Neurocognitive Correlates of Rumination Risk in Children: Comparing Competing Model Predictions in a Clinically Heterogeneous Sample

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Abstract

The current study examined associations between rumination and executive function difficulties in preadolescent youth, using predictions outlined in the attentional scope and multiple systems models of rumination. This study aimed to (a) extend current conceptual models of rumination to youth, (b) clarify disparate model predictions regarding working memory updating (“updating”), inhibition, and shifting abilities, and (c) examine differential neurocognitive predictions between two forms of rumination, sadness and anger. One hundred and fifty-nine youths oversampled for ADHD and other forms of child psychopathology associated with executive dysfunction (aged 8–13; 53.5% male; 59.1% Caucasian) completed a battery of assessments, including self-report measures of rumination and computerized neurocognitive tasks. Multiple regression analyses were conducted assessing relations between rumination and each executive function, controlling for both sadness and anger rumination to assess their unique associations. Sadness rumination was associated with poorer updating ($\beta=-.18$, $p=.046$) and shifting abilities ($\beta=.20$, $p=.03$) but not inhibition ($\beta=-.04$, $p=.62$), offering partial support to the attentional scope and multiple systems models. In contrast, anger rumination was associated with *better* updating abilities ($\beta=.20$, $p=.03$) but not shifting ($\beta=-.15$, $p=.11$) or inhibition ($\beta=.08$, $p=.35$). Together, these results suggest (a) developmental differences in the neurocognitive correlates associated with rumination risk in youth compared to findings from the adult literature, and (b) that the executive function correlates of children’s responses to negative emotions are affect-specific, such that sadness rumination is associated with difficulties replacing negative thoughts and shifting between mental sets, while anger rumination is associated with a better ability to maintain negative thoughts.

Keywords

executive function; rumination; response styles; anger; sadness

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Rumination, as a maladaptive cognitive response, refers to the tendency to mentally perseverate on the symptoms, causes, and consequences of one's negative mood (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). This, in turn, perpetuates a sustained state of negative affect (Nolen-Hoeksema et al., 2008), which can increase risk and maintenance of psychological distress (e.g., McLaughlin & Nolen-Hoeksema, 2011; Rood, Roelofs, Bogels, Nolen-Hoeksema, & Schouten, 2009; Watkins, 2009). However, our understanding of mechanisms that contribute to one's proneness towards rumination remains limited, especially among youth. Given its demonstrated stability across development (Nolen-Hoeksema et al., 2008) and its potential for adverse outcomes over time (e.g., Hilt, McLaughlin, & Nolen-Hoeksema, 2010; Caprara, Paciello, Gerbino, & Cugini, 2007; McLaughlin, Aldao, Wisco, & Hilt, 2014; Nolen-Hoeksema, Stice, Wade, & Bohon, 2007; Peled & Moretti, 2007, 2010; Rood et al., 2009), identifying factors that influence why some youth ruminate can help inform developmental theory and intervention efforts.

A growing body of literature suggests that individual differences in ruminative tendencies are linked to underlying executive function impairments (e.g., Davis & Nolen-Hoeksema, 2000; Whitmer & Gotlib, 2013). Consistent with previous studies (Vălenaş & Szentágotai-Tătar, 2017), the current study focuses on three core executive functions that are interrelated, yet distinguishable processes: updating and monitoring working memory, inhibiting prepotent responses, and shifting between tasks or mental sets (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Updating and monitoring working memory (henceforth, referred to as "updating") consists of the ability to monitor and code incoming information that is task-relevant, replacing information that is no longer relevant with this newer information (Morris & Jones, 1990). Inhibition consists of the ability to deliberately override prepotent response tendencies or interference from previously relevant information and unwanted thoughts and emotions (Miyake et al., 2000). The third executive function, shifting, involves the ability to flexibly switch between tasks, operations, and mental sets by disengaging from an irrelevant task set and subsequently engaging in a relevant task set (Monsell, 1996). Shifting may also involve the ability to perform a new operation despite interference or negative priming (Miyake et al., 2000). This three-factor framework has received substantial support in both adult (e.g., Miyake et al., 2000; Miyake & Friedman, 2012) and child samples (e.g., Karr et al., 2018; St Clair-Thompson & Gathercole, 2006).

