Concurrent and Short-term Prospective Relations of Attention and Inhibition to Emotion Regulation and Depressive Symptoms in Children

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Depression is among the most prevalent of all psychiatric disorders, affecting nearly 20 percent of American adults (Kessler et al., 2009) and 14 percent of adolescents (Merikangas et al., 2010). Children and adolescents with depression experience serious academic and social problems, suicidal ideation and behavior (Lagrange et al., 2011; Thapar, Collishaw, Pine, & Thapar, 2012), and recurrent episodes into adulthood (Reinherz, Paradis, Giaconia, Stashwick, & Fitzmaurice, 2003). Identifying risk factors that contribute to the onset, maintenance, and recurrence of depression is crucial for developing early interventions for treating and preventing it (Horowitz & Garber, 2006; Kendall, 2011; Stice, Shaw, Bohon, Marti, & Rohde, 2009; Thapar et al., 2012). Two potentially important risk factors for depression in children and adolescents are difficulties with executive function (EF) and with emotion regulation (ER); these two factors may be related not only to depression, but also to each other.

Limited EF resources likely contribute to difficulties with ER, which in turn, contributes to depression. The aim of the present study was to investigate the relations of two particular EF skills — attention and inhibition — to ER and depressive symptoms in children. This study examined the direct links among EF, ER, and depressive symptoms, as well as whether ER partially mediated the relation between EF and depressive symptoms.

Executive Function (EF) refers to the set of processes that support cognitive and behavioral control in the service of pursuing a particular goal (Denckla, 1996; Welsh, Pennington, & Groisser, 1991). Goal-directed behavior requires maintaining a goal,

directing attention and cognitive resources toward pursuing the goal, sequencing actions to work toward achieving the goal, and inhibiting distractions and inappropriate or irrelevant behaviors along the way. Deficits in these and other EF skills have been related to poor academic performance, poor socio-emotional competence, and various psychiatric disorders including depression, anxiety, and Attention Deficit Hyperactivity Disorder (Blair & Razza, 2007; Pennington & Ozonoff, 1996; Rueda, Checa, & Rothbart, 2010).

Emotion Regulation (ER) consists of strategies for altering the amount, intensity, or duration of emotional experiences (Cole, Martin, & Dennis, 2004; Cole, Michel, & Teti, 1994). Emotions can be up-regulated to feel more or down-regulated to feel less of a given emotion (Gross & Thompson, 2007). Children who have difficulty regulating their emotions tend to be less academically and socially competent, have fewer friends, and are more vulnerable to developing psychopathology (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Denham, McKinley, Couchoud, & Holt, 1990; Eisenberg & Fabes, 1992).

ER skills show a similar developmental trajectory to EF skills both behaviorally and neurologically (Ochsner & Gross, 2005; 2007). Previous research on ER and EF using functional neuroimaging revealed two primary regions of overlap in the prefrontal cortex (PFC) – the ventrolateral PFC and the cingulate cortex (Zelazo & Cunningham, 2007). These findings are consistent with the hypothesized relations between EF and ER, and suggest a potential core neurobiological network underlying these processes.

Executive Function: Attentional Control and Inhibitory Control

Attentional control. Although many EF skills likely contribute to the development and maintenance of depression, two are particularly relevant to difficulties in

implementing ER strategies that could impact depression: attentional control and inhibitory control. Attention is defined as the concentration of the mind on a single object or thought, or the capacity to maintain selective or sustained concentration. Attentional abilities are needed for orienting to emotionally relevant stimuli in the environment. Individuals with depression, however, have been characterized by biased attention to negative stimuli (Hankin, Gibb, Abela, & Flory, 2010; Joormann & Gotlib, 2007; Koster, de Raedt, Goeleven, Franck, & Crombez, 2005). Thus, stronger attentional control abilities may be required to counteract this tendency. Attentional control also may facilitate the disengagement of attention from an emotion-eliciting stimulus in order to focus on enacting strategies that reduce excessively emotional reactions, and thereby may prevent or reduce symptoms of depression.

Evidence of a link between attention and depression has been found in depressed adults (Moriya & Tanno, 2008; Murphy et al., 1999; Paelecke-Habermann, Pohl, & Leplow, 2005; Paradiso, Lamberty, Garvey, & Robinson, 1997; Trichard et al., 1995; Weiland-Fiedler et al., 2004), depressed children (Cataldo, Nobile, Lorusso, Battaglia, & Molteni, 2005; Wilkinson & Goodyer, 2006), adults with remitted depression (Gotlib, Krasnoperova, Yue, & Joormann, 2004; Joormann & Gotlib, 2007; Leyman, de Raedt, Schacht, & Koster, 2007), and children at risk for depression (Joormann, Talbot, & Gotlib, 2007; Pérez-Edgar, Fox, Cohn, & Kovacs, 2006). Overall, the relation between attentional problems and depression tends to be stronger for adults than children. A recent meta-analysis of EF and depression in adults showed a moderately strong relation (d=.47) between attention, particularly attention shifting, and depression (Snyder, 2013).

Difficulty with emotion regulation may partially explain the connection between

attentional problems and depression. One of the first steps in regulating one's emotions is to recognize and orient toward an emotional experience (Lang, Bradley, & Cuthbert, 1990; Wells & Matthews, 1995). Orienting attention to positive feedback from internal or external sources also may reinforce the use of effective ER strategies.

Even more important for successful regulation than these basic orienting and alerting aspects of attention is the ability to selectively attend to relevant stimuli and disengage from or resist attending to irrelevant stimuli (Posner & Rothbart, 2000; 2007; Rueda, Posner, & Rothbart, 2004b). Attentional control, especially attentional shifting, may be needed to disengage attention from emotion-provoking stimuli and shift attention to implementing ER strategies. Individuals who have difficulty controlling their attentional resources likely will be less able to utilize potentially beneficial regulation strategies, such as distraction.

Evidence of a relation between attention and ER has been found in adults and children. For example, adults with a greater ability to shift attention from emotional to neutral stimuli also were better at regulating frustration (Johnson, 2009). In children, studies have shown that orienting can be used to regulate distress in infants as young as 3 months (Harman, Rothbart, & Posner, 1997; Rothbart, Ziaie, & O'Boyle, 1992) and that better attentional control is associated with more effective ER as assessed by both parent-rated and observed ER (Hocking et al., 2011; Simonds, Kieras, Rueda, & Rothbart, 2007; Wilson, Derryberry, & Kroeker, 2007).

One construct that is related to, although distinct from ER is coping. Therefore, we highlight here several studies showing links between attention and coping. *Coping* is defined as "conscious volitional efforts to regulate emotion, cognition, behavior,

physiology, and the environment in response to stressful events or circumstances" (Compas, Connor-Smith, Saltzman, Thomsen, & Wadsworth, 2001). Although the focus of the current study was on ER, we note here a few studies that have demonstrated links between EF and coping. For example, lower attentional control abilities were associated with greater use of maladaptive disengagement coping strategies in young adults (Matthews, Coyle, & Craig, 1990). Similarly, adults with negative attentional biases were more likely to use maladaptive disengagement strategies and less likely to use adaptive primary coping strategies (Luecken, Tartaro, & Appelhans, 2004). A study of children with functional abdominal pain found a significant association between selective attention and coping with a pain-related stressor. Moreover, adaptive coping strategies have been found to mediate the link between selective attention and symptoms of psychopathology (e.g., anxiety) (Hocking et al., 2011). Thus, some evidence exists of a significant relation between executive attention and emotion regulation (and coping) in children.

Inhibitory control. Another EF skill hypothesized to be related to emotion dysregulation and depression is inhibitory control. Inhibition is defined as the suppression or avoidance of a prepotent response in favor of a more context appropriate but less automatic response, which includes the inhibition of a natural or learned tendency (Miyake et al., 2000). The ability to inhibit predicts a number of important outcomes such as higher educational attainment, higher employment status and salary, lower peer rejection, fewer behavior problems, and less psychopathology (Mischel et al., 2011).

Difficulties inhibiting a normative reaction of sadness once a stressor has occurred may lead to more severe and persistent distress that is characteristic of

depression. Additionally, being unable to inhibit the expression of some depressive symptoms (e.g., sadness, irritability, anhedonia) during social interactions may contribute to others becoming frustrated with the depressed person, and thereby lead to isolation and further depression. If depressed individuals can inhibit their sadness, at least temporarily, then they may be able to preserve their relationships and even receive social support. Thus, low inhibitory control can exacerbate depressive symptoms, whereas high inhibitory control can help reduce symptoms.

Inhibitory control deficits have been found in both depressed adults (Gohier et al., 2009; Joormann & Gotlib, 2010; Lau, Christensen, Hawley, Gemar, & Segal, 2007; Moriya & Tanno, 2008; Ruchsow et al., 2008) and depressed children (Cataldo et al., 2005; Kyte, Goodyer, & Sahakian, 2005; Neshat-Doost, Taghavi, Moradi, Yule, & Dalgleish, 1997). A recent meta-analysis of 48 studies examining the relation between inhibition and MDD in adults revealed a moderate effect size ($d = 0.58$; 3) that increased with symptom severity.

