THE RELATIONSHIP BETWEEN DIMENSIONS OF EXECUTIVE FUNCTIONING AND RUMINATION IN YOUTH: A LONGITUDINAL AND BIDIRECTIONAL STUDY

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By
Rebekah J. Mennies
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Examining Committee Members:
Thomas Olino, PhD, Advisory Chair, Psychology
Lauren Alloy, PhD, Psychology
Tania Giovannetti, PhD, Psychology
Michael McCloskey, PhD, Psychology
Philip Kendall, PhD, Psychology
Johanna Jarcho, PhD, Psychology

ABSTRACT

Extensive work has examined the relationship between rumination and executive functioning (EF) mainly in adult samples, lending support for theory that rumination is characterized by poorer shifting, inhibition, and/or working memory updating abilities. However, literature on the relationship between rumination and EF in youth is more equivocal. Further, the directionality of this relationship is somewhat unclear, and may differ as a function of EF type. The present study conducted a longitudinal, bidirectional examination of the relationship between rumination on both negative and positive affect and several types of EF in a sample of 175 youth (aged 9-13) at baseline, 9-month, and 18-month follow-up assessments. Although rumination was not associated with shifting, inhibition, and/or working memory, support generally emerged for significant concurrent relationships between rumination and greater problems with inhibition, planning/organization, and monitoring. There was minimal support for significant longitudinal relationships between rumination and EF, and no evidence emerged for relationships between rumination on positive affect and EF. The present study provides some support for a "common cause" model of the relationship between rumination and EF (e.g., depressive symptoms; shared neurobiological dysfunction), although more research is needed to examine longitudinal relationships between these constructs.

This thesis is dedicated

in honor and loving memory of my grandfather,

Howard Edgar Hoffman, PhD, a scientist of over 30 years

who embodied the best qualities of academia and research. Without his

earnest love of knowledge and science education, and his mentorship

through my elementary school science fair projects,

I would not have pursued a PhD of my own.

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CHAPTER 1

INTRODUCTION

Background

Executive functioning (EF) deficits and rumination are core features and correlates of psychopathology, including in youth (Aldao & Nolen-Hoeksema, 2010; Hosenbocus & Chahal, 2012; Jenness et al., 2016; White et al., 2017; Willem, Bijttebier, Claes, & Raes, 2011). Theoretical models have proposed that EF deficits in shifting, inhibition, and/or working memory may underlie rumination (Joormann, 2010; Koster, De Lissnyder, Derakhshan, & De Raedt, 2011; Linville, 1996; Whitmer & Gotlib, 2013), yet engaging in rumination also may consume cognitive resources required for adaptive EF broadly (Philippot & Brutoux, 2008; Watkins & Brown, 2002). Thus, the directionality of the relationship between rumination and EF is unclear, and may depend on the dimension of EF assessed. Meta-analytic results show associations between EF deficits, particularly with regard to shifting, inhibition, and/or working memory updating, and rumination primarily with adults (Valenas & Szentagotai-Tatar, 2017; Yang et al., 2017; Zetsche, Bürkner, & Schelze, 2018). However, less is known about the association between EF and rumination in childhood and adolescence, with little published longitudinal work. The present study addresses this gap in the literature by examining cross-sectional and longitudinal associations between EF dimensions and rumination in a community sample of youth.

Rumination, the repetitive focus on negative mood or experiences, is associated with greater anxiety, depression, and eating disorder severity (Aldao & Nolen-Hoeksema,

2010), substance abuse (Willem et al., 2011), and post-traumatic stress symptoms (Jenness et al., 2016) in adolescence. Moreover, there is some evidence that rumination prospectively predicts onset of adolescent depressive episodes (e.g., Stange et al., 2016). More recently, researchers also have begun to examine rumination on *positive* affect, the repetitive focus on positive emotional states or personal attributes. Greater rumination on positive affect is associated with reduced depressive symptoms and greater hypomanic symptoms in youth (Bijttebier, Raes, Vasey, & Feldman, 2012). Any subsequent reference to rumination on negative affect will refer to "rumination" unless otherwise specified, whereas any reference to rumination on positive affect will refer to "rumination on positive affect." Given its role as a key feature of multiple forms of psychopathology, rumination in all of its forms is an important target for prevention and intervention efforts. However, less is known about the origins of this style of thinking.

Broadly defined, executive functioning (EF) is defined as a variety of higher-order reasoning skills that coordinate several cognitive processes to facilitate goal-oriented behavior. EF consists of several subdimensions, including set-shifting/cognitive flexibility, planning, organization, emotion regulation, inhibiting undesired responses, and working memory that are characterized both by unity (i.e., are typically correlated) and diversity (i.e., have unique features; e.g., Friedman & Miyake, 2017). These higher-order skills require the ability to flexibly shift attention, inhibit cognitive or behavioral impulses, and regulate emotions (Jurado & Rosselli, 2007). Similar to rumination, EF deficits are also often characteristic of psychopathology more broadly. Reviews of the literature have found that EF problems are evident in most forms of youth psychopathology (Hosenbocus & Chahal, 2012; White et al., 2017).

Theoretical models have proposed mechanisms through which EF may be associated with rumination, typically positing that EF deficits underlie risk for rumination. Whitmer and Gotlib (2013) suggested that low mood leads to a narrower scope of attention, keeping the same negative information in working memory, or holding information in mind and rehearsing or manipulating it. This failure to update working memory with more positive or goal-relevant information may manifest as rumination via repetitive focus on past events. In an alternative model, Linville (1996) and Joormann (2010) proposed that deficits in the inhibition of negative or goal-irrelevant material contribute to problems with removing negative/goal-irrelevant material from working memory, leading to rumination. Koster, De Lissnyder, Derakhshan, and De Raedt (2011) proposed that rumination originates from problems with flexibly shifting attention away from negative and/or self-referential information. As such, there are several competing, though not unrelated, proposed models indicating how alterations in EF may contribute to the development of rumination. Although these models have been proposed for rumination on negative affect or experiences specifically, they also may be relevant to the perseverative aspect of rumination on positive affect as well.

Alternatively, initial experimental research in adults indicates that higher levels of rumination may consume cognitive resources required for adaptive EF. This work has found that experimentally induced rumination is associated with poorer inhibition in adults with depression or undergraduates who are higher in dysphoria. In contrast, group differences in inhibition are not evident as a function of levels of depression/dysphoria following distraction (Philippot & Brutoux, 2008; Watkins & Brown, 2002). However, it remains unclear whether EF deficits are permissive of rumination by preventing the

effective regulation of thoughts related to negative stimuli; rumination diminishes cognitive resources necessary for adaptive EF; bidirectional effects between these factors are evident; or EF deficits and elevated rumination reflect shared neurobiological dysfunction or other etiology (a "common cause" model).

A large number of studies have evaluated the relationship between EF and rumination in adults. In a meta-analytic review of 34 studies, most with adult samples, Yang et al. (2017) found that rumination was associated with greater task-based inhibition *(r* = -.23, 95% CI: -.31 to -.15) and shifting problems (*r* = -.19, 95% CI: -.32 to -.05), but not with working memory problems (*r* = -.05, 95% CI: -.19 to .10). In a separate meta-analysis of 70 studies on the association between rumination and EF, primarily in adults, Valenas and Szentagotai-Tatar (2017) found modest associations between rumination and problems with inhibition (*r* = .11, 95% CI: .02 to .12) and shifting (*r* = .17, 95% CI: .08 to .25). However, there was no significant relationship between working memory (*r* = 0.06, 95% CI: 0.01, 0.14) or global EF (*r* = 0.09, 95% CI: 0.04, 0.15) and rumination. In contrast, in a meta-analysis of the relationship between repetitive negative thinking (RNT) and EF in 94 studies of adults (18 years and older), Zetsche et al. (2018) found the relationship between RNT and poorer EF was significant across studies for working memory *updating* only, with a small effect size ($r = -0.20$; 95% CI $= -0.26, -0.13$) and with no significant moderation by RNT subtype (rumination vs. worry). This work supports some specificity to shifting, inhibition, and/or working memory updating deficits in higher-ruminating adults. However, there is a dearth of literature on the relationship between rumination and other forms of EF, and on rumination on positive affect and EF across the lifespan.