Several conceptual models of rumination have been proposed to characterize the neurocognitive correlates of trait rumination. For instance, trait rumination has been attributed to difficulty inhibiting negative information from entering working memory (Joormann, 2010) and impaired disengagement from negative information once it enters working memory (Koster, De Lissnyder, Derakshan, & De Raedt, 2011). This, in turns, leads to a state of sustained attention on the negative information. Extending these predictions, the *attentional scope model* posits that trait ruminators exhibit key characteristics of a constricted attentional scope, including difficulties updating working memory and inhibiting no-longer-relevant information, regardless of the valence of the information entering working memory (Whitmer & Gotlib, 2013). Accordingly, when individuals with a constricted attentional scope experience negative mood, mood-congruent thoughts are activated. This further limits the array of thoughts accessible in the already limited working memory. Because individuals with a constricted attentional scope also have difficulty processing and replacing new information, these thoughts remain accessible in working memory which increases perseveration on negative information (Whitmer & Gotlib, 2013).

On the other hand, the *multiple systems model of angry rumination* provides a framework for understanding the phenomenological experience of rumination across five levels of analysis: cognitive, neurobiological, affective, executive control, and behavioral. Upon encountering an emotionally inducing event, specific regions in the prefrontal cortex implicated in cognitive and emotional processes are activated and physiological responses are heightened (neurobiological level) based on how one perceives the event (cognitive level). This, in turn, influences the intensity and duration of the emotional experience (affective level). The ability to stop rumination once it begins is related to difficulty inhibiting and disengaging one's attention from negative information, as well as shifting one's attention from negative thoughts and stimuli (executive control level), which helps to maintain affect-specific cognitions. At the same time, ceasing rumination is effortful and can deplete executive control resources, which reduces self-control behavior and increases risk for aggression (behavioral level; Denson, 2013).

While current conceptual models converge in their emphasis on difficulty *inhibiting* information from entering working memory as a key neurocognitive correlate of rumination risk, they differ in their predictions regarding associations with other core executive functions, including some that do not implicate executive dysfunction beyond the inhibition system (Joormann, 2010; Koster et al., 2011). For instance, the attentional scope model focuses on individual differences in *updating* the contents of working memory with mood-incongruent thoughts in response to one's current mood state. In contrast, the multiple systems model points to *shifting* from mood-congruent to mood-incongruent thoughts as critical to regulating rumination. Therefore, questions remain regarding which executive functions are associated with rumination. The current study is the first to examine all three of these executive functions together in youth and to test these shared (inhibition) and competing (updating vs. shifting) predictions head-to-head.

At the same time, a limitation of current conceptual models is that their empirical bases are primarily drawn from literature focused on one type of negative affect, namely depressive or sad mood (sadness rumination; Whitmer & Gotlib, 2013). For instance, while the multiple systems model was developed within the aggression literature to explain the underlying processes associated with rumination in response to anger (anger rumination), much of its empirical support is drawn from literature on sadness rumination (Denson, 2013). However, similar to sadness rumination, anger rumination is associated with a range of psychological symptoms in adults and in youth, including increased aggression (e.g., Anestis, Anestis, Selby, & Joiner, 2009; Peled & Moretti, 2007; Smith, Stephens, Repper, & Kistner, 2016; Vasquez, Osman, & Wood, 2012), borderline personality features (Baer & Sauer, 2010), and depressive symptoms (e.g., Besharat, Nia, & Farahani, 2013; Harmon, Stephens, Repper, Driscoll, & Kistner, 2019; Selby, Anestis, & Joiner, 2007). Yet, few studies have examined the relation between anger rumination and executive control mechanisms, and this was particularly true at the time of the conceptualization of the multiple systems model. Since then, more empirical evidence has emerged demonstrating significant associations between anger rumination and impaired executive control, including poorer inhibitory (e.g., Ding, Yang, Qian, & Gordon-Hollingsworth, 2015; Whitmer & Banich, 2010) and shifting abilities (e.g., Ding et al., 2015; Whitmer & Banich, 2007).