The relation between inhibition and depression may be partially a function of problems with emotion regulation. For example, an inability to inhibit internal emotional experiences or external emotional expressions might contribute to interpersonal difficulties that can precipitate depression. Inhibition also is important for preventing the use of maladaptive regulation strategies (e.g., rumination) when experiencing stress (Joormann & Gotlib, 2010). Joormann and Gotlib found that better cognitive inhibition on a negative priming task was related to individual differences in rumination, cognitive reappraisal, and suppression in adults. Better inhibition on a Go-No Go task also has been associated with less rumination in adults; individual differences in rumination have been

linked with greater dorsolateral PFC activity (Vanderhasselt, Kühn, & Raedt, 2011). Thus, there is behavioral evidence of a relation between inhibition and ER and neural evidence of the importance of the lateral prefrontal cortex for both inhibition and ER.

A few studies have examined the relation between inhibition and ER in children. Poor inhibition on the stop signal task has been related to poor ER observed during a competitive game in which children were instructed to hide their feelings (Walcott & Landau, 2004). In children as young as 4 years old, better observed inhibition on various laboratory tasks was related to better observed ER, even after controlling for verbal ability (Carlson & Wang, 2007). Better inhibitory control also was found to be associated with greater use of primary control coping strategies and less use of disengagement coping strategies (Copeland, 2004). Thus, although limited, the literature to-date provides preliminary evidence of a link between EF and ER. In particular, attention and/or inhibition problems appear to be related to ER difficulties.

Limitations of the existing literature provide directions for the current investigation. First, many of the previous studies have used measures of attentional control that involved emotional stimuli. Before investigating the effects of emotional "load," however, an important first step is to examine the relation between more general (and less emotional) measures of attention and ER. Using emotionally neutral EF tasks can help isolate the unique contribution of underlying EF abilities separately from emotions.

Second, some studies used reports of children's ER from parents or teachers. Although young children may lack awareness of their ER strategies, as they mature, they are increasingly able to report about their own ER (Flavell, 2004; Saarni, 1997). Basic

information about the direct links between the executive functions of inhibition or attention and ER in normative samples of children can serve as a comparison to children with depression or other psychopathology.

In summary, although evidence exists of a relation between EF and ER, prior studies have not specifically investigated the associations among EF, ER, and depression in typically developing youth (see Figure 1). Two studies have found significant relations among attentional control, ER or coping, and anxiety (Hocking et al., 2011; Johnson, 2009). Another study showed significant associations among inhibition, coping, and externalizing and internalizing symptoms (Copeland, 2004). Finally, a study of adults found a relation among inhibition, rumination (a form of emotion dysregulation), and depression (Joormann & Gotlib, 2010). The primary aim of the present study was to examine the strength of the relations among two EF components – attention and

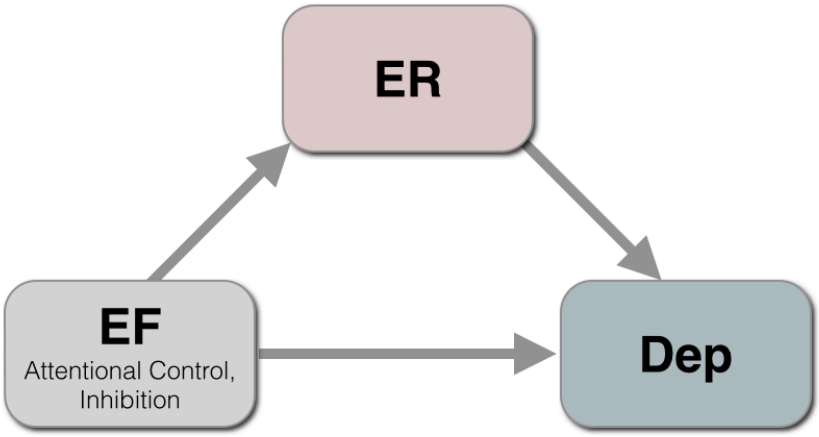

Figure 1. Conceptual model of the relations between EF, ER, and symptoms of depression. We predict that higher executive function (EF) skills will be associated with both emotion regulation (ER) and symptoms of depression (D), that ER will be associated with D controlling for EF, and that the effect of EF on D will be mediated by ER.

inhibition – emotion regulation, and depressive symptoms in a normative sample of children and adolescents.

EF abilities provide a foundation for the effective selection and utilization of appropriate and successful ER, which are associated with better social and academic functioning (Graziano, Reavis, Keane, & Calkins, 2006). Difficulties regulating emotions are associated with various forms of psychopathology (Barlow, 1991; Gross & Muñoz, 1995; Kring & Bachorowski, 1999; Rottenberg, Kasch, Gross, & Gotlib, 2002; Silk, Steinberg, & Morris, 2003). The current study examines in typically developing children and adolescents: (a) the link between specific EF skills (i.e., attentional control and inhibitory control) and strategies used for regulating emotions; (b) the association between these EF skills and depressive symptoms, and (b) whether the relation between EF and depressive symptoms is partially mediated by ER. Acquiring this information in typically developing children will help build a knowledge base for subsequently examining the connections among these variables in youth who have mood disorders and often exhibit poor emotion regulation. These data then can guide the construction of interventions aimed at maximizing cognitive functioning in the service of improving ER and preventing the onset and maintenance of emotional problems in youth.

Aims and Hypotheses

Aim 1: To examine the relation between attentional control and emotion regulation in youth.

Hypothesis 1: Poorer attentional control will be significantly associated with less use of adaptive ER strategies concurrently and prospectively (i.e., at a four-month follow-up).

Aim 2: To examine the relation between inhibitory control and emotion regulation in youth.

Hypothesis 2: Poorer inhibitory control will be significantly associated with less use of adaptive ER strategies concurrently and prospectively (i.e., at a four-month follow-up).

Aim 3: To test the concurrent and prospective relations between EF (i.e., attentional control and inhibitory control) and depressive symptoms.

Hypothesis 3: Poorer attentional and inhibitory control will be significantly associated with higher levels of depressive symptoms both concurrently and at a four-month follow-up, controlling for baseline symptoms.

Aim 4: To test the concurrent and prospective relation between emotion regulation and depressive symptoms.

Hypothesis 4: Less use of adaptive emotion regulation strategies and greater use of maladaptive emotion regulation strategies will be significantly associated with higher levels of depressive symptoms both concurrently and at a four-month follow-up, controlling for baseline symptoms.

Aim 5: To test whether the relation between EF (i.e., attentional control and inhibitory control) and depressive symptoms is partially accounted for by ER.

Hypothesis 5: Emotion regulation strategies will partially mediate the relation between executive functioning and symptoms of depression.

METHOD

Participants

Participants were 195 children and adolescents between the ages of 8 and 17 (*Mean* = 12.31, *SD* = 1.82) recruited from (a) local middle schools via letters and emails explaining the study with consent forms sent to parents of children in grades 5–8, and (b) from a university-based email list through which parents were informed about the study. Interested parents and children were asked to contact the experimenter (SSL) by phone or e-mail to schedule the first (T1) session. Exclusion criteria included parents' report of children's traumatic brain injury, neurological conditions (e.g. seizures, stroke), developmental delay (e.g. autism spectrum disorder), or significant learning or reading problems that could prevent them from understanding and completing the assessment.

Power. The plan to include approximately 200 participants was based on an analysis of power. Primary and secondary hypotheses were tested using partial correlations and linear regressions. In analyses involving EF, IQ was included as a control for global cognitive ability. Using STATA, we tested whether adding additional predictors to our linear multiple regression model would result in a significant increase in the value of R^2 (Cohen, 1988). According to Cohen's criteria, effects sizes $f^2 = 0.02$, $f^2 = 0.15$, and $f^2 = 0.35$ are considered "small," "medium," and "large," respectively. Based on existing research, we estimated the overall R^2 for the full model with four predictors (T1 EF, T1 ER, T1 Depressive Symptoms, IQ) to be between 0.5-0.6, and the increase in R^2 from adding another predictor to be between 0.02-0.03, considered within the "small" range. To have adequate power to detect an increase in R^2 of 0.03, a total sample size of 106–132 is needed, and to detect an increase in R^2 of 0.02 a sample size of 159–198 is

needed. Given the likelihood of about 10% attrition, we attempted to collect data from approximately 200 subjects to be able to assess the smallest effects. Due to exclusions detailed below some analyses were run with different sample sizes. The fewest number of participants used for cross-sectional analyses (Time 1) was 168 and the fewest number of participants used for longitudinal analyses (Time 2) was 148. Post-hoc estimated power for cross-sectional analyses (with at least 168 subjects) was .82 and for longitudinal analyses (with at least 148 subjects) was .77.

Measures

Executive Functioning: Attention. To examine attentional control abilities, all participants completed the Attention Networks Task (ANT), which is a commonly used computerized task that measures various components of attention (Fan & Posner, 2004; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Fan, McCandliss, Sommer, Raz, & Posner, 2002). The three components of attention measured by the ANT are: alerting, orienting, and conflict resolution or executive attention. These three aspects of attention have been shown to be related to different subcortical thalamic (alerting, executive), parietal cortical (orienting), lateral frontal cortical (orienting, executive), and medial frontal cortical (executive) brain systems (Fan et al., 2005; Niogi, Mukherjee, Ghajar, & McCandliss, 2010).