Research on the cross-sectional relationship between rumination and EF is examined less frequently and reported results are more equivocal in samples of youth. The most consistent associations have emerged when EF is assessed as self- or parent-reported problems in daily life. These studies indicate that in youth, greater rumination is associated with greater problems in shifting (Dickson & Ciesla, 2018; Dickson et al., 2017), but not monitoring (Dickson et al., 2017), and equivocal findings are evident with regard to inhibition (Dickson & Ciesla, 2018; Dickson et al., 2017).

A less clear pattern of results exists across studies of cross-sectional associations between rumination and task-based assessments of EF. In some task-based studies in youth, greater rumination is associated with greater problems with cognitive flexibility (Jiang et al., 2016; Hilt, Leitzke, & Pollak, 2017), although rumination and performance on cognitive flexibility tasks are not significantly associated in several other studies in youth (Hilt, Leitzke, & Pollak, 2014; Stange et al., 2016; Stewart, Hunter, & Rhodes, 2018; Wilkinson & Goodyer, 2016). The few studies conducted on task-based inhibition and rumination in youth have produced equivocal results. Hilt and colleagues (2014) found that rumination was associated with greater commission errors during a go/no-go task in a community sample. However, Jiang et al. (2016) did not find a significant association between rumination and go/no-go performance in a sample of youth with oppositional defiant disorder. Consistent with the adult literature (Valenas & Szentagotai-Tatar, 2017; Yang et al., 2017), no significant associations were found between working memory during a digit span task and rumination (Connolly et al., 2014; Wagner, Alloy, & Abramson, 2015), although work on rumination and working memory only has been conducted within a single youth sample to date. Taken together, this work provides only

partial support for theoretical models of rumination and problems with cognitive flexibility (Koster et al., 2011) or inhibition (Joormann, 2010), with no evidence as of yet to support theory that deficits in working memory underlie rumination (Whitmer & Gotlib, 2013), although this theory may apply specifically to working memory *updating* rather than working memory broadly. However, minimal work has examined the relationship between rumination and working memory in youth.

As such, the nature of the relationship between rumination and EF in youth, including its directionality, remains unclear, and little longitudinal research has been conducted. Cross-sectional research is unable to clarify which proposed model best captures the relationship between EF and rumination. As such, addressing the directionality of associations between EF and rumination requires longitudinal examinations in youth samples as these processes are developing. Core dimensions of EF such as shifting, inhibition, and working memory develop throughout childhood and adolescence: development of inhibitory control tends to peak by the preschool years and subsequently level off, while shifting and working memory tend to follow a more gradual and linear developmental pattern (Best & Miller, 2010). Cognitive vulnerabilities begin to stabilize in adolescence, potentially corresponding with the development of abstract thought capabilities (Cole et al., 2008; Hankin, 2008). Further, adolescents and young adults ruminate more than middle-aged and older adults (Nolen-Hoeksema & Aldao, 2011; Sütterlin, Paap, Babic, Kübler, & Vögele, 2012). Together, this indicates that childhood and adolescence may be a sensitive period for the normative development of EF and cognition, and therefore, also may serve as a period of risk for the development of these processes to go awry. As such, the transition from childhood to adolescence is a key

time to examine associations between EF and rumination longitudinally. Further, work is needed that examines the relationship between rumination and several subdimensions of EF within a single study. It is possible that some of these dimensions (e.g., inhibition, shifting, working memory) predispose risk for rumination (Joormann, 2010; Koster et al., 2011; Linville, 1996; Whitmer & Gotlib, 2013), while the attention and energy consumed by engaging in rumination may impact these and/or other dimensions of EF (Philippot & Brutoux, 2008; Watkins & Brown, 2002).

To date, few studies have examined associations between rumination and EF longitudinally in youth samples. This research suggests that greater rumination is negatively associated with cognitive flexibility over time, but not vice-versa (Connolly et al., 2014); that cognitive flexibility and brooding (a maladaptive subtype of rumination) are not associated when assessed six months apart (Stewart, Hunter, & Rhodes, 2019); that early childhood inhibition problems may be associated with greater rumination in middle childhood in the context of higher anger (Schweizer, Olino, Dyson, Laptook, & Klein, 2018); and that global EF problems may be linked to greater rumination in the future through an intermediate pathway of greater dependent stressors (Snyder & Hankin, 2016). As such, no clear pattern has emerged with regard to the directionality of the relationship between EF subtypes and rumination.

Current Study

To examine whether EF deficits underlie rumination, rumination contributes to problems with EF, the relationship is bidirectional, or a common cause underlies the association, longitudinal research is needed in samples of youth. Further, research is needed to determine whether EF deficits may be similarly associated with rumination on

positive affect, an understudied topic to date. The present study begins to address this gap in the literature by examining the concurrent and longitudinal relationships between rumination on both negative and positive affect and EF problems (including inhibition, shifting, emotional control, initiation, working memory, planning/organizing, organization of materials, and monitoring) across three time points over 18 months using multiple statistical approaches. In line with extant theoretical models and limited work, significant associations are expected between rumination and EF across dimensions cross-sectionally. Longitudinally, only dimensions of EF at baseline (T1) that are theorized to give rise to rumination (e.g., shifting/cognitive flexibility, inhibitory control, working memory) or are otherwise relevant (emotional control) are expected to predict increases in rumination over time. Consistent with models of rumination as a source of depletion of the cognitive resources required by EF, rumination is expected to predict increases in EF problems across dimensions more broadly over time. Given a dearth of literature on this topic, all models examining the relationship between EF and rumination on positive affect were exploratory in nature. More specific aims and hypotheses, including additional exploratory aims, are detailed below.

Specific Aims and Hypotheses

Primary Aim 1

The first aim of the present study was to examine Time 1 (T1) cross-sectional associations between EF and youth-reported rumination. Greater parent-reported problems with shifting, emotional control, planning/organization, initiation, organizing materials, and working memory was hypothesized to be associated with greater self-reported rumination. Exploratory analyses examined the associations between (1)

inhibition (parent-reported questionnaire, commission errors during a go/no-go task) and self-reported rumination and (2) parent-reported monitoring and self-reported rumination. Although modest associations have been established overall between inhibition and rumination in adults (Yang et al., 2017; Valenas & Szentagotai-Tatar, 2017), the data are equivocal in youth, with three studies finding an association between inhibition and rumination (Dickson & Ciesla, 2018; Schweizer et al., 2018; Hilt et al., 2014) and two others finding no evidence for an association (Dickson et al., 2017; Jiang et al., 2016). Further, available assessments of inhibition may assess behavioral rather than cognitive inhibition difficulties most accurately. With regard to monitoring, operationalized as the awareness of the effect of one's behavior on others, only one study has examined the relationship between this construct and rumination in youth and no significant association was evident (Dickson et al., 2017). One might expect those high in rumination to find the effect of their behaviors on others to be *more* salient, yet EF deficits rather than strengths are typically evident as rumination increases. As such, no a priori hypotheses were made, and both of these analyses were considered exploratory in nature. Further, I explored baseline associations between EF domains (parent-reported questionnaire, commission errors) and self-reported rumination on positive affect (self-focused and emotion-focused rumination on positive affect).

Primary Aim 2

The second aim of the present study was to examine whether T1 problems with EF were associated with the trajectory (i.e., slope) of rumination/rumination on positive affect from T1 through 9-month and 18-month follow-up. Greater parent-reported problems at T1 with shifting, emotional control, and working memory – but not

planning/organizing, initiation, or organization of materials – was hypothesized to predict greater positive slope of self-reported rumination from T1 to 18-month follow-up. Exploratory analyses examined the associations between (1) T1 inhibition (parent-reported questionnaire, commission errors) and trajectories of self-reported rumination, and (2) T1 parent-reported monitoring and trajectories of self-reported rumination from T1 through 9-month and 18-month follow-up. Further, I explored associations between T1 EF (parent-reported questionnaire; commission errors) and trajectories of self-reported rumination on positive affect (self-focused and emotion-focused rumination on positive affect) from T1 through 9-month and 18-month follow-up.