There has also been an expansion of research that distinguishes between sadness rumination and anger rumination, yet rarely are both forms of rumination examined in the same study. Studies assessing both sadness and anger rumination have highlighted their unique emotional and behavioral correlates. For example, Peled and Moretti (2007, 2010) found that sadness rumination uniquely predicted depression and anger rumination uniquely predicted aggression in samples of adolescents and young adults. In contrast, Harmon and colleagues (2019) found that anger rumination, but not sadness rumination, uniquely predicted both aggressive and depressive symptoms in preadolescent youth, suggesting that anger rumination may be a bigger risk in the development of internalizing and externalizing psychopathology in preadolescent youth. As such, it is becoming clear that sadness and anger rumination are distinct, albeit correlated, constructs, but it remains unclear whether they differentially relate to executive function impairments in youth.

Another limitation to current conceptual models is that they have focused almost exclusively on adults. Examining the relation between rumination and executive functioning in preadolescent youth is important given that cognitive processes undergo significant developmental changes as children transition into adolescence (e.g., Boll & Bryant, 1988). Rumination is also operative during this developmental period and increases significantly into adolescence (Jose & Brown, 2008) where the primary outcomes of rumination (e.g., increased depressive symptoms) begin to fully manifest (Cohen et al., 1993; Kofler et al., 2011). Only a handful of studies have assessed associations between rumination and executive functions in youth, with mixed results (e.g., Connolly et al., 2014; Hilt, Leitzke, & Pollak, 2014; Wagner, Alloy, & Abramson, 2015; Wilkinson & Goodyer, 2006). For instance, only one study has examined the association between rumination and inhibition in youth (Hilt, Leitzke, & Pollak, 2014). Results of this study indicated a significant association between sadness rumination and difficulty inhibiting negative information. However, results examining relations between rumination and shifting are mixed, with one study showing a significant association between sadness rumination and shifting (Dickerson, Ciesla, & Zelic, 2017), but others failing to find such an association (Connolly et al., 2014; Hilt et al., 2014; Wagner et al., 2015; Wilkinson & Goodyer, 2006). Additionally, studies have failed to find links between sadness rumination and working memory maintenance/manipulation (Connolly et al., 2014; Wagner et al., 2015). To our knowledge, no study has examined sadness rumination in relation to working memory updating, examined anger rumination and executive functioning in youth, or concurrently examined all three primary executive functions in relation to sadness or anger rumination in youth. In addition, with few exceptions, studies examining executive functions and rumination have been limited to community samples, which may obfuscate relations by oversampling for higher levels of executive function abilities and lower levels of mood-related symptoms relative to clinically-enriched samples that are more likely to include children with internalizing symptoms and/or executive dysfunction impairments (Kofler et al., 2018; Wilkinson & Goodyear, 2006). As such, conclusions regarding associations between rumination and executive function abilities in youth are limited.

The current study addressed these limitations and was the first to test model-driven predictions regarding neurocognitive correlates of rumination in a clinically heterogeneous sample of preadolescent youth using a well-validated executive function framework and a battery of non-emotional executive function tasks. Non-emotional stimuli were selected to minimize the confounding effects of emotional stimuli on neurocognitive outcomes. A clinically heterogeneous sample including an oversampling of children with ADHD was recruited, which was expected to provide a broader range of executive functioning abilities given the disorder's well-documented neurocognitive heterogeneity (Kofler et al., 2019) as well as emerging evidence linking ADHD with increased risk for rumination (e.g., Jonkman, 2017; Mitchell, 2013). Based on consensus across existing theoretical frameworks (Denson, 2013; Joormann, 2010; Koster et al., 2011; Whitmer & Gotlib, 2013), we hypothesized that sadness and anger ruminative tendencies would be associated with poor inhibition. Given the scarcity of research examining rumination in relation to working memory updating and shifting in preadolescent youth, no specific hypotheses were offered. Finding that ruminative tendencies predict updating but not shifting abilities would provide support for the attentional scope model (Whitmer & Gotlib, 2013) and be consistent with recent findings in the adult literature (Zetsche, Bürkner, & Schulze, 2018). On the other hand, finding that ruminative tendencies predict shifting but not updating would provide support for the multiple systems model (Denson, 2013). No hypotheses were offered regarding differential associations between sadness and anger rumination with each executive function given the paucity of research examining both forms of rumination together and anger rumination specifically.