The ANT is an elaboration of an Eriksen flanker task (B. A. Eriksen & Eriksen, 1974). The overall objective on this task is to indicate via button presses the direction of a central arrow on the screen (see Figure 2). *Alerting* is defined as "achieving and maintaining a state of high sensitivity to incoming stimuli" (Posner & Rothbart, 2007),

and is assessed by comparing reaction time on trials in which there is a cue presented prior to the arrow compared to when no cue is presented. *Orienting* is defined as the "selection of information from sensory input" (Posner & Rothbart, 2007), and is assessed by comparing reaction time on trials when a directional cue is presented that indicates the subsequent location of the arrow. *Executive attention* is defined as the "mechanisms for monitoring and resolving conflict among thoughts, feelings, and responses" (Posner & Rothbart, 2007), and is assessed by measuring reaction time on trials where there are flanking arrows, which are incongruent to the central arrow (pointing in the opposite direction), compared to trials where there are flanking arrows that are congruent with the central arrow (pointing in the same direction). An advantage of the ANT is its clear link to the dimensions of attention. The primary focus of interest in the present study was the executive attention score, which reflects children's ability to control their attention and resolve attentional conflicts; in turn, attentional control is hypothesized to be related to more effective emotion regulation.

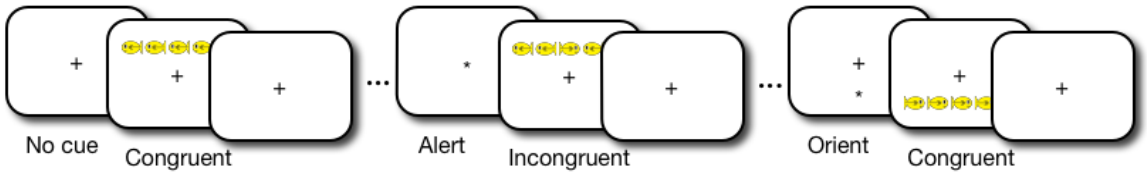

Figure 2. Depiction of sample trials from the Attention Networks Task adapted for children and adolescents. Each trial contains a cue phase (no cue, alerting cue, or spatial orientation cue) and a target phase where participants are required to indicate the direction that the central fish is pointing. On some trials the flanking fish are pointing in the same direction (congruent) and on other trials they are pointed in the opposite direction (incongruent).

We used a version of the ANT that has been modified for children (Rueda et al., 2004a) (see Figure 2). The primary goal of the task is to indicate via a button press in which direction the central fish is pointed to ensure that the fish gets fed. Correct responses result in positive auditory feedback ("Woohoo!") and a visual depiction of the fish eating. Incorrect responses result in negative auditory feedback (a beep) and no change in the visual display. This version of the task frequently has been used with children (Akshoomoff et al., 2014; Posner, Rothbart, Sheese, & Voelker, 2014; Rothbart, Sheese, Rueda, & Posner, 2011) and takes approximately 10 to 15 minutes to complete.

Executive Functioning: Inhibition. Participants completed the Stop Signal Task (SST), which is a commonly used experimental task assessing response inhibition (Logan & Cowan, 1984; Verbruggen & Logan, 2008; Verbruggen, Logan, & Stevens, 2008). In the original version of the SST, there is a "GO" cue such as a star or circle that appears

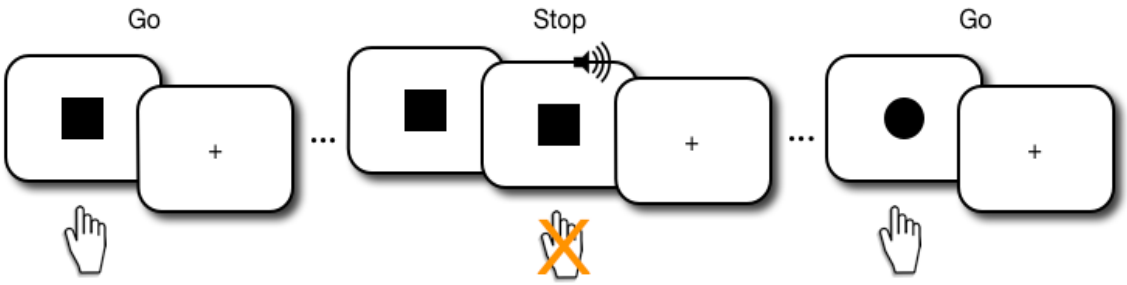

Figure 3. Depiction of sample trials from the Stop Signal Task. Participants are required to press a button as soon as possible after the onset of a "Go" cue (circle or square) in the center of the screen. However, on some trials the "Go" cue is followed very shortly after by a "Stop" auditory tone indicating that the response should be withheld (depicted above as trial 2). The time delay between the onset of the "Go" cue and the onset of the "Stop" tone is referred to as the Stop Signal Delay (SSD). This interval is calibrated throughout the experiment and used to estimate stopping times.

briefly on the screen. The primary goal of the task is to make a specific button press as quickly as possible when the GO cue appears. The majority of trials are GO trials to establish a quick motor action as the prepotent response. On some trials, however, the GO cue is followed by a STOP signal (e.g., an auditory tone; beep) and the individual must inhibit the prepotent response to GO and instead prevent a motor response (see Figure 3).

Cognitive models of the SST suggest that performance depends on two independent systems (Logan & Cowan, 1984; Verbruggen & Logan, 2009). According to the independent race model, there is a GO system and a STOP system that might be partially dissociable. Two distinct performance metrics that assess individual differences in each of these two systems can be obtained from the task. A simple averaging of reaction time on successful GO trials (GoRT) is a measure of the speed of the GO system. The speed of stopping is slightly more difficult to assess because it involves measuring a response that never actually occurs. Task design optimization techniques, however, allow stopping time to be estimated. This is achieved through trial-by-trial adjustments of the delay before stop signal onset (stop-signal delay: SSD) such that individuals successfully inhibit the motor response on 50% of trials. The stop-signal reaction time (SSRT) is calculated by subtracting the average SSD necessary to maintain 50% accuracy from the average GoRT. The independent race model suggests that on every trial, the GO process is initiated by the onset of the cue and takes time to complete before a motor response is made (GoRT). On stop trials, the STOP process is initiated at the onset of the tone. If the STOP process completes before the GO process, then the motor response is withheld. If the GO process finishes before the STOP process, then the

motor response is completed. In the current study, SSRT was the primary index of inhibition (Logan & Cowan, 1984; Verbruggen & Logan, 2008).

The stop signal task is considered to be one of the best laboratory measures of inhibition available (Verbruggen & Logan, 2008). In fact, SST performance shows the highest loading on the inhibition factor in the Miyake diversity model of EF and the highest loading on the common EF factor in the Miyake unity model (Miyake & Friedman, 2012). Thus, this measure is considered to be a core index of EF.

Executive Functioning: Self-Report. Children completed the Behavior Rating Inventory of Executive Function – Child Version (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000), which measures impairment in several domains of executive functioning. Children (5 to 18 years old) rate their own behavior frequency using a three-point Likert scale (0 to 2) on 80 items covering nine non-overlapping clinical scales and three validity scales. The clinical scales comprise two broader indices of Behavioral Regulation (Inhibit, Shift, and Emotional Control) and Metacognition (Initiate, Working Memory, Plan/Organize, Organization of Materials, Self-Monitor, and Task Monitor). The BRIEF has been normed on appropriate census populations in the United States and has satisfactory internal consistency reliability (Roth, Isquith, & Gioia, 2005). We focused here on the Inhibit and Shift scores from the Behavioral Regulation Index. Internal consistency for our sample was good for both Inhibit (α=.84) and Shift (α=.82).

Emotion Regulation. The two measures of children's ER skills were – the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003) and the Children's Emotion Management Scales (CEMS; Zeman, Cassano, Suveg, & Shipman, 2010; Zeman, Shipman, & Penza-Clyve, 2001; Zeman, Shipman, & Suveg, 2002). The ERQ

contains 10-items that assess two specific aspects of ER: Cognitive Reappraisal and Expressive Suppression. Cognitive Reappraisal is the ability to reframe an initial appraisal of an event into a more realistic or positive interpretation and has been shown to be related to better functioning and well-being. The cognitive reappraisal subscale includes items such as "When I want to feel more *positive* emotion (such as joy or amusement), I *change what I'm thinking about*." Expressive Suppression is the inhibition of the facial and behavioral expression of an activated emotion and has been shown to be related to poorer functioning and worse well-being. The Expressive Suppression subscale includes items such as "When I am feeling *positive* emotions, I am careful not to express them" (Gross & John, 2003). The ERQ has good test-retest reliability (α = .69), internal consistency (α = .80 for Reappraisal and α = .73 for Suppression), and convergent and discriminant validity (Gross & John, 2003). Internal consistency in our sample for Reappraisal was α=.79, and for Suppression was α=.56.

The Children's Emotion Management Scales (CEMS; Zeman et al., 2001; 2002; 2010) consist of three separate, but related, scales designed to measure children's regulation of sadness, anger, and worry, respectively. CEMS-sadness contains 12 items that assess how children regulate their sadness; CEMS-anger has 11 items measuring how children regulate their anger; and CEMS-worry has 10 items that assess how children regulate worry.

All three sets of questions on the CEMS consist of three subscales: Emotion Expression Inhibition (EEI), Dysregulated Expression, and Emotion Regulation Coping. The EEI subscale on the CEMS is similar to the Expressive Suppression subscale on the ERQ in that it involves the inhibition of expressions of emotion, and includes items such

as “I get sad inside but don’t show it.” So as to not confuse the use of the terms “inhibition,” we refer here to this scale as Emotion Expression Inhibition (EEI). The Dysregulated Expression subscale includes items such as “I do things like mope around when I am sad” and indicates difficulty constraining or regulating emotions. The Emotion Regulation Coping subscale of the CEMS includes items such as “When I’m sad, I do something totally different until I calm down,” and indicates adaptive strategies used to regulate negative emotions. The CEMS scales have adequate test-retest reliability (α = .61 – .80), internal consistency (α = .62 – .77), and convergent and discriminant validity (Zeman et al., 2001; 2002; 2010).