Primary Aim 3

The third aim of the present study was to examine whether T1 levels of rumination are associated with the trajectory (i.e., slope) of problems with EF from T1 through 9-month and 18-month follow-up. Greater self-reported rumination at T1 will predict greater positive slope of parent-reported problems with shifting, emotional control, planning/organization, initiation, organization of materials, and working memory at T1. Exploratory analyses examined the associations between (1) T1 self-reported rumination and trajectories of inhibition problems and (2) T1 self-reported rumination and trajectories of monitoring problems from T1 through 9-month and 18-month follow-ups. Further, I explored associations between T1 rumination on positive affect (self-reported self-focused and emotion-focused rumination on positive affect) and trajectories of EF (parent self-report) from T1 through 9-month and 18-month follow-up. Go/No-Go commission errors will not be used for this aim, given no data collected at 9 months and

data collection halted at 18 months by the COVID-19 pandemic (see methods for more information).

Supplementary Aim 1

A supplemental aim was to model within-person and between-person changes in rumination and rumination on positive affect as a function of EF dimensions (and vice-versa) at T1, 9-month follow up, and 18-month follow up. Given the exploratory nature of this approach and lack of extant work on EF and rumination on positive affect, these analyses exclusively focused on the relationship between EF and rumination.

CHAPTER 2

METHOD

Participants

Participants were youth and their parents taking part in a community-based, longitudinal study of reward functioning and depression in an urban northeastern area. The full sample consisted of 232 youth enrolled at T1 who met inclusion criteria, and 57 of these participants failed to provide enough data on constructs of interest to be included. At T1, youth (N = 175; 68% female) were aged 9, 10, 12, or 13 (M = 10.95, SD = 1.48). Parents of participants described their child's race as White or European American (44%), Black or African American (42%), multiracial (11%), or "other" (3%). With regard to ethnicity, 92% were identified by a parent as non-Hispanic or Latinx, whereas 8% were identified as Hispanic or Latinx. Twenty-three percent of the sample reported a household income that fell below the United States Census Bureau poverty threshold in 2017. Youth were ineligible for participation due to the following reasons: child or parental history of a bipolar spectrum disorder, psychotic disorder; child history of obsessive-compulsive disorder; child history of a learning disability; evidence of non-normative or impacted development (e.g., pervasive developmental disorders; neurological disorder or insult); inability to speak English; no biological parent in the home; and/or overall intellectual functioning two standard deviations or greater below the mean (KBIT-2 Full Scale IQ < 70).

Procedure

Following verbal consent, an initial phone screening procedure was conducted to determine eligibility for the study. If eligible, youth and one or two (if available/willing) parents/legal guardians participated in a laboratory visit where written consent was obtained, followed by the administration of semi-structured diagnostic interviews, behavioral tasks, and questionnaires. Questionnaires were completed by youth and parents at the visit if time permitted; if not, incomplete questionnaires were sent home with participants and mailed back to the laboratory or returned in person shortly after the visit. An average of 4.2 months (*SD* = 2.5) following this assessment, youth participated in a Magnetic Resonance Imaging (MRI) assessment at a local hospital, at which time a series of behavioral tasks (including a go/no-go task) were completed inside the scanner. Behavioral data from the go/no-go task was collected from 152 youth at T1.

Nine (9mo) and eighteen (18mo) months following the T1 laboratory visit, participants repeated procedures from the T1 laboratory visit (including all questionnaires of interest to the present study). As at the time of data analysis, completion of the MRI assessments was pending due to the nature of the COVID-19 pandemic, no analyses were conducted using 18-month MRI data.

Measures

Children's Response Styles Questionnaire

The Children's Response Styles Questionnaire (CRSQ; Abela, Rochon, & Vanderbilt, 2000) is a self-reported measure of rumination, distraction, and problem solving in youth. Only the 13-item Rumination scale of the CRSQ was administered in the present study, which assesses the tendency to engage in rumination in response to sad mood. Participants rated their agreement on a 0 ("almost never") to 3 ("almost always")

Likert scale with items such as "when I am sad, I think about all of my failures, faults, and mistakes" and "when I am sad, I think about a recent situation wishing it had gone better." The ruminative response subscale of the CRSQ has demonstrated internal consistency of $\alpha = .75$ to $\alpha = .84$, as well as predictive criterion-related validity via prediction of increases in future depressive symptom severity, in samples of early adolescents (Abela et al., 2002; Abela et al., 2004). In the present sample, internal consistency was $\alpha = .89$ at T1, $\alpha = .94$ at 9mo, and $\alpha = .74$ at 18mo. Data were available for 145 participants for this measure at T1, 139 at 9mo, and 138 at 18mo.

Responses to Positive Affect Questionnaire Child Version

The Responses to Positive Affect Questionnaire – Child Version (RPA-C; Bijttebier et al., 2012) is a 17-item assessment of self-focused rumination on positive affect (4 items), emotion-focused rumination on positive affect (5 items), and dampening (8 items). The RPA-C was adapted from the Responses to Positive Affect Questionnaire for adults (Feldman, Joormann, & Johnson, 2008). Confirmatory factor analysis supported a three-factor structure of self-focused rumination on positive affect, emotion-focused rumination on positive affect, and dampening (Bijttebier et al., 2012). Of theoretical relevance to the present study were self-focused and emotion-focused rumination on positive affect, as dampening is not a repetitive thinking strategy. In the present sample, internal consistencies for the self-focused rumination on positive affect scale were $\alpha = .79$ at T1, $\alpha = .77$ at 9mo, and $\alpha = .84$ at 18mo. Internal consistencies for the emotion-focused rumination on positive affect scale were $\alpha = .83$ at T1, $\alpha = .83$ at 9mo, and $\alpha = .84$ at 18mo. Data were available for 170 participants for this measure at T1, 150 at 9mo, and 133 at 18mo.

Behavior Rating Inventory of Executive Function Short Form

The Behavior Rating Inventory of Executive Function–Short Form (BRIEF-SF; LeJeune et al., 2010) is a 24-item abbreviated version of the 86-item BRIEF Parent Form (Gioia, Isquith, Guy, & Kenworthy, 1996), a widely utilized measure of executive functioning among clinical neuropsychologists. Correlations between the original and short form have been strong (≥.88) in prior work (LeJeune et al., 2010). Parents reported on their child's level of executive functioning in daily life over the past six months across eight domains (inhibition, shifting, emotional control, initiation, working memory, planning/organizing, organization of materials, and monitoring). Each of the eight subscales were assessed using three items with the following response options: "never," "sometimes," and "often." Raw scores for each subscale were converted into t-scores using sex- and age-based norms. Higher scores indicate *greater* difficulty with EF in daily life relative to same-sex, same-aged peers. Clinically, t-scores below 65 on the BRIEF are considered to be within normal limits, while scores of 65 or above are considered to be elevated.

The Inhibit scale captures difficulty with inhibiting behaviors through items such as "has trouble putting the brakes on his/her actions," with an internal consistency of α = .76 at T1, α = .74 at 9mo, and α = .69 at 18mo. The Shift scale, which assesses cognitive flexibility and set-shifting, consists of items including "resists change of routine, foods, places, etc." and had an internal consistency of α = .79 at T1, α = .73 at 9mo, and α = .72 at 18mo. The Emotional Control scale assesses emotion regulation (e.g., "small events trigger big reactions") and had an internal consistency of α = .72 at T1, α = .76 at 9mo, and α = .77 at 18mo. The Initiate scale, which includes items such as "is not a self-

starter," assesses the ability to independently begin tasks or generate ideas; this scale's internal consistency was α = .65 at T1, α = .63 at 9mo, and α = .63 at 18mo. The Working Memory scale ("has trouble with chores or tasks that have more than one step") captures the ability to hold and modify information in mind to carry out goals, with an internal consistency of α = .83 at T1, α = .81 at 9mo, and α = .80 at 18mo. The Plan/Organize scale assesses planning and organization of concepts with items such as "has trouble carrying out actions needed to reach goals (saving money for a special item, studying to get a good grade);" the internal consistency for this scale was = .81 at T1, α = .80 at 9mo, and α = .83 at 18mo. The Organization of Materials scale captures organization with regard to belongings (e.g., "leaves messes that others have to clean up") and had an internal consistency of α = .81 at T1, α = .86 at 9mo, and α = .85 at 18mo. The Monitor scale assesses the awareness one has of the effect of their behavior on others (e.g., "does not notice when his/her behavior causes negative reactions); this scale had an internal consistency of α = .70 at both T1 and 9mo and α = .60 at 18mo. The internal consistency of scales for each domain has ranged from 0.68 to 0.81 in past research with a normative sample (LeJeune et al., 2010), which is relatively consistent with the present sample. Data were available for 130 participants (as reported by mothers) for this measure at T1, 101 at 9mo, and 94 at 18mo.

