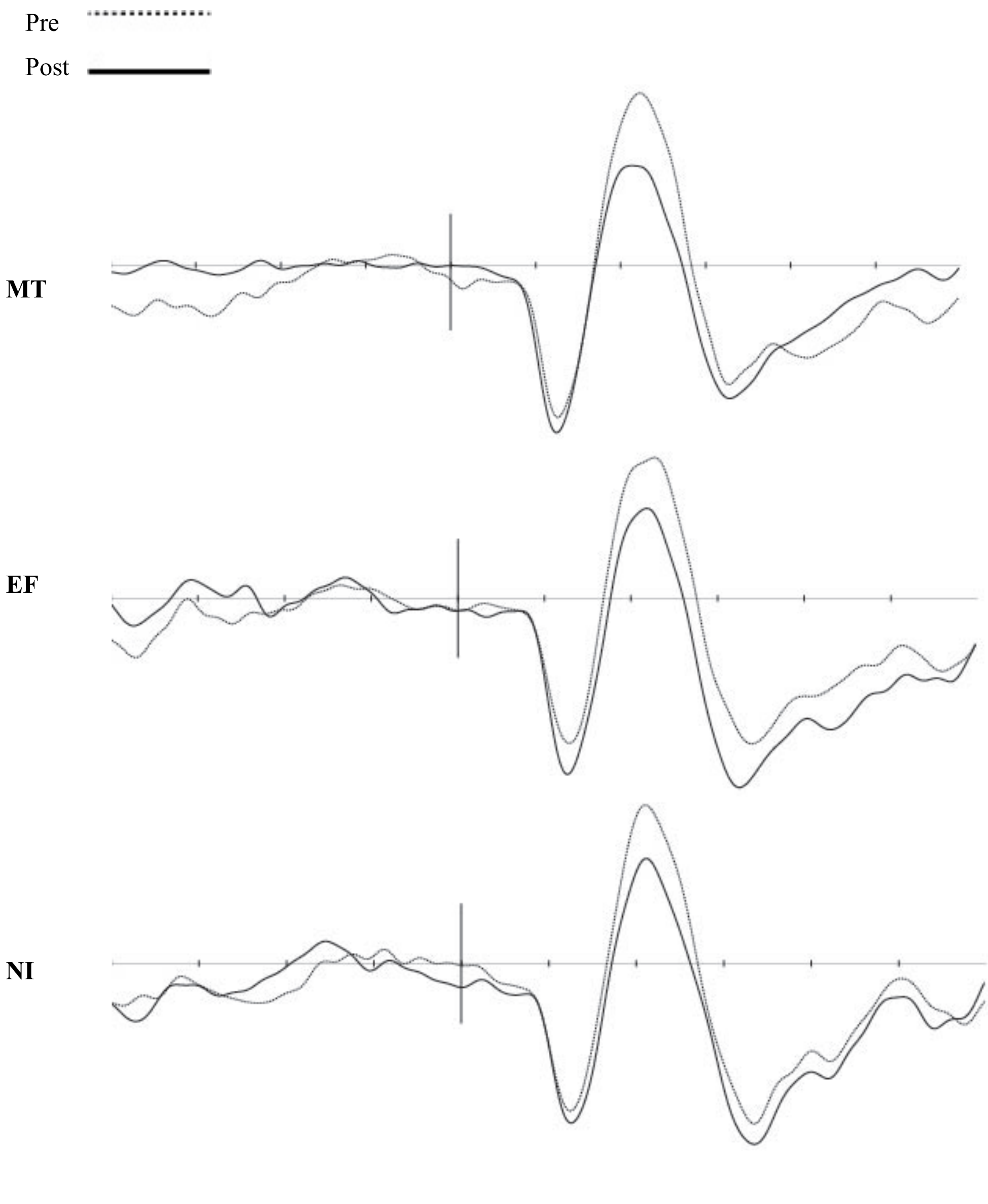
Imagination Games and Stories

Objective: Be able to think flexibly and creatively. Be able to reflect on problems and reason under changing circumstances.

- Sample Activities
  - Cheerios Box: Bring a Cheerios box with a surprising object inside it. Children guess what might be inside besides Cheerios.
  - "Who am I?": show children silhouette image of a person and encourage them to generate the background story as well as stories about mental state
  - *Planet Opposites* story and Drawing Activity: After reading *Planet Opposites*, children draw pictures of things that could be silly or opposite in the classroom
  - Imagine Island: the class brainstorms and then collectively works on a large poster/ picture of "Imagine Island," where everything is silly and opposite.
  - Problem Solving Story Game: provide children with story "seeds" and encourage them to reflect on and solve problems that come up in the story

Appendix C

Grand averaged waveforms of the incongruent N2 for each group at site Fz.



Appendix D

Grand averaged waveforms of the FRN difference wave for each group at site CFz.