We created composite scores averaging (after z-scoring) across the three emotions (sad, anger, worry) such that the original nine scores from the CEMS were reduced to three scores: CEMS emotion expression inhibition (referred to here as EEI), CEMS dysregulation, and CEMS emotion regulation coping (which we refer to here as CEMS coping). Internal consistencies for the three individual emotion expression inhibition subscales were:α = .73 – .77; the internal consistency of the composite including all emotion expression inhibition items was α=.82. Internal consistencies for the three individual emotion dysregulation subscales were α = .52 – .65; the internal consistency of the composite including all dysregulation items was α=.72. Internal consistencies for the three individual emotion regulation coping subscales were α = .27 – .64; internal consistency of the composite including all emotion regulation coping items was α=.76.

Symptoms of Psychopathology. The Children's Depression Inventory (CDI; Kovacs, 1992) was used to measure children’s report of their symptoms of depression. Each of the 26 items lists three statements in order of symptom severity (the item

regarding suicidal ideation was removed for this study). Internal consistency, test-retest reliability, and convergent validity have been found to be adequate for the CDI (Kovacs, 1992). Internal consistency for our sample was α=.82.

Intelligence Quotient (IQ). To control for general cognitive ability, we used the Wechsler Abbreviated Scale of Intelligence, Second Edition (WASI-II; Wechsler, 1999), a widely-used, brief individual measure of intelligence for children. A two-subtest short form for the WASI-II, which contains one subtest from the Vocabulary Comprehension Index (i.e., Vocabulary subtest) and one subtest from the Perceptual Reasoning Index (i.e., Matrix Reasoning subtest) has been shown to correlate about .93 with Full Scale IQ (Wechsler, 2003). The Vocabulary subtest measures word knowledge and verbal comprehension. The Matrix Reasoning subtest taps the ability to analyze visually presented information and understand visual-spatial information. These two subtests combine to create an estimated IQ score.

Health Background. A Health Information Form was used to assess demographic and health history information (e.g., major illnesses, diagnoses, treatment history). Questions about amount and quality of sleep, left or right-handedness, special education classes in school, and English language skills also were included because of their potential effect on performance on the tasks and self-report measures.

Table 1. Study Variables of Interest

Variable Name	Variable Description	T1	T2 (4 mo.)
Emotion Regulation	ERQ (Reappraisal, Suppression) CEMS (Inhibition, Dysregulated Emotion Expression, Emotion Regulation Coping)	X	X
Attentional Control	ANT Executive Attention score	X	
Inhibition	Stop Signal Task SSRT score	X	
Self-Reported EFs	BRIEF Index Scores (Shift, Inhibition)	X	
Psychopathology	CDI score	X	X
Estimated IQ	WASI Full Scale IQ score	X	
Age	Child's chronological age	X	X

ERQ = Emotion Regulation Questionnaire; CEMS = Children's Emotion Management Scales; ANT = Attention Networks Task; SSRT = stop-signal reaction time; BRIEF = Behavior Rating Inventory of Executive Function; WASI = Wechsler Abbreviated Scales of Intelligence

Procedure

Participants completed two sessions, one in-person baseline (T1) session lasting about 3 hours, and a brief (~30 minutes) follow-up evaluation 4 months post-baseline (T2) conducted online or by phone. At the baseline session (T1), the CDI, BRIEF, ERQ and CEMS, computerized EF tasks (ANT and SST), and WASI-II were administered in a random order. To limit fatigue, participants were encouraged to take breaks as needed throughout the baseline session. Sessions occurred in small groups of 4 to 5 children, and were conducted at a location convenient for the participant (i.e., at a local school or at Vanderbilt University). All participants were compensated $20 for the first session. Four

months later, children were re-contacted and asked to again complete the CDI, ERQ, and CEMS. Participants were compensated $10 for completion of the follow-up assessment. The purpose of the second evaluation was to examine the extent to which EF and ER skills predicted changes in mood symptoms over time.

Data Analytic Plan

To address the primary aims of the study, we used correlational analyses and regression models. First, we examined the bivariate correlations among all study variables. To assess concurrent relations between EF and ER variables, we conducted cross-sectional analyses of the measures obtained at the baseline session (Time 1). Next, we conducted separate regression analyses with each measure of EF (i.e., attentional control and inhibition) as the independent variable, and measures of ER as the dependent variables, controlling for age, sex, and IQ. We also explored the short-term longitudinal relations between EF at T1 as a predictor of ER at T2, controlling for ER at T1, age, sex, and IQ.

Similarly, we conducted regression analyses with the EF measures as independent variables and depressive symptoms as the dependent variable, controlling for age, sex, and IQ. Concurrent relations between EF variables and depressive symptoms were analyzed using the cross-sectional measures obtained at the first session (T1). We also explored the short-term longitudinal relations between EF at T1 as a predictor of depressive symptoms at T2, controlling for T1 depressive symptoms, age, sex, and IQ. Separate analyses were conducted for each EF variable (i.e., attentional control and inhibition).

To assess concurrent relations between ER variables and depressive symptoms, we conducted analyses of the cross-sectional measures obtained at the T1. We then explored the longitudinal relations between ER at T1 as a predictor of depressive symptoms at T2, controlling for T1 depressive symptoms, age, sex, and IQ.

Mediation. Finally, we explored the extent to which children's ER accounted for the relation between each EF (i.e., attentional control and inhibition) and depressive symptoms. Although meditational models often have been tested using cross-sectional designs based on the methods outlined by (Baron & Kenny, 1986), the assumptions required to demonstrate meditation using purely cross-sectional data are unlikely to be met, thereby producing misleading estimates (Cole & Maxwell, 2003). A true test of mediation requires (a) the passage of time between all variables under consideration and (b) ruling out potential third variables. A longitudinal design satisfies the first requirement and statistical control for prior levels of the dependent variable partially addresses the second. The current study design has both of these features: we had longitudinal data across two time points, and we controlled for prior levels of the dependent variable in addition to other possible third variables.

A subset of the variables (i.e., ER, depressive symptoms) were assessed at the follow-up evaluation four months later. The preferred design for testing mediation would involve collecting all measures at least three times. Nevertheless, the current design had advantages over a purely cross-sectional approach. Cole and Maxwell (2003) outlined strategies that would allow for testing mediation models in a "half-longitudinal" design with only two time points, as in the present study. We followed these design guidelines to examine longitudinal cross-lagged effects. This method includes the assumption of

stationarity; that is, the influence of one variable on change in another is stable over time (Kenny, 1979). For example, the effect of T1 ER on T2 depressive symptoms would be equivalent to the effect of T2 ER on T3 depressive symptoms under the stationarity assumption. For our analyses, we assumed stationary, although at least three times points are required to actually test this assumption.

In studies with two data points, Cole and Maxwell recommended running a pair of longitudinal tests: (1) estimate the effect of T1 EF on T2 ER controlling for T1 ER and (2) estimate the effect of T1 ER on T2 depressive symptoms controlling for T1 depressive symptoms. We used this approach in all mediation analyses in order to "minimize common biases in half-longitudinal designs" (Cole & Maxwell, 2003).

Although this approach is superior to commonly used alternatives, there are still limitations. First, because we have only two time points, we could not directly test the significance of the path from T1 EF to T3 depressive symptoms (the "direct effect") or test whether the assumption of stationarity was violated. Nevertheless, according to Cole and Maxwell (2003) this "half-longitudinal" meditational analysis is still better than a purely cross-sectional meditational analysis because fewer assumptions are required. Furthermore, Cole and Maxwell argued that the failure to control for prior levels of the predictors (e.g., T1 ER) is more problematic than stationarity violations. Thus, the approach used here allowed us to test for partial mediation. Cole and Maxwell (2003) recommended using a product of coefficients to estimate the indirect effect. Therefore, we computed indirect effects by multiplying the path A and B coefficients and used Sobel tests of the significance of the indirect effect. Path A was estimated by regressing emotion regulation at T2 (M) on executive function at T1 (X), controlling for emotion

regulation at T1, depressive symptoms at T1, age, sex, and IQ. Path B was estimated by regressing depressive symptoms at T2 (Y) on emotion regulation at T1 (M), controlling for executive function at T1, depressive symptoms at T1, age, sex, and IQ.

RESULTS

Exclusions and Sample Sizes. A total of 195 participants completed T1; 175 participants completed assessments at T1 and T2. One participant was excluded from some analyses for not completing the CEMS. Thirty-seven participants were excluded from some analyses due to having low performance on one of the two EF tasks using standard exclusion procedures as described in the literature (detailed below). Excluding these individuals was necessary because extreme accuracy levels, defined as performance far below 100% accuracy in the ANT, and stop-signal response rates significantly different than 50% in the SST, would seriously bias the reaction-time-based performance measures of interest in both tasks. In the case of the SST, the SSRT values are not interpretable when the stop-signal response rate is significantly different from 50%. Ten participants were excluded from ANT-related analyses due to task performance levels lower than three standard deviations below the sample mean (accuracy < 77%). These 10 participants excluded from ANT-related analyses did not differ from non-excluded children on the CDI, $t_{193} = -1.52$, $p = .13$, but were significantly younger, $t_{193} = 3.00$, $p < .01$, tended toward having lower IQ scores, $t_{193} = 1.69$, $p = .09$, had significantly lower ERQ cognitive reappraisal scores, $t_{193} = 2.90$, $p < .01$, but did not differ in the other ER-related variables (from the CEMS or ERQ), all $p > .35$.