Go/No-Go Task

Youth completed a go/no-go paradigm (see Smith, Rosenbaum, Botdorf, Steinberg, & Chein, 2018; modified from Casey et al., 2007) while undergoing an MRI at T1 and 18mo. Participants viewed a series of 120 letters (each presented for .5 seconds) over six blocks (8 minutes and 30 seconds in total), and were instructed to respond to

targets (i.e., any letter but 'X') by pressing the button under their index finger and to withhold a response to non-targets (i.e., the letter 'X'). Of all letters presented, 75% were targets and 25% were non-targets. Problems with response inhibition were operationalized as the number of commission errors during this task, or instances of pressing the button in response to the letter 'X' due to failure inhibiting a pre-potent response. Thus, a greater number of commission errors made during this task indicated greater difficulty with response inhibition. Data were excluded for participants with 25 percent or greater omission errors, as this is an index of lack of task engagement and/or understanding. As 18-month MRI data collection was halted due to the COVID-19 pandemic, analyses using the go/no-go data focused solely on the T1 data. Data were available for 153 participants for this measure at T1 (N=133 with <25% omission errors).

Mood and Feelings Questionnaire Child Version

Youth completed the 33-item Mood and Feelings Questionnaire (MFQ-C; Costello & Angold, 1988) at T1 as a measure of depressive symptom severity that will be used as a covariate for significant primary analyses (see data analytic plan for more information). Youth participants rated statements such as "I felt miserable or unhappy" using a 0 to 2 Likert scale (0 = Not True, 1 = Sometimes True, 2 = True). The reliability of this scale in the current sample at T1 was excellent, $\alpha = .95$, which is consistent with other studies (Burleson Daviss et al., 2006). Data were available for 154 participants for this measure at T1.

Data Analytic Plan

All descriptive analyses were conducted using IBM SPSS Version 26 (2019) and included examination of normality, skewness, and kurtosis. When outliers (defined as >3

SD above or below the mean) emerged, sensitivity analyses were conducted to determine whether they were influential for cross-sectional analyses. Correlations and linear regression analyses were estimated using SPSS. Other inferential statistical analyses (linear mixed models and random intercept cross-lagged panel models) were conducted using Mplus 8.4 software (Muthén & Muthén, 1998-2012). These analyses were conducted using robust full information maximum likelihood, which adjusted standard errors to account for any non-normality in the data. For linear regression models, results from an a priori power analysis conducted in G*Power indicated that the study's power exceeded .80 to detect $r = .21$ for a sample of 175. With regard to linear mixed models, Monte Carlo simulations indicated that the present study's power exceeded .80 to detect an effect of .30 for the intercept and an effect of .325 for the slope for a sample of 175. No power analysis was conducted for the random-intercept cross-lagged panel models, as these analyses were exploratory in nature.

Consideration of Covariates

As a large body of literature has demonstrated greater rumination and EF impairment in depression (for meta-analytic reviews, see Rood, Roelofs, Bögels, Nolen-Hoeksema, & Shouten, 2009 and Snyder, 2013), for all significant linear regression analyses, additional analyses were conducted that controlled for T1 depressive symptom severity. This clarified whether significant associations between rumination and EF dimensions were significant above and beyond depressive symptom severity. Similarly, for each mixed linear model with a significant association between the predictor and intercept and/or slope of the outcome, the model was re-estimated with T1 depressive symptom severity included as a covariate.

Although assessments of EF via the BRIEF are already age-normed, some studies suggest that rumination (which is not age-normed) is still developing in this age group, as it increases from childhood to adolescence in some studies (Hampel & Petermann, 2005; Jose & Brown, 2008), but not in others (Gentzler, Wheat, Palmer, & Burwell, 2013; Hankin, 2008), and the construct of rumination may change in stability over the course of adolescent development (Hankin, 2008). Thus, a model was planned to examine the association between T1 child age and rumination. The a priori decision made was to include age as a covariate in significant linear regression analyses only if T1 age was significantly correlated with T1 rumination. If T1 age (between-subjects) significantly predicted the intercept and/or slope of rumination, it would have also been included as a covariate in all significant linear mixed model analyses. No covariates were included for random-intercept cross-lagged panel model analyses, as this was an exploratory aim that may be underpowered with the inclusion of covariates.

Planned Inferential Analyses

To examine the cross-sectional associations between T1 rumination/rumination on positive affect and T1 EF (Primary Aim 1), correlations examined the association between each dimension of EF at T1 and rumination/rumination on positive affect (self-focused and emotion-focused) at T1. All significant correlations also were estimated as linear regressions with the appropriate covariates included (see above). For Primary Aims 2 and 3, linear mixed models were estimated with time included as a within-subjects variable and EF dimension as a between-subjects variable to estimate the intercept and slope of the outcome variable. For Primary Aim 2, an EF variable was the between-subjects predictor and a rumination or rumination on positive affect variable was the

outcome for each model; for Primary Aim 3, a rumination or rumination on positive affect variable was the between-subjects predictor and an EF variable was the outcome for each model.

To model the within-person and between-person associations between rumination/rumination on positive affect and EF from T1 through the 18-month follow-up period (Supplementary Aim 1), I attempted to estimate random-intercept cross-lagged panel models (Hamaker, Kulper, & Grasman, 2015), which provide information about reciprocal relationships between constructs over time. These models distinguish within- and between-person sources of variance, and provide information about the degree of associations between the traits of each domain and the within-person cross-time associations. This approach was considered exploratory because no extant work has modeled dynamic changes between these constructs in this fashion and because of power limitations with sample size.

CHAPTER 3

RESULTS

Descriptive Statistics

Descriptive statistics were conducted for all T1 predictor and outcome variables in SPSS to examine the normality of the data prior to conducting correlations and linear regression analyses, in line with Primary Aim 1. Tables 1-3 show the means, standard deviations, skew statistics and standard errors, and kurtosis statistics and standard errors for each variable at T1, 9mo, and 18mo, respectively.

Table 1. *T1 Descriptive Statistics.*

	N	Mean	SD	Skew	SE_Skew	Kurtosis	SE_Kurtosis
CRSQ: Rumination	145	24.42	8.37	0.81	0.2	0.54	0.4
RPA-C: Emotion Focused	170	8.53	3.73	0.15	0.19	-0.53	0.37
RPA-C: Self Focused	170	5.95	3.26	0.19	0.19	-0.71	0.37
BRIEF: Inhibit	130	48.2	9.06	1.49	0.21	2.51	0.42
BRIEF: Shift	130	48.02	9.42	0.68	0.21	-0.06	0.42
BRIEF: Emotional Control	130	46.78	8.88	1.05	0.21	0.63	0.42
BRIEF: Initiate	130	49.94	10.39	0.51	0.21	-0.45	0.42
BRIEF: Working Memory	130	52.79	10.65	0.46	0.21	-0.23	0.42
BRIEF: Plan/Organize	130	51.26	11.26	0.7	0.21	-0.23	0.42
BRIEF: Org. of Materials	130	50.05	9.36	0.22	0.21	-0.62	0.42
BRIEF: Monitor	130	48.59	9.83	0.55	0.21	0.002	0.42
GNG Comm. Err.	133*	26.39	9.15	-0.07	0.21	-0.75	0.42

*Org. of Materials = Organization of Materials. GNG Comm. Err. = Go/No-Go Commission Errors. SD = Standard Deviation. SE = Standard Error. *N = 133 when excluding participants with 25% or greater omission errors.*

Table 2. *9mo Descriptive Statistics.*

	N	Mean	SD	Skew	SE_Skew	Kurtosis	SE_Kurtosis
CRSQ: Rumination	139	24.58	9.02	.88	.21	.39	.41
RPA-C: Emotion Focused	150	8.80	3.77	-.07	.20	-.66	.39
RPA-C: Self Focused	148	6.17	3.08	.05	.20	-.57	.40
BRIEF: Inhibit	100	49.57	9.66	.96	.24	.28	.48
BRIEF: Shift	101	49.75	9.23	.55	.24	.17	.48
BRIEF: Emotional Control	101	47.85	9.04	1.06	.24	1.20	.48
BRIEF: Initiate	101	52.73	10.70	.16	.24	-.78	.48
BRIEF: Working Memory	101	54.54	10.67	.35	.24	-.40	.48
BRIEF: Plan/Organize	101	51.55	10.60	.75	.24	.06	.48
BRIEF: Org. of Materials	101	50.90	10.03	.11	.24	-.92	.48
BRIEF: Monitor	101	49.63	9.73	.57	.24	-.15	.48

Org. of Materials = Organization of Materials. SD = Standard Deviation. SE = Standard Error.