Method

Participants

The sample comprised 159 children, aged 8–13 years (mean age = 10.38, SD = 1.34; 53.5% male), from the Southeastern U.S. recruited through community resources from 2015–2018 for participation in a clinical research study of the neurocognitive mechanisms underlying pediatric attention and behavioral problems. This sample was ethnically diverse: 59.1% Caucasian (n = 94), 13.8% African American (n = 22), 11.9% Multiracial (n = 19), 10.1% Hispanic (n = 16), and 5.1% Asian/Pacific Islander (n = 8). The mean socioeconomic status for the sample was 47.20, which corresponds to caregiver(s) with a high school diploma employed as managers or small business owners (SD = 12.35; Hollingshead, 1975). All parents and children gave informed consent/assent, and approval was obtained from the Florida State University Institutional Review Board. Exclusion criteria included: 1) children with gross neurological, sensory, or serious motor impairment, or a history of seizure disorder, psychosis, or intellectual disability; and 2) children taking medications other than psychostimulants (e.g., selective serotonin reuptake inhibitors) used to treat ADHD due to the unknown impact of these medications on the cognitive functions of interest. Children meeting exclusion criteria were excluded prior to the start of the study via the initial phone screen or psychoeducational testing.

The first 97 participants completed a comprehensive evaluation that included detailed, semi-structured clinical interviewing using the Kiddie Schedule for Affective Disorders and

Schizophrenia for School-Aged Children (K-SADS; Kaufman et al., 1997). The K-SADS (2013 Update) allows differential diagnosis according to symptom onset, course, duration, quantity, severity, and impairment in children and adolescents based on DSM-5 criteria (APA, 2013), and was supplemented with parent and teacher ratings from the Behavior Assessment System for Children (BASC-2/3; Reynolds & Kamphaus, 2004; 2015) and ADHD Rating Scale-4/5 (ADHD-4/5; DuPaul et al., 2016). Please see the larger study's preregistration for a detailed account of the comprehensive psychoeducational evaluation and study procedures: https://osf.io/nvfer/. A psychoeducational report was provided to parents. Children who completed the comprehensive evaluation received primary DSM-5 clinical diagnoses of ADHD (58%), anxiety (3%), conduct problems (2%), autism spectrum disorder (ASD; 2%), or no diagnosis (typically developing; 35%) based on parent and teacher reports on the aforementioned assessments. Medication was withheld at least 24 hours for children taking psychostimulants (n=27).

Due to funding constraints, the final 62 participants completed an abbreviated screening evaluation that included parental report of current symptoms assessed by the BASC-3 (Reynolds & Kamphaus, 2015), parental report of developmental, medical, educational, and psychiatric histories via a semi-structured questionnaire, and a 1-subtest screener of intellectual functioning (IQ; WISC-V Matrix Reasoning; Wechsler, 2014) completed by the child. Children who completed the abbreviated evaluation presented with the following parent-reported previous clinical diagnoses: ADHD (13.8%), anxiety (1.7%), depression (1.7%), or no diagnosis (typically developing; 82.8%). Psychostimulants were withheld for 9 children (15.3%). Children did not differ significantly based on whether they received a full or abbreviated evaluation in terms of age, gender, or IQ (all $p > .05$). The abbreviated subgroup was, on average, more diverse (51.6% vs. 63.9% Caucasian) and had slightly lower socioeconomic status (M = 44.42, SD = 12.17 vs. M = 48.97, SD = 12.20) (both $p < .05$). Among the abbreviated evaluation subsample, BASC 2/3 T-scores for participants with a parent-reported diagnosis with ADHD was M=65.69 (SD = 8.01) for attention problems compared to M=54.33 (SD = 11.16) for those without ADHD. T-scores for hyperactivity/impulsivity was M=65.98 (SD = 13.12) for those with ADHD compared to M=54.57 (SD = 11.15) for those without.