Twenty-six participants were excluded from SST-related analyses due to having response inhibition rates significantly different from 0.5 (determined with a binomial test); one additional child was excluded from SST-related analyses for having a negative SSRT (i.e., their performance did not meet the assumptions of the race model used to estimate SSRT). These 27 children excluded from SST-related analyses did not differ from non-excluded participants on the CDI, $t_{193} = 0.03$, $p = .98$, age, $t_{193} = 0.43$, $p = .67$, IQ, $t_{193} = 0.07$, $p = .94$, or any of the ER-related variables (from the CEMS or ERQ), all p's $> .06$.

Descriptive statistics for all study variables of interest are presented in Table 2.

Relation between Measures of Attention and Inhibition. The executive attention score on the ANT was not significantly correlated with response inhibition (SSRT) on the SST (Table 3) $\beta = -.16$, $t_{156} = -1.74$, $p = .09$, after controlling for age, sex, and IQ. Therefore, all analyses examined the effects of executive attention (i.e., from the ANT) on ER-related variables and depressive symptoms, separately from the effects of response inhibition (i.e., from the SST) on ER-related variables and depressive symptoms. Only participants that were excluded for task performance within a particular task were removed from the analyses, rather than excluding all 37 children who had poor performance on either of the two tasks. In each section below, we first report the simple bivariate correlations (see Table 3) and then report regression analyses controlling for key covariates.

Relation of Behavioral and Self-report Measures of EF. We had planned to create separate composite indices for attention and inhibition (combining behavior and self-

reports) if the behavioral and self-report indices of EF were moderately correlated (e.g., ≥ .30), but because these measures were not correlated, we examined them separately.

Table 2. Descriptives for Study Variables

Variable Name	Mean (SD)	Observed
Children's Depression Inventory (CDI) at T1	6.07 (5.24)	195
Children's Depression Inventory (CDI) at T2	6.09 (6.09)	175
ANT Executive Attention score at T1	60.43 (49.49)	185
Stop Signal Task SSRT score at T1	288.66 (79.64)	168
BRIEF Shift at T1	1.54 (0.38)	195
BRIEF Inhibit at T1	1.49 (0.36)	195
ERQ Reappraisal at T1	28.50 (7.46)	195
ERQ Reappraisal at T2	30.01 (7.60)	153
ERQ Suppression at T1	15.20 (4.88)	195
ERQ Suppression at T1	15.28 (5.11)	153
CEMS Emotion Expression Inhibition at T1	1.98 (0.31)	194
CEMS Emotion Expression Inhibition at T2	1.97 (0.32)	158
CEMS Dysregulated Emotion Expression at T1	1.59 (0.38)	194
CEMS Dysregulated Emotion Expression at T2	1.53 (0.38)	158
CEMS Emotion Regulation Coping at T1	2.25 (0.38)	194
CEMS Emotion Regulation Coping at T2	2.21 (0.35)	158
Age	12.31 (1.82)	195
Estimated IQ (WASI)	111.61 (13.33)	195
Sex	103 F, 92 M	195

ERQ = Emotion Regulation Questionnaire; CEMS = Children's Emotion Management Scales; ANT = Attention Networks Task; SSRT = stop-signal reaction time; BRIEF = Behavior Rating Inventory of Executive Function; WASI = Wechsler Abbreviated Scales of Intelligence; T1 = Time 1; T2 = Time 2

Table 3. Pairwise Relations among Study Variables

	CDI1	CDI2	ANT	SSRT	BRIEFs	BRIEFi	ERQr1	ERQr2	ERQs1	ERQs2	CEMSi1	CEMSi2	CEMSd1	CEMSd2	CEMSc1	CEMSc2	Age
CDI1	--																
CDI2	.63* 175	–															
ANT	–.01 185	–.07 168	–														
SSRT	.10 168	.18* 148	–.09 158	–													
BRIEFs	.46* 195	.34* 175	–.11 185	.02 168	–												
BRIEFi	.31* 195	.26* 175	–.11 185	.09 168	.65* 195	–											
ERQr1	–.29* 195	–.18* 175	.13 185	–.01 168	–.11 195	–.14 195	–										
ERQr2	–.41* 153	–.44* 153	.08 147	–.10 127	–.23* 153	–.19* 153	.51* 153	–									
ERQs1	.16* 195	.13 175	.04 185	.23* 168	.04 195	.04 195	.04 195	–.19* 153	–								
ERQs2	.19* 153	.19* 153	–.04 147	–.01 127	.00 153	.03 153	–.12 153	–.08 153	.40* 153	–							
CEMSi1	-.07 194	.06 175	.09 184	–.03 167	–.06 194	–.06 194	.09 194	.07 153	.38* 194	.36* 153	–						
CEMSi2	.22* 158	.29* 158	–.07 152	–.02 132	.05 158	.08 158	.06 158	.01 153	.28* 158	.51* 153	.46* 158	–					
CEMSd1	.34* 194	.19* 175	–.09 184	.03 167	.36* 194	.29* 194	–.10 194	–.02 153	–.18* 194	–.25* 153	–.31* 194	–.14 158	–				
CEMSd2	.21* 158	.33* 158	–.06 152	.11 132	.40* 158	.32* 158	–.11 158	–.17* 153	–.07 158	–.20* 153	–.18* 158	–.15 158	.54* 158	–			
CEMSc1	-.36* 194	–.21* 175	.15* 184	–.18* 167	–.32* 194	–.34* 194	.30* 194	.34* 153	.05 194	.08 153	.34* 194	.13 158	–.37* 194	–.22* 158	–		
CEMSc2	–.40 158	–.35 158	.06 152	–.22* 132	–.27* 158	–.21* 158	.32* 158	.55* 153	–.10 158	–.01 153	.18* 158	.15 158	–.18* 158	–.28* 158	.50* 158	–	
Age	.18* 195	.11 175	–.10 185	–.43* 168	.06 195	.03 195	–.02 195	–.03 153	–.19* 195	–.22* 153	.00 194	.04 158	.08 194	.09 158	–.05 194	.09 158	–
IQ	–.25* 195	–.17* 175	.06 185	–.11 168	–.08 195	–.07 195	.12 195	.13 153	–.02 195	.09 153	.18* 194	–.05 158	–.05 194	–.14 158	.22* 194	.12 158	–.36* 195
Sex	–0.85 195	–1.21 175	–0.16 185	0.02 168	–1.14 195	0.52 195	0.20 195	0.40 153	1.97* 195	1.50 153	1.80 194	–0.48 158	–1.40 194	–0.79 158	1.31 194	1.13 158	–0.35 195

Correlation coefficients displayed above number of observations in each cell. Bottom row lists t-statistics above observations rather than correlations given the dichotomous variable. * indicates $p < .05$, two-tailed. CDI1 = CDI at time 1; CDI2 = CDI at time 2, ANT = ANT executive attention score at T1; SSRT = SST stop-signal reaction time at T1; BRIEFs = BRIEF shift score at T1; BRIEFi = BRIEF inhibit score at T1; ERQr1 = ERQ cognitive reappraisal score at T1; ERQr2 = ERQ cognitive reappraisal score at T2; ERQs1 = ERQ expressive suppression score at T1; ERQs2 = ERQ expressive suppression score at T2; CEMSi1 = CEMS emotion expression inhibition score at T1; CEMSi2 = CEMS emotion expression inhibition score at T2; CEMSd1 = CEMS dysregulation score at T1; CEMSd2 = CEMS dysregulation score at T2; CEMSc1 = CEMS emotion regulation coping score at T1; CEMSc2 = CEMS emotion regulation coping score at T2; Age = chronological age of participant; IQ = full-scale IQ score

Aim 1: Attentional Control and Emotion Regulation

Aim 1 was to examine the relation between attentional control and emotion regulation concurrently and four months later. Correlations of the executive attention score on the ANT with T1 CEMS coping (ER) and with cognitive reappraisal from the T1 ERQ were not significant (see Table 3). The executive attention score on the ANT was not significantly correlated with T2 CEMS coping, T2 ERQ cognitive reappraisal, or other study variables (T1 or T2 CEMS emotion expression inhibition (EEI), T1 or T2 CEMS dysregulation, T1 or T2 ERQ suppression, age, IQ) (Table 3). In regression analyses, controlling for age, sex, and IQ, ANT executive attention significantly predicted T1 CEMS coping, $\beta = .14$, $t_{179} = 1.98$, $p = .05$, but did not significantly predict T2 CEMS coping, $\beta = .01$, $t_{146} = 0.19$, $p = .85$, when T1 CEMS coping also was controlled.

Regression analyses further revealed that ANT executive attention did not significantly predict T1 CEMS dysregulation, $\beta = -.08$, $t_{179} = -1.07$, $p = .29$, controlling for age, sex, and IQ, and did not significantly predict T2 CEMS dysregulation, $\beta = .00$, $t_{146} = 0.03$, $p = .97$, when T1 CEMS dysregulation also was controlled. In regression analyses, controlling for age, sex, and IQ, ANT executive attention did not significantly predict T1 CEMS EEI, $\beta = .10$, $t_{179} = 1.35$, $p = .18$, and did not significantly predict T2 CEMS EEI, $\beta = -.11$, $t_{146} = -1.59$, $p = .11$, when T1 CEMS EEI also was controlled.