Table 3. *18mo Descriptive Statistics.*

	N	Mean	SD	Skew	SE_Skew	Kurtosis	SE_Kurtosis
CRSQ: Rumination	138	23.95	8.48	.89	.21	.65	.41
RPA-C: Emotion Focused	132	8.79	3.71	-.06	.21	-.64	.42
RPA-C: Self Focused	133	6.24	3.39	.08	.21	-.81	.42
BRIEF: Inhibit	94	48.86	8.42	1.12	.25	1.89	.49
BRIEF: Shift	94	48.83	9.28	.67	.25	.13	.49
BRIEF: Emotional Control	94	47.66	9.28	1.04	.25	.69	.49
BRIEF: Initiate	94	51.92	9.87	.41	.25	-.16	.49
BRIEF: Working Memory	94	53.16	10.47	.61	.25	-.12	.49
BRIEF: Plan/Organize	94	52.47	11.22	.72	.25	-.05	.49
BRIEF: Org. of Materials	94	51.04	10.05	.24	.25	-.96	.49
BRIEF: Monitor	94	49.21	9.34	.69	.25	.28	.49

Org. of Materials = Organization of Materials. SD = Standard Deviation. SE = Standard Error.

Examination of Shapiro-Wilk statistics (i.e., .9 or above indicating normal distribution) and outliers (defined as greater than 3 SDs from the mean) indicated that all T1 variables of interest were normally distributed with the following exceptions: CRSQ: Rumination (Shapiro-Wilk statistic = .94, but 2 outliers >3 SD from the mean), BRIEF: Inhibition (Shapiro-Wilk statistic = .83, 3 outliers >3 SD from the mean), BRIEF: Shift (Shapiro-Wilk statistic = .84, 2 outliers >3 SD from the mean), and BRIEF: Emotional Control (Shapiro-Wilk statistic = .83, 2 outliers >3 SD from the mean). As such, analyses first were estimated with all participants included, and subsequent sensitivity analyses were conducted with the removal of outliers associated with the variables in each analysis. Results will be presented in both manners below.

Primary Aim 1

Correlations: All Participants

First, correlations were estimated between CRSQ (rumination), RPA-C (self-focused and emotion-focused rumination on positive affect), BRIEF (inhibition, shift, emotional control, initiate, working memory, plan/organize, organization of materials, monitor), and go/no-go (commission errors) indices. For analyses including commission errors, 21 participants were excluded in accordance with the a priori decision to exclude participants with 25% or greater omission errors. Consistent with hypotheses, greater rumination was associated concurrently at T1 with greater problems with shifting relative to same-aged peers, $r = .23$, $p = 0.02$. Greater rumination at T1 also was associated with greater T1 problems with monitoring, $r = .21$, $p = 0.03$. No significant relationship emerged between concurrent T1 rumination and any other index of EF (BRIEF, go/no-go commission errors); further, no significant relationship was evident between either form

of rumination on positive affect and EF indices. Please refer to Table 4 for these correlations.

Table 4. *T1 Correlation Matrix.*

	CRSQ	RPA-C: Emotion	RPA-C: Self	BRIEF: Inhibit	BRIEF: Shift	BRIEF: Emotional Control	BRIEF: Initiate	BRIEF: Working Memory	BRIEF: Plan/ Organize	BRIEF: Org. of Materials	BRIEF: Monitor	GNG Comm. Err.
CRSQ	1											
RPA-C: Emotion	0.08	1										
RPA-C: Self	-0.03	.75**	1									
BRIEF: Inhibit	0.13	0.06	0.02	1								
BRIEF: Shift	.23*	-0.05	-0.04	.37**	1							
BRIEF: Emotional Control	0.04	-0.01	-0.05	.64**	.52**	1						
BRIEF: Initiate	0.19	-0.05	-0.12	.29**	.38**	.39**	1					
BRIEF: Working Memory	0.13	-0.02	-0.07	.48**	.39**	.53**	.71**	1				
BRIEF: Plan/Organize	0.16	0.07	0.06	.34**	.25**	.32**	.71**	.70**	1			
BRIEF: Org. of Materials	0.03	0.09	0.04	.48**	.33**	.44**	.49**	.63**	.52**	1		
BRIEF: Monitor	.21*	0.11	0.05	.61**	.41**	.57**	.55**	.63**	.64**	.54**	1	
GNG Comm. Err.	-0.08	0.13	0.05	0.07	0.12	0.18	.28*	.31**	0.18	.25*	0.14	1

*$^{+}p<0.1$; *$p<0.05$; **$p<0.01$. Org. of Materials = Organization of Materials. GNG Comm. Err. = Go/No-Go Commission Error.*

Correlations: Outlier Sensitivity Analyses

When defined as any value 3 standard deviations or greater from the mean, 2 outliers were evident from the CRSQ rumination scale, 3 from the BRIEF inhibit scale, 2 from the BRIEF shift scale, and 2 from the BRIEF emotional control scale (though 1 of the 2 was also a previously identified outlier from the inhibit scale). Thus, sensitivity analyses were conducted after removing those observations. After excluding rumination outliers, the relationship between greater T1 rumination and greater problems with monitoring at T1 became only marginally significant, $r = .19$, $p = 0.06$. After excluding both rumination and shifting outliers, the relationship between T1 rumination and T1 shifting problems became non-significant, $r = .13$, $p = .21$. After excluding rumination outliers, the previously non-significant relationship between rumination and initiation became statistically significant, such that greater T1 rumination was associated with greater T1 problems with initiation, $r = .21$, $p = 0.04$. There continued to be no significant association between self- or emotion-focused rumination on positive affect (no outliers evident), and any EF variable, or between rumination and go/no-go commission errors. Please refer to Appendix A (Table S1) for correlations with outliers removed.

Linear Regression Analyses with Covariates

For significant associations between rumination and EF, follow-up linear regressions examined whether these associations continued to be significant when controlling for depressive symptoms. Further analyses examined whether any potential non-normality (i.e., outliers) may have led to spurious associations. Age at T1 was not significantly correlated with rumination at T1, $r = .003$, $p = .97$, and therefore, was not

included as a covariate. Thus, child-reported T1 depressive symptom severity was the only covariate included in these analyses.

Previously, when all participants were included, rumination was significantly associated with greater problems with shifting and monitoring. While controlling for depression with all participants included, the relationship between T1 rumination and T1 shifting remained significant, $b = .16$, $SE = .08$, $t(98) = 1.99$, $p = .05$, but the relationship between T1 rumination and T1 monitoring was no longer statistically significant, $b = .10$, $SE = .08$, $t(98) = 1.28$, $p = 0.21$.

Previously, when outliers were excluded, rumination was significantly associated with greater problems with initiation and marginally associated with greater problems with monitoring. As the relationship between rumination and shifting was previously non-significant with outliers removed, this model was not re-estimated covarying for depression with outliers removed. While controlling for depression with outliers removed, the relationships between T1 rumination and T1 initiation ($b = .09$, $SE = .07$, $t(96) = 1.16$, $p = 0.25$) and greater monitoring problems at T1 were non-significant, $b = .10$, $SE = .07$, $t(96) = 1.33$, $p = 0.19$.