Procedure

All children completed a series of questionnaires assessing their tendency to ruminate and a battery of computerized neurocognitive tasks to assess specific executive functions. Research procedures were conducted in one or two 3-hour visits. Neurocognitive tasks were counterbalanced to minimize order effects. The examiner was stationed just out of the child's view to provide a structured setting while minimizing performance improvements associated with examiner demand characteristics (Gomez & Sanson, 1994). All children received preset breaks (5–10 mins) after every 2–3 tasks to minimize fatigue.

Measures

Executive Functions.—Executive functions were measured using a battery of neurocognitive tasks selected based on evidence for strong construct validity and demonstrated ability to detect individual differences in various populations, including nonclinical adults (e.g., Miyake et al., 2000), typically developing children (e.g., St Clair-Thompson & Gathercole, 2006), and children with neurocognitive disorders (e.g., Alderson, Rapport, Sarver, & Kofler, 2008; Kofler et al., 2019; Raiker, Rapport, Kofler, & Sarver, 2012). Similar tasks have also been used in previous studies examining rumination in adults (e.g., Ding et al., 2015).

Letter Updating.: Updating ability was evaluated using the Letter Updating task (adapted for use with children from Miyake and colleagues' (2000) letter memory task). In this computerized task, letters were presented on the screen one at a time and children were instructed to keep track of the last three letters presented. To ensure continuous updating of working memory, children were instructed to rehearse out loud the last three letters by mentally adding the most recent letter and dropping the fourth letter back until the end of each trial (Miyake et al., 2000). Each child completed a practice block which required that each child complete three correct trials before advancing to the test phase. For the full task, four blocks of 3 trials each were administered. The number of letters presented (4–8 letters per trial, 1200 ms presentation, 2400 ms interstimulus interval) was varied randomly across trials to ensure continuous updating. Children responded by using the mouse to select the last three letters presented. The dependent variable was the mean stimuli recalled correctly per trial with scores ranging from 0–3 for each of the 4 test blocks. Higher scores indicated better updating ability. Internal consistency for this sample was $\alpha = 0.75$.

Stop-signal.: The stop-signal task was used to measure inhibition. The protocol was identical to those described in Alderson et al. (2008). Go-stimuli were displayed for 1000 ms as uppercase letters X and O positioned in the center of a computer screen (500 ms interstimulus interval; total trial duration = 1500 ms) and participants were asked to use a game-pad device to indicate which letter appeared on the display (e.g., press the left button after seeing the letter 'X', and the right button after seeing the letter 'O'). Xs and Os appeared with equal frequency throughout the experimental blocks. A 1000 Hz auditory tone (i.e., stop-stimulus) was presented randomly on 25% of trials. Children were instructed to stop responses when they heard the tone. All children completed two practice blocks and 4 consecutive experimental blocks of 32 trials per block (24 go-trials, 8 stop-trials per block). Stop-signal reaction time (SSRT), which reflects the speed of children's inhibition (stop) process, served as the dependent variable. SSRT at each of the four blocks served as the primary indices of inhibition with higher scores reflecting slower inhibition abilities. Psychometric evidence includes high internal consistency and 3-week test-retest reliability (0.72; Soreni, Crosbie, Ickowicz, & Schachar, 2009), as well as convergent validity with other inhibitory control measures (e.g., Alderson et al., 2008). Internal consistency in this sample was $\alpha = 0.98$.

Global-Local.: The Global-Local task was used to measure shifting. This task is based on the Miyake et al. (2000) local-global task and adapted for use with children (Irwin et al., 2019). Children were presented with Navon figures (Navon, 1977) which are larger shapes made up of different, smaller shapes presented in one of four quadrants on the computer screen. When stimuli appeared in either of the top two quadrants, children were asked to respond based on the global (larger) shape, disregarding the