Regression analyses revealed that ANT executive attention did not significantly predict T1 ERQ cognitive reappraisal, $\beta = .12$, $t_{180} = 1.65$, $p = .10$, controlling for age, sex, and IQ, or T2 ERQ cognitive reappraisal, $\beta = .02$, $t_{141} = 0.28$, $p = .78$, when T1 ERQ cognitive appraisal was controlled as well. ANT executive attention also did not

significantly predict T1 ERQ expressive suppression, $\beta = .03$, $t_{180} = 0.35$, $p = .73$, controlling for age, sex, and IQ, or T2 ERQ expressive suppression, $\beta = -.07$, $t_{141} = -0.90$, $p = .37$, when T1 ERQ expressive suppression also was controlled.

The measure of attentional control (*shift*) from the BRIEF significantly correlated with CEMS coping at T1 and T2 (Table 3), such that children reporting more difficulty with shifting also reported lower levels of coping. Regression analyses similarly indicated that *shift* significantly predicted T1 CEMS coping, $\beta = -.30$, $t_{189} = -4.48$, $p < .001$, controlling for age, sex, and IQ, and predicted CEMS coping at T2, $\beta = -.15$, $t_{152} = -2.10$, $p < .05$, controlling for age, sex, IQ, and T1 CEMS coping. *Shift* also correlated significantly with CEMS dysregulation at T1 and T2, such that more difficulty with shifting was associated with higher levels of dysregulation (Table 3). Regression analyses revealed that *shift* significantly predicted T1 CEMS dysregulation, $\beta = .35$, $t_{189} = 5.17$, $p < .001$, controlling for age, sex, and IQ, and predicted CEMS dysregulation at T2, $\beta = .22$, $t_{152} = 3.21$, $p < .01$, after also controlling for T1 CEMS dysregulation.

Shift also correlated with T2 ERQ cognitive reappraisal, but not with T1 ERQ cognitive reappraisal (Table 3). Regression analyses, controlling for age, sex, and IQ, revealed that *shift* did not predict T1 ERQ cognitive reappraisal, $\beta = -.11$, $t_{190} = -1.46$, $p = .15$, but did predict T2 ERQ cognitive reappraisal, $\beta = -.17$, $t_{147} = -2.35$, $p < .05$, even after also controlling for T1 ERQ cognitive reappraisal. *Shift* was not correlated with CEMS emotion expression inhibition at T1 or T2, ERQ suppression at T1 or T2, age, or IQ (Table 3); the regression analyses of *shift* predicting these T1 or T2 ER variables, when controlling for age, sex, IQ, and T1 ER (when predicting a T2 variable) were not significant.

Aim 2: Inhibition and Emotion Regulation

Aim 2 examined the relation between the executive function of inhibitory control and emotion regulation in youth. The behavioral measure of inhibition (SSRT) correlated significantly with T1 and T2 CEMS coping (Table 3), such that slower stop-signal reaction times (i.e., poorer response inhibition) were associated with lower levels of emotion regulation coping. Regression analyses revealed that inhibition (SSRT) predicted T1 CEMS coping, $\beta = -.18$, $t_{162} = -2.12$, $p = .04$, controlling for age, sex, and IQ, but did not predict T2 CEMS coping, $\beta = -.11$, $t_{126} = -1.28$, $p = .20$, when also controlling for T1 CEMS coping. SSRT was not correlated with either expressive suppression or cognitive reappraisal from the ERQ or emotion expression inhibition or dysregulation from the CEMS at T1 or T2 (Table 3).

Regression analyses, controlling for age, sex, and IQ, revealed that the prediction of T1 ERQ expressive suppression by inhibition (SSRT) was not significant, but marginal, $\beta = .15$, $t_{163} = 1.76$, $p = .08$, and the prediction of T2 ERQ expressive suppression by SSRT also was marginal, $\beta = -.18$, $t_{121} = -1.93$, $p = .06$, when also controlling for T1 ERQ expressive suppression. Regression analyses indicated that inhibition (SSRT) did not predict T1 or T2 CEMS dysregulation, CEMS EEI, or ERQ cognitive reappraisal, controlling for age, sex, IQ, and the T1 ER measure (when predicting the T2 variable).

SSRT was not correlated with IQ, but was significantly associated with age (Table 3) such that older children had faster stopping times. When age, sex, and IQ were included in a model, both age, $\beta = -.53$, $t_{164} = -7.36$, $p < .001$, and IQ, $\beta = -.29$, $t_{164} = -$

4.04, $p < .001$, significantly predicted SSRT, such that older ages and higher IQ scores were associated with faster stopping times; SSRT was not predicted by sex, $\beta = -.01$, $t_{164} = -0.19$, $p = .85$.

The measure of inhibition from the BRIEF, the *Inhibit* subscale, measured at Time 1 significantly correlated with T1 and T2 CEMS coping (Table 3), such that greater difficulty with inhibition was associated with lower levels of emotion regulation coping. Regression analyses similarly indicated that BRIEF *Inhibit* significantly predicted T1 CEMS coping, $\beta = -.33$, $t_{189} = -4.88$, $p < .001$, controlling for age, sex, and IQ, but did not predict T2 CEMS coping, $\beta = -.08$, $t_{152} = -1.05$, $p = .29$, when T1 CEMS coping also was controlled.

BRIEF *Inhibit* also correlated significantly with T1 and T2 CEMS dysregulation, such that greater difficulty with inhibition was associated with higher levels of dysregulation. Regression analyses, controlling for age, sex, and IQ, revealed that BRIEF *Inhibit* significantly predicted T1 CEMS dysregulation, $\beta = .29$, $t_{189} = 4.21$, $p < .001$, and T2 CEMS dysregulation, $\beta = .16$, $t_{152} = 2.33$, $p = .02$, when T1 CEMS dysregulation also was controlled.

In addition, BRIEF *Inhibit* correlated significantly with T2 ERQ cognitive reappraisal and tended to correlate with T1 ERQ reappraisal. Regression analyses, controlling for age, sex, and IQ, revealed that the prediction of BRIEF *Inhibit* was not significant, but marginal when predicting T1 ERQ reappraisal, $\beta = -.13$, $t_{190} = -1.82$, $p = .07$, and T2 ERQ cognitive reappraisal, when T1 ERQ cognitive reappraisal also was controlled, $\beta = -.13$, $t_{147} = -1.82$, $p = .07$. Finally, BRIEF *Inhibit* was not correlated with T1 or T2 CEMS EEI, T1 or T2 ERQ suppression, age, or IQ (Table 3). Regression

analyses, controlling for age, sex, IQ, and T1 ER (when predicting a T2 variable) were not significant.

Aim 3: Executive Function and Symptoms of Depression

Attentional Control and Symptoms of Depression. The behavioral measure of attentional control (executive attention score) on the ANT was not significantly correlated with T1 or T2 CDI total scores. The measure of attentional control (*Shift*) from the BRIEF was significantly correlated with the T1 and T2 CDI such that greater difficulty with shifting was associated with higher levels of depressive symptoms. Regression analyses, controlling for age, sex, and IQ, indicated that the *Shift* subscale (from the BRIEF) significantly predicted T1 CDI, $\beta = .43$, $t_{190} = 6.91$, $p < .001$, but did not significantly predict T2 CDI, $\beta = .08$, $t_{169} = 1.13$, $p = .26$, when T1 CDI also was controlled.

Inhibition and Symptoms of Depression. The behavioral measure of inhibition (SSRT) was not correlated with T1 CDI, but was significantly correlated with T2 CDI (Table 3), such that slower stop-signal reaction times (i.e., poorer response inhibition) were associated with higher levels of depressive symptoms. Regression analyses, controlling for age, sex, and IQ, revealed a nonsignificant, but marginal prediction of SSRT to T1 CDI, $\beta = .15$, $t_{163} = 1.70$, $p = .09$, and T2 CDI, $\beta = .13$, $t_{142} = 1.79$, $p = .08$, when also controlling for T1 CDI.

The measure of *Inhibit* from the BRIEF was significantly correlated with T1 and T2 CDI total scores (Table 3), such that greater difficulty with inhibition was significantly associated with higher levels of depressive symptoms. Regression analyses,

controlling for age, sex, and IQ, indicated that BRIEF *Inhibit* significantly predicted T1 CDI, $\beta = .30$, $t_{190} = 4.47$, $p < .001$, but not T2 CDI, $\beta = .09$, $t_{169} = 1.46$, $p = .17$, when also controlling for T1 CDI.

Aim 4: Emotion Regulation and Symptoms of Depression

The fourth aim was to test the concurrent and prospective relations between emotion regulation and depressive symptoms. Table 3 shows the correlations among the ER variables and the CDI total score. The emotion regulation coping score from the CEMS at T1 was negatively correlated with the CDI at T1 and T2, such that higher levels of emotion regulation coping were associated with lower levels of depressive symptoms. Regression analyses, controlling for age, sex, and IQ, indicated that CEMS coping at T1 significantly predicted T1 CDI, $\beta = -.32$, $t_{189} = -4.77$, $p < .001$, but did not predict T2 CDI, $\beta = -.01$, $t_{169} = -0.11$, $p = .91$, when also controlling for T1 CDI.