Primary Aim 2

To examine the relationship between T1 EF and rumination/rumination on positive affect trajectories across the three time points, mixed linear models were estimated including a T1 EF variable (BRIEF: inhibit, shift, emotional control, initiate, working memory, plan/organize, organization of materials, monitor; go/no-go: commission errors) as the between-subject predictor variable, and time (age centered at 9, or the youngest age of a participant at baseline) as the within-subjects predictor variable.

For each model, the intercept (i.e., starting value) and slope (i.e., trajectory over time) of rumination [either rumination (CRSQ), self-focused rumination on positive affect (RPA-C), or emotion-focused rumination on positive affect (RPA-C)] was estimated using the between-subjects EF predictor and time.

First, a model was estimated to examine whether T1 age (between-subjects) predicted the intercept or slope of rumination. T1 age was not significantly associated with the intercept (b = 4.54, SE = 3.79, t = 1.20, p = .23) or slope (b = -.37, SE = .77, t = -.49, p = .63), and therefore, was not included as a covariate in the re-estimation of any significant analyses as a specificity test (i.e., only baseline depression scores were included as covariates in those analyses). No T1 EF variable (8 BRIEF domains and go/no-go commission errors) significantly predicted the intercept or slope of rumination, self-focused rumination on positive affect, or emotion-focused rumination on positive affect (all ps>0.09). Please refer to Appendix A (Tables S2-S3) for the parameters for analyses for Aim 2.

Primary Aim 3

To examine the relationship between T1 rumination on negative/positive affect and EF trajectories across the three time points, mixed linear models were estimated including a T1 rumination on negative/positive affect variable (CRSQ rumination, RPA-C self-focused rumination on positive affect, RPA-C emotion-focused rumination on positive affect) as the between-subject predictor variable, and time (age centered at 9, or the youngest age of a participant at baseline) as the within-subjects predictor variable. For each model, a rumination/rumination on positive affect between-subjects variable and time predicted the intercept (i.e., starting value) and slope (i.e., trajectory over time) of

EF (BRIEF: inhibit, shift, emotional control, initiate, working memory, plan/organize, organization of materials, monitor).

Greater rumination at T1 was a significant predictor of the intercept for initiation, indicating greater concurrent difficulty with initiation as T1 rumination increased (b = .38, SE = .15, t = 2.56, p = 0.01); however, T1 rumination did not significantly predict the slope of initiation problems across time (b = -.08, SE = .05, t = -1.55, p = 0.12). Similarly, greater rumination at T1 significantly predicted the intercept for planning/organization, indicating greater concurrent difficulty in this domain as T1 rumination increased (b = .28, SE = .14, t = 2.06, p = 0.04); once again, T1 rumination did not significantly predict the slope of planning/organization difficulties across time (b = -.04, SE = .05, t = -.87, p = 0.38).

When the models were re-estimated with T1 child-reported depression scores included as a covariate, the relationship between T1 rumination and the intercept of initiation problems remained significant (b = .40, SE = .19, t = 2.12, p = 0.03), and depression was not significantly associated with the initiation intercept (b = .03, SE = .14, t = .20, p = 0.84). With T1 depression symptoms included as a covariate, the relationship between T1 rumination and the intercept for planning/organization became non-significant (b = .24, SE = .16, t = 1.48, p = 0.14), and the relationship between T1 rumination and the slope of planning/organization remained non-significant (p>0.05). No other significant relationships emerged between any other T1 rumination variable (rumination, self-focused rumination on positive affect, emotion-focused rumination on positive affect) and the intercept or slope of any other EF indices (all ps>0.05). Please refer to Appendix A (Table S4) for the parameters for analyses for Aim 2.

Supplementary Aim 1

Complete random-intercept cross-lagged panel models did not yield admissible solutions (e.g., negative residual variances were evident), suggesting that the models were unable to accurately provide estimations from the data. To remedy this, regression relationships between the intercepts and slopes of each construct were not included; instead, the models estimated correlations between growth (i.e., intercept and slope) parameters using parallel process growth models, which yielded admissible model solutions in 6 of 8 instances (i.e., for all but shifting and inhibition; these models did not converge, and these analyses are not described further). Models also could not be estimated with within-person effects; thus, these paths were trimmed from the model. The focal parameters of these models were the correlations between the intercepts and slopes of rumination and each EF construct. All models showed excellent model fit. Please refer to Figure 1 for a diagram depicting these models. Fit indices are presented in Table 5, and correlations between intercepts and slopes are presented in Table 6.

Figure 1. *Revised Parallel Process Growth Models.*

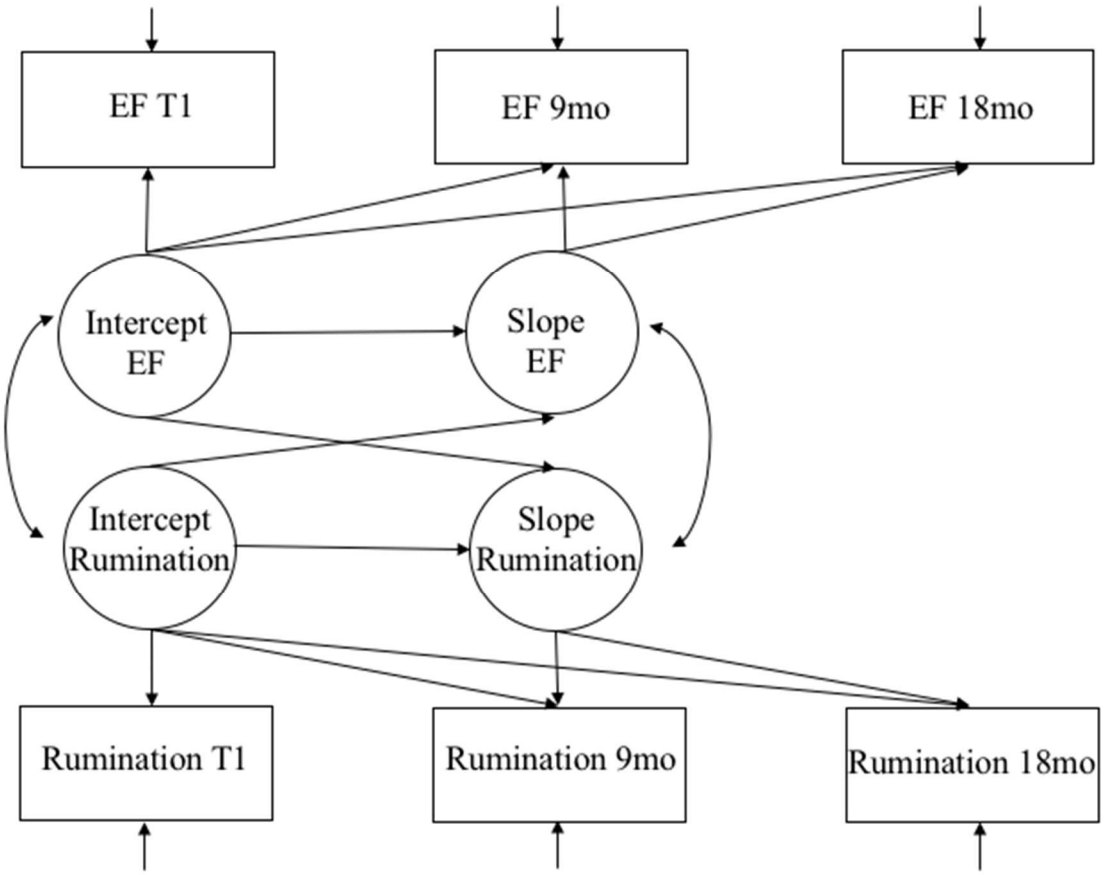

Table 5. *Fit Indices from Parallel Process Growth Models.*

EF Dimension	Parameters	Chi-Square	df	CFI	RMSEA	SRMR
EC	20	8.24	7	0.99	0.03 (0-0.09)	0.05
Initiate	20	4.11	7	1	0 (0-0.06)	0.04
Working Memory	20	7.67	7	0.99	0.02 (0-0.09)	0.05
Org. of Mat.	20	2.52	7	1	0 (0-0.03)	0.02
Plan/Org.	20	5.74	7	1	0 (0-0.08)	0.03
Monitor	20	7.79	7	0.99	0.023 (0-0.09)	0.04

EC = Emotional Control. Org. of Mat. = Organization of Materials. Plan/Org. = Plan/Organize.

*$^{+}p<0.1$; *$p<0.05$; **$p<0.01$*

Table 6. *Correlations Among Growth Parameter Estimates from Parallel Process Growth Models.*

	Rumination Intercept	Rumination Slope
EC Intercept	.04	.50*
EC Slope	.91^{+}	-.29
Initiate Intercept	.32*	.09
Initiate Slope	-.12	-.07
WM Intercept	.22	.15
WM Slope	-.01	-.22
Plan/Org. Intercept	.28*	-.32
Plan/Org. Slope	-.08	.27
Org. of Mat. Intercept	.10	.16
Org. of Mat. Slope	.17	-.72
Monitor Intercept	.42**	-.20
Monitor Slope	-.47^{+}	.72^{+}

EC = Emotional Control. Org. of Mat. = Organization of Materials. Plan/Org. = Plan/Organize. Parameters in table are standardized growth estimates which reflect correlations.

*$^{+}p<0.1$; *$p<0.05$; **$p<0.01$*

In terms of significant intercept-intercept associations, there was a significant positive association between the initiate and rumination intercepts, such that greater starting problems with initiation were associated with greater starting rumination. Similarly, there was a significant positive association between the intercepts for plan/organize and rumination, with starting problems with planning and organization greater as starting rumination was higher. Finally, significant positive associations between the intercepts for monitor and rumination were evident, such that greater starting problems with monitoring were associated with greater starting rumination. In terms of significant intercept-slope associations, there was a significant association between the intercept for emotional control and the slope of rumination, such that youth with greater emotional control difficulties relative to same-aged, same-sex peers experienced greater increases in rumination over time. No other significant intercept-intercept or intercept-slope relationships emerged for any other model, nor were there any significant slope-slope relationships.

CHAPTER 4

DISCUSSION

The present study examined the cross-sectional and longitudinal relationships between EF across domains and both rumination and rumination on positive affect. Most consistently, there were cross-sectional relationships between greater rumination and greater problems with monitoring, initiation, and planning/organization relative to same-aged, same-sex peers. At T1 with outliers removed, greater rumination was correlated with greater problems with initiation, and the previously significant correlation between greater rumination and greater problems with monitoring became marginally significant. Results from mixed linear modeling showed that greater T1 rumination was associated with greater starting problems with initiation and planning/organization, though the models examining relationships between T1 EF and starting values of rumination were non-significant. Parallel process growth models suggested that cross-sectionally, significant intercept-intercept associations were evident between starting greater rumination and starting problems with initiation, planning/organization, and monitoring. Minimal support was found for longitudinal relationships between EF and rumination.

Extant theory (Joormann, 2010; Koster et al., 2011; Linville, 1996; Whitmer & Gotlib, 2013) and empirical research in predominantly adult samples (Valenas & Szentagotai-Tatar, 2017; Yang et al., 2017; Zetsche et al., 2018) suggest that shifting, inhibition, and/or working memory deficits may underlie rumination. However, the youth literature has produced equivocal findings on the relationship between rumination and these domains of EF (Connolly et al., 2014; Dickson & Ciesla, 2018; Dickson et al., 2017; Hilt et al., 2014; Hilt et al., 2017; Jiang et al., 2016; Schweizer et al., 2018; Stange

et al., 2016; Stewart et al., 2018; Stewart et al., 2019; Wagner et al., 2015; Wilkinson & Goodyer, 2016). Consistent with much of the youth literature, no significant relationships emerged cross-sectionally *or* longitudinally between rumination and problems with shifting (once influential outliers were removed), inhibition, or working memory in the present study, indicating limited support for theory suggesting that these domains of EF give rise to rumination or for cognitive resource depletion models (e.g., Philippot & Brutoux, 2008; Watkins & Brown, 2002). However, these theories (Joormann, 2010; Koster et al., 2011; Linville, 1996; Whitmer & Gotlib, 2013) focus on EF difficulties in these domains in the context of negative affect or information specifically, and the measure of EF utilized examined EF in broader contexts of daily life. It is possible that a significant relationship between shifting, inhibition, and/or working memory and rumination only is evident for negative and/or self-referential information. This interpretation may be further supported by the null associations that were evident between rumination on positive affect and EF broadly, indicating that valence may play an important role in the relationship between repetitive thinking and EF.

However, some significant cross-sectional relationships emerged between rumination and several domains of EF without considering the affective context of EF. Of the significant cross-sectional relationships that did emerge between rumination and EF, the clearest pattern of results across various methodological approaches included cross-sectional relationships between rumination and problems with initiation, monitoring, and planning/organization (i.e., in support of a "common cause" rather than longitudinal cognitive resource depletion models). It is possible that rumination, which may serve an avoidant function (Cribb, Moulds, & Carter, 2006; Stroebe et al., 2007), leads to short-

term avoidance of initiating tasks (particularly those that are stressful or taxing in nature). Potentially, rumination also diminishes cognitive resources required to engage in effective planning/conceptual organization concurrently, though this relationship only was evident at our threshold for significance with more rigorous (i.e., higher-powered) methodological approaches (i.e., only evident when also accounting for the relationship with slope in the mixed linear model and parallel process growth model, but not evident in simple correlational analyses). In terms of monitoring, rumination may be a logical immediate consequence of difficulty monitoring behavior if such difficulties lead to more negative feedback from others, as rumination is a maladaptive attempt to understand one's behavior and its consequences.

Of important note, inconsistent evidence emerged as to whether these relationships might be better accounted for by baseline depressive symptoms. Although the relationship between rumination and monitoring problems teetered on significance (i.e., became trending) when controlling for depressive symptoms, the relationship between rumination and initiation problems became non-significant when controlling for depressive symptoms in the linear regression models (though remained significant when controlling for depressive symptoms in the mixed linear model), and the significant relationship between rumination and planning/organization difficulties in the mixed linear model became non-significant when controlling for depression. This may indicate that rather than one contributing to the other, these cross-sectional associations are rather explained by greater concurrent symptomatology of a diagnosis characterized by both rumination and executive dysfunction ("common cause" model).

There was little evidence in the present study for longitudinal relationships between rumination and EF; as such, the present study provided little support to schools of thought that EF dysfunction may give rise to rumination over time, or that rumination diminishes cognitive resources over time. This may reflect that rather than one contributing to the other, rumination and EF difficulties may reflect a shared concurrent tendency towards "getting stuck" and difficulty with goal pursuits resulting from a common cause, such as a shared tendency towards depression, as partially indicated by the present study. Alternatively, it is possible that the time course (9- and 18-month follow-ups) was not appropriate to capture longitudinal relationships between these constructs. The sole significant longitudinal association indicated that greater starting problems with emotional control predicted greater increases in rumination over time, although this relationship emerged only with the parallel process growth models and not through linear mixed modeling. There is a dearth of research that has examined the relationship between rumination and difficulties with emotional control (as assessed with the BRIEF) in youth, with further research needed to replicate these findings. This lack of research is somewhat surprising, given that difficulties with "hot" EF (i.e., affectively-laden) may be particularly relevant for rumination, and rumination is conceptualized as a maladaptive emotion regulation strategy (Nolen-Hoeksema & Aldao, 2011).

The present study is characterized by a number of important strengths, which will add to our knowledge of the relationship between rumination and EF in a developing sample. First, this is one of the few longitudinal examinations of the relationship between these constructs in youth or adults, as the majority of literature to date is cross-sectional in nature. Adult samples may not be developmentally appropriate to detect potential

longitudinal effects, as cognitive vulnerabilities (e.g., rumination) and executive functioning abilities likely have stabilized and/or developed by this point; as such, longitudinal studies in youth are critical. Second, the present study utilized a multi-informant (parent-reported EF; child-reported rumination and rumination on positive affect) and multi-method (questionnaire and task-based EF) approach. Third, as there is a dearth of literature on the role of EF deficits in rumination on *positive* affect, the present study informs our knowledge of the relationship between EF and repetitive thinking broadly, indicating specificity for at least some relationships between rumination in response to negative affect or experiences and EF. Fourth, the developmental focus on 9- to 13-year-old youth at baseline may be a particularly important window for capturing the transition from childhood to adolescence, when these processes are continuing to develop.