The dysregulation score from the CEMS at T1 was positively correlated with CDI at both T1 and T2, such that higher levels of dysregulation were associated with higher levels of depressive symptoms. Regression analyses, controlling for age, sex, and IQ, indicated that CEMS dysregulation at T1 significantly predicted T1 CDI, $\beta = -.32$, $t_{189} = -4.81$, $p < .001$, but did not predict T2 CDI, $\beta = -.02$, $t_{169} = -0.25$, $p = .80$, when T1 CDI also was controlled. The emotion expression inhibition (EEI) score from the CEMS at T1 was not correlated with the CDI at T1 or T2. Regression analyses, controlling for age, sex, and IQ, indicated that CEMS EEI at T1 did not predict T1 CDI, $\beta = -.02$, $t_{189} = -0.34$, $p = .73$, or T2 CDI, $\beta = .07$, $t_{169} = 1.26$, $p = .21$, after also controlling for T1 CDI.

The cognitive reappraisal score from the ERQ at T1 was negatively correlated with both T1 and T2 CDI, such that higher levels of cognitive reappraisal were associated with lower levels of depressive symptoms (Table 3). Regression analyses, controlling for age, sex, and IQ, indicated that cognitive reappraisal at T1 significantly predicted T1 CDI, $\beta = -.27$, $t_{190} = -3.98$, $p < .001$, but did not predict T2 CDI, $\beta = -.04$, $t_{169} = -0.58$, $p = .56$, after also controlling for T1 CDI. The expressive suppression score from the ERQ at T1 was positively correlated with T1 CDI such that higher levels of expressive suppression were associated with higher levels of depressive symptoms; ERQ suppression at T1 was not correlated with T2 CDI (Table 3). Regression analyses, controlling for age, sex, and IQ, indicated that expressive suppression at T1 significantly predicted T1 CDI, $\beta = .20$, $t_{190} = 2.79$, $p < .01$, but did not predict T2 CDI, $\beta = .02$, $t_{169} = 0.34$, $p = .73$, after also controlling for T1 CDI.

Aim 5: Mediation Analyses

Mediation of the Relation between Attentional Control and Depression by Emotion Regulation. Given the significant relations between attentional control (*Shift)* from the BRIEF and both ER (CEMS coping, CEMS dysregulation) and depressive symptoms (CDI), we examined whether ER statistically mediated the relation between shifting and depressive symptoms. *Shift* (on the BRIEF) did not predict CEMS coping at T2 (path A), $\beta = -0.04$, $t_{151} = -0.46$, $p = .65$, controlling for T1 CEMS coping, T1 depressive symptoms, age, sex, and IQ. CEMS coping at T1 did not predict depressive symptoms at T2 (path B), $\beta = -0.03$, $t_{151} = -0.50$, $p = .62$, controlling for BRIEF Shift, T1 depressive symptoms, age, sex, and IQ. The Sobel test was not significant.

Shift (on the BRIEF) significantly predicted T2 CEMS dysregulation (path A), $\beta = 0.27$, $t_{151} = 3.47$, $p < .001$, after controlling for T1 CEMS dysregulation, T1 depressive symptoms, age, sex, and IQ. CEMS dysregulation at T1 did not predict depressive symptoms at T2 (path B), $\beta = -0.01$, $t_{151} = -0.20$, $p = .84$, however, controlling for BRIEF Shift, T1 depressive symptoms, age, sex, and IQ. Again, the Sobel test was not significant. Given the lack of reliable associations between the behavioral measure of attentional control from the ANT and either ER or symptoms of depression (CDI), we did not conduct longitudinal tests of mediation using scores from the ANT.

Mediation of the Relation between Inhibition and Depression by Emotion Regulation. Given the significant relations between the behavioral measure of inhibition (SSRT) and both ER (CEMS coping) and depressive symptoms (CDI), we examined whether ER mediated the relation between SSRT and depressive symptoms. SSRT did not predict T2 CEMS coping (path A), $\beta = -0.08$, $t_{151} = -0.89$, $p = .37$, controlling for T1 CEMS coping, T1 depressive symptoms, age, sex, and IQ. T1 CEMS coping did not predict T2 depressive symptoms (path B), $\beta = 0.04$, $t_{151} = 0.56$, $p = .58$, when controlling for SSRT, T1 depressive symptoms, age, sex, and IQ. The Sobel test was not significant.

Given the significant relations between the measure of inhibition from the BRIEF and both measures of ER (CEMS coping, CEMS dysregulation) and depressive symptoms (CDI), we examined whether ER mediated the relation between inhibition and depressive symptoms. BRIEF Inhibit did not predict CEMS coping at T2 (path A), $\beta = 0.01$, $t_{151} = 0.12$, $p = .91$, after controlling for T1 CEMS coping, T1 depressive symptoms, age, sex, and IQ. T1 CEMS coping did not predict T2 depressive symptoms (path B), β

$= -0.03, t_{151} = -0.48, p = .63$, after controlling for BRIEF Inhibit, T1 depressive symptoms, age, sex, and IQ. The Sobel test was not significant.

BRIEF Inhibit measured at T1 did significantly predict CEMS dysregulation at T2 (path A), $\beta = 0.17, t_{151} = 2.38, p = .018$, after controlling for CEMS dysregulation at T1, T1 depressive symptoms, age, sex, and IQ. T1 CEMS dysregulation did not predict depressive symptoms at T2 (path B), $\beta = -0.01, t_{151} = -0.15, p = .88$, after controlling for BRIEF Inhibit, T1 depressive symptoms, age, sex, and IQ. The Sobel test, again, was not significant.

DISCUSSION

The overall goal of the present study was to examine the relations among executive functioning (EF), the ability to regulate emotions, and depressive symptoms in children and adolescents. We hypothesized that poorer executive functioning in the form of attentional and inhibitory control would be significantly associated with less use of adaptive ER strategies concurrently and four months later. Results of the analyses testing the relation between executive functioning and emotion regulation varied by the particular EF and ER constructs and the method of measurement used. Overall, we found several significant relations between both behavioral and self-report measures of executive function and children's reports of emotion regulation and depressive symptoms. The link between executive functioning and depressive symptoms was not found to be mediated by emotion regulation, however.

Relations among Attentional Control, Emotion Regulation, and Depressive Symptoms

Attentional Control and Emotion Regulation. Attentional control was measured with the *executive attention* score of the ANT and the *Shift* scale of the BRIEF. Emotion regulation was measured with the CEMS (emotion expression inhibition, emotion regulation coping, and dysregulation) and ERQ (cognitive reappraisal, expressive suppression). Results of the regression analyses, which controlled for age, sex, and IQ, revealed that the behavioral measure of executive attention (ANT) significantly predicted the emotion regulation subscale of coping (CEMS) concurrently, but did not predict coping at Time 2, controlling for T1. The ANT also did not predict the other subscales of the CEMS or the ERQ concurrently or four months later.

In contrast, the measure of attentional control (*Shift*) from the BRIEF significantly predicted the coping and emotion dysregulation subscales of the CEMS both concurrently and four months later. That is, more difficulty with shifting was associated with lower levels of coping and higher levels of emotion dysregulation. *Shift* also predicted ERQ cognitive reappraisal (ERQ) at Time 2, but not at T1; it did not predict inhibition of emotional expression (CEMS) or suppression (ERQ) at either T1 or T2.

Attention and depressive symptoms. The behavioral measure of attentional control did not significantly predict depressive symptoms. When measured with the BRIEF, greater difficulty with attentional control (Shift) significantly predicted higher levels of depressive symptoms concurrently, but not at follow-up when T1 CDI was controlled in addition to age, sex, and IQ.

Attentional problems have been found in depressed adults (Moriya & Tanno, 2008; Murphy et al., 1999; Paelecke-Habermann et al., 2005; Paradiso et al., 1997;

Trichard et al., 1995; Weiland-Fiedler et al., 2004), depressed children (Cataldo et al., 2005; Wilkinson & Goodyer, 2006), adults with remitted depression (Gotlib et al., 2004; Joormann & Gotlib, 2007; Leyman et al., 2007), and children at risk for depression (Joormann et al., 2007; Pérez-Edgar et al., 2006). Most of these prior studies, however, identified a specific, emotional attentional deficit, such as biased attention to negative stimuli (Hankin et al., 2010; Joormann & Gotlib, 2007; Koster et al., 2005). It is possible that there are differences in attentional control abilities in "cold" (i.e., emotionally neutral) and "hot" (i.e., emotionally charged) states. The behavioral measure of attentional control used here was a fairly neutral task that did not contain emotional stimuli. Perhaps stronger links between emotion regulation and depression would emerge if the measure of attentional control used emotional stimuli (Zelazo & Cunningham, 2007). Future studies should test both emotional and nonemotional tasks or should conduct mood inductions to strengthen the relations among EF, ER, and depression as compared to assessing EF in a neutral state.

Developmental considerations. The relations between attentional control and emotion regulation or depression have been found to be generally weaker prior to adulthood (Hocking et al., 2011; Joormann et al., 2007; Pérez-Edgar et al., 2006; Simonds et al., 2007; Wilkinson & Goodyer, 2006; Wilson et al., 2007). Children, particularly young children, may not have yet developed the abstract skills necessary to ruminate about negative cognitions commonly associated with depression. Indeed, an underdeveloped attentional system in childhood may be protective from rumination.

Another reason for differences between children and adults may be that attentional problems in children are more likely to be misattributed to diagnoses other

than depression such as ADHD. Children's attentional problems often are first recognized in school where the consequences of inattention are more observable. Future studies should directly measure externalizing symptoms and include adults as well as children in order to directly test whether attention problems are associated with other forms of psychopathology, and the extent to which these associations are stronger during childhood than in adulthood.

Relations among Inhibitory Control, Emotion Regulation, and Depressive Symptoms

Inhibitory Control and Emotion Regulation. The behavioral measure of inhibitory control was the stop-signal response time (SSRT). Similar to the findings for the measure of attention, inhibitory control (SSRT) significantly predicted coping (CEMS) at T1, controlling for age, sex, and IQ, but not at T2, when also controlling for T1 coping. Additionally, SSRT did not significantly predict emotion expression inhibition or emotion dysregulation from the CEMS at either T1 or T2, or cognitive reappraisal (ERQ) at T1 or T2. There was a nonsignificant trend for inhibition (SSRT) to predict expressive suppression (ERQ) at both T1 and T2.

The measure of *Inhibit* from the BRIEF significantly predicted T1 CEMS coping and CEMS dysregulation at both time points, but did not predict T2 CEMS coping or CEMS emotion expression inhibition at either T1 or T2. There was a nonsignificant trend for BRIEF Inhibit to predict cognitive appraisal on the ERQ, but not ERQ suppression at T1 and T2. Thus, overall greater levels of attentional control and inhibitory control, measured both behaviorally and by self-report, predicted better coping (CEMS).

Additional significant relations were found between the self-report measure of executive functioning and ER, particularly emotion dysregulation.

Inhibitory control and symptoms of depression. With regard to the behavioral measure of inhibition, there was a nonsignificant trend for the SSRT to predict depressive symptoms both concurrently, controlling for age, sex, and IQ, and four months later, when also controlling for T1 CDI. The BRIEF measure of *Inhibit* significantly predicted depressive symptoms concurrently, but not at the follow-up. Thus, significant relations were found between the behavioral measure of inhibition and both measures of ER and symptoms of depression. Better inhibitory control (faster stop-signal reaction time) was associated with both higher levels of emotion regulation coping (CEMS) and lower levels of depressive symptoms. This finding is consistent with prior evidence of inhibitory control deficits in both depressed adults (Gohier et al., 2009; Joormann & Gotlib, 2010; Lau et al., 2007; Moriya & Tanno, 2008; Ruchsow et al., 2008) and depressed children (Cataldo et al., 2005; Kyte et al., 2005; Neshat-Doost et al., 1997).

The present study found a significant relation among inhibition of motor responses, ER, and depressive symptoms. Prior research, primarily with adults, has shown consistent positive associations between cognitive inhibition, rather than response inhibition, and depression. The extent to which cognitive inhibition also is related to depression in children should be explored in the future.

Mediation of the Relation between Executive Functions and Depression by Emotion Regulation.

We had hypothesized that the relation between executive functioning and depressive symptoms would be mediated by emotion regulation. Despite the fact that many of the pairwise associations between EF, ER, and depressive symptoms were significant, longitudinal tests of these relations in the mediation analyses were no longer significant when baseline depressive symptoms were controlled. For example, significant relations were found between the behavioral measure of inhibition (SSRT) and both ER (CEMS coping) and depressive symptoms (CDI). However, SSRT did not predict T2 CEMS coping controlling for T1 CEMS coping, T1 depressive symptoms, age, sex, and IQ, and T1 CEMS coping did not predict T2 depressive symptoms, when controlling for SSRT, T1 depressive symptoms, age, sex, and IQ. Similarly, significant relations were found between inhibition (BRIEF) and CEMS coping and dysregulation, and depressive symptoms, but Inhibit did not predict CEMS coping at T2, after controlling for T1 CEMS coping, T1 depressive symptoms, age, sex, and IQ. T1 CEMS coping did not predict T2 depressive symptoms, after controlling for BRIEF Inhibit, T1 depressive symptoms, age, sex, and IQ. The Sobel test was not significant in either of these mediation models. Thus, although several of the expected relations among components of the mediation model were observed, evidence supporting the overall models was not found.

It is possible that the direction of the relations among these constructs was reversed. That is, depressive symptoms may predict deficits in both EF and ER. Unfortunately, because we only collected measures of EF at Time 1 we were not able to test alternative mediation models of different directional relations using the half-

longitudinal analyses. Future studies should measure all three variables (EF, ER, depressive symptoms) across at least three time points to conduct more comprehensive mediation models involving these three variables. Another reason why the proposed mediation effects may not have been significant is that a relatively short interval (4 months) elapsed between Time 1 and Time 2. Future studies should use longer periods between time points to test whether effects are stronger over time.

Limitations and Future Directions

Limitations of the current study included attrition from Time 1 to Time 2, the number of participants excluded due to low task performance, the measures used, and the narrow range of scores (particularly on the measure of depressive symptoms). Forty-two participants did not complete Time 2. Additionally, children were excluded due to poor performance on the SST and a few were excluded for not completing the primary measures of the study. This reduced our power to detect evidence of longitudinal effects in the mediation analyses. To reduce attrition, future studies should provide larger incentives (e.g., higher payment) for completion of the second assessment.

Another limitation of the current design was the relatively short duration between the Time 1 and Time 2 assessments. It is possible that the four-month follow-up was not enough time for significant change in ER or depressive symptoms to have occurred. Future studies should include more than two waves of data collection to increase the chances of observing change over time in the variables of interest, and to allow for the use of more comprehensive mediation analyses (Cole & Maxwell, 2003).

In contrast to the behavioral and self-report assessment of EF skills, the study used only self-report measures of ER and depressive symptoms. The fact that stronger associations were found among the child self-report measures (i.e., self-reported EF on the BRIEF and self-reported ER on the CEMS and ERQ) than with the behavioral measures (ANT or SST) suggests that some of these relations might have been due to mono-method bias. Using a single measurement format ("mono-method") to assess EF, ER, and depressive symptoms may be a problem because the resulting measures may be related more to individual, internal, and potentially biased perceptions of ability or symptoms rather than true abilities or symptoms. Inclusion of additional measures using other methods (e.g., behavioral or informant reports) could reduce this potential bias. Given the already lengthy assessment battery, however, it was not feasible to also obtain behavioral measures of ER. Moreover, not only are most behavioral measures of emotion regulation time intensive, but they also often still depend on participants' self-reports. When possible, future studies should use multiple informants, particularly parents, to possibly improve the reliability and validity of the measures of each construct.

In contrast to the mono-method (self-report) assessment of ER and depressive symptoms, the study assessed EF skills with both behavioral and self-report measures. We had anticipated that including multiple measures would improve assessment of EF skills (e.g., by combining scores), but the self-report measures (from the BRIEF) and behavioral measures (from the ANT or SST) were not correlated with each other. The behavioral and self-report measures of EF appeared to be measuring two independent constructs. Inspection of individual items on the BRIEF subscales suggests that the self-reports measure a much more general ability than the very specific measures of executive

attention and motor response inhibition assessed by the behavioral tasks. The BRIEF subscales also tend to assess the consequences of poor attentional control or inhibition more so than the basic attentional control and inhibition measured by the behavioral tasks. Thus these two types of measures may be assessing different aspects of EF skills.

It is also worth noting the behavioral measures of EF (ANT attention and SST inhibition) were uncorrelated with each other whereas the self-report measures (BRIEF shift and BRIEF inhibit) were highly correlated with each other. The findings suggest that research studies that primarily use behavioral measures might be more likely to conclude that specific cognitive skills are more differentiated whereas studies that use self-reports would conclude that there is more overlap across specific cognitive skills. The results of the present study do not definitively suggest that one method should be preferred over another in future research. Although the findings show that the self-reports of EF are better correlated with both ER and depressive symptoms, we did not comprehensively assess either ER or depressive symptoms in everyday life (e.g., using experience sampling by individuals or informants or observational measures by expert clinicians) so we do not have sufficient data to demonstrate that one set of measures is more valid than another. It is worth noting that almost all measures used in clinical practice are based on self-reports. The high correlations among these measures in the present study suggest that this may be a reasonable approach (however, see discussion below about limitations in the range of responses in this sample).

Finally, given that this was a community sample, the range of scores, particularly on our measure of depressive symptoms (CDI), was somewhat restricted. The range of scores on the CDI was fairly narrow (0–29) and was skewed such that the majority of

individuals had low levels of depressive symptoms. This relatively narrow range of scores may have limited our ability to detect relations between EF and ER and depression. Future studies should test the relations among executive functioning, emotion regulation, and depressive symptoms in a more clinically diverse sample of youth who would provide a larger range on the measures of interest. Future studies could broaden recruitment efforts (e.g., advertising the study to children seeking treatment) to attempt to assess these relations in more individuals with moderate to high levels of depressive symptoms.

Conclusion

A central aim of the current study was to examine the extent of the relations among EF, ER, and depressive symptoms in order to guide the construction of prevention efforts for children and adolescents, with the long-term goal of reducing risk for the development of depression. Recent research has shown that EF is malleable and can be modified through behavioral interventions (Diamond & Lee, 2011). Enhancing executive functioning also may improve ER skills and thereby reduce the risk of depression. More research is needed to clarify whether these specific executive functioning skills should be the primary targets of such interventions.

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