At the same time, the present study has some important limitations of note. Although a multi-method and multi-informant approach was utilized, the majority of analyses were conducted using questionnaire-based indices only, and shared method variance may have contributed to the significance of some results. Further, the version of the BRIEF used in the present study was an older version of the measure, as well as a shorter form with only three items per EF dimension, which contributed to the lower internal consistency of some of these scales and, potentially, subsequent lack of many significant findings. In addition, to better understand temporal processes, more frequent and longer-term assessments may have been needed to characterize the relationship between EF and rumination longitudinally. As such, the study would have benefitted from additional time points and/or longer windows of time between waves of data

collection to capture potential longer-term relationships between rumination and EF. Finally, due to unforeseen difficulties with estimating planned random-intercept cross-lagged panel models, our study was unable to provide formal information about within-person and between-person associations simultaneously.

Future studies should address these limitations by attempting to replicate findings in a larger sample of youth with 1) inclusion of more task-based indices of EF spanning different domains to most comprehensively assess how domains of EF differentially associate with rumination, 2) additional time points to maximize ability to capture potential longitudinal associations, and 3) use of the updated and full BRIEF-2 to assess EF difficulties in daily life, which may be a more reliable measure of EF. It also may be beneficial for this work to be conducted in relevant clinical (i.e., youth with diagnoses of depression, anxiety, and/or OCD) rather than community samples, as relationships between specific EF domains and rumination may be more evident among these populations specifically. Finally, research is needed that examines both within-person and between-person changes in order to most accurately test extant theory surrounding longitudinal associations between EF and rumination. Future work should also consider important mediators (e.g., fronto-limbic neural activation; depressive symptom severity) and/or moderators (e.g., negative affect-laden contexts specifically) that may clarify our understanding of the relationship between EF and rumination, particularly in light of partial support for the "common cause" model in the present study.

Such future research may aid mental health professionals in identifying youth vulnerable to psychopathology by clarifying whether there is an early emergence of a relationship between these two transdiagnostic risk factors. If this is in fact the case, such

work may lead to these youth more readily accessing prevention and intervention efforts that directly target EF skills and/or rumination. Potentially, an intervention that integrates EF skill-building (e.g., teaching organization and planning, effective emotion regulation/coping strategies, and increasing cognitive flexibility), acceptance-based approaches to rumination (e.g., learn to attach less meaning to thoughts; mindfulness), and change-based approaches to behaviors that stem from rumination (such as problem-solving and exposure) may best support these youth.

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APPENDIX A

Table S1. *T1 correlation matrix, results with outliers removed.*

	CRSQ	RPA-C: Emotion	RPA-C: Self	BRIEF: Inhibit	BRIEF: Shift	BRIEF: Emotional Control	BRIEF: Initiate	BRIEF: Working Memory	BRIEF: Plan/ Organize	BRIEF: Org. of Materials	BRIEF: Monitor	GNG Comm. Err.
CRSQ	1											
RPA-C: Emotion	.09	1										
RPA-C: Self	-.01	!	1									
BRIEF: Inhibit	.16	.10	.06	1								
BRIEF: Shift	.13	-.04	-.05	.31**	1							
BRIEF: Emotional Control	-.02	.02	-.06	.52**	.49	1						
BRIEF: Initiate	.21*	-0.05	-0.12	.13	.41**	.31**	1					
BRIEF: Working Memory	.11	-0.02	-0.07	.37**	.39**	.47**	.71**	1				
BRIEF: Plan/Organize	.18^{+}	0.07	0.06	.23**	.29**	.27**	.71**	.70**	1			
BRIEF: Org. of Materials	.03	0.09	0.04	.41**	.30**	.39**	.49**	.63**	.52**	1		
BRIEF: Monitor	.19^{+}	0.11	0.05	.51**	.41**	.50**	.55**	.63**	.64**	.54**	1	
GNG Comm. Err.	-.03	0.13	0.05	.05	.06	.14	.28*	.31**	0.18	.25*	0.14	1

*$^{+}$p<0.1; *p<0.05; **p<0.01. Org. of Materials = Organization of Materials. GNG Comm. Err. = Go/No-Go Commission Errors*

Table S2. *Mixed linear modeling results, models with EF as predictor.*

	Rumination		*Self-Focused RPA*		*Emotion-Focused RPA*	
	Intercept	Slope	Intercept	Slope	Intercept	Slope
T1 Inhibit	.31 (.18)$^{+}$	-.03 (.05)	.04 (.05)	-.02 (.02)	.03 (.06)	-.01 (.02)
T1 Shift	.11 (.18)	.01 (.05)	-.05 (.05)	.02 (.02)	-.08 (.06)	.02 (.02)
T1 EC	.11 (.18)	.01 (.06)	-.02 (.06)	.01 (.02)	-.05 (.06)	.02 (.02)
T1 Initiate	.24 (.14)$^{+}$	-.03 (.05)	-.03 (.04)	<.01 (.01)	.01 (.05)	-.01 (.02)
T1 WM	.16 (.15)	-.01 (.05)	-.01 (.04)	<.01 (.01)	-.03 (.05)	.01 (.02)
T1 Plan/Org.	.21 (.13)$^{+}$	-.05 (.04)	.04 (.05)	-.01 (.01)	.08 (.05)$^{+}$	-.01 (.01)
T1 Org. of M.	.09 (.17)	-.01 (.05)	<-.01 (.05)	.01(.02)	.01 (.06)	.01 (.02)
T1 Monitor	.15 (.18)	<-.01 (.05)	.05 (.05)	-.02 (.02)	.05 (.06)	-.01 (.02)
T1 GNG Comm.	-.30 (.24)	.09 (.09)	.03 (.06)	.01 (.02)	.05 (.07)	<-0.01 (.02)

Parameters presented are estimate (SE). RPA = Rumination on Positive Affect. EC = Emotional Control. WM = Working Memory. Plan/Org=Plan/Organize. Org of M. = Organization of Materials. GNG Comm. = Go/No Go Commission Errors.
$^{+}p<0.1$; $^{*}p<0.05$; $^{**}p<0.01$

Table S3. *Mixed linear modeling results, models with rumination/RPA as predictor.*

	Inhibit		*Shift*		*EC*		*Initiate*	
	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
T1 Rumination	.12 (.13)	.02 (.04)	.27 (.14)$^{+}$	-.02 (.05)	.06 (.14)	.01 (.04)	.38 (.15)*	-.08 (.05)
T1 Self-Focused RPA	-.32 (.34)	.09 (.11)	-.25 (.36)	.03 (.12)	-.44 (.34)	.11 (.11)	-.52 (.34)	.02 (.12)
T1 Emotion-Focused RPA	-.22 (.29)	.13 (.08)	-.19 (.33)	.04 (.10)	-.44 (.35)	.11 (.11)	-.15 (.32)	-.04 (.12)

Parameters presented are estimate (SE). RPA = Rumination on Positive Affect. EC = Emotional Control.
$^{+}p<0.1$; $^{*}p<0.05$; $^{**}p<0.01$

Table S4. *Mixed linear modeling results, models with rumination/RPA as predictor (continued).*

	WM		*Plan/Org*		*Org. of M.*		*Monitor*	
	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
T1 Rumination	.27 (.17)	-.05 (.05)	.28 (.14)*	-.04 (.05)	.16 (.15)	-.04 (.04)	.26 (.16)$^{+}$	-.03 (.05)
T1 Self-Focused RPA	-.58 (.39)	.09 (.13)	.22 (.42)	-.04 (.14)	-.11 (.37)	-.02 (.12)	.02 (.35)	-.09 (.12)
T1 Emotion-Focused RPA	-.42 (.35)	.14 (.12)	.08 (.05)$^{+}$	-.02 (.01)	.10 (.34)	-.01 (.10)	.06 (.31)	-.04 (.11)

Parameters presented are estimate (SE). RPA = Rumination on Positive Affect. WM = Working Memory. Plan/Org=Plan/Organize. Org of M. = Organization of Materials.
$^{+}p<0.1$; $^{*}p<0.05$; $^{**}p<0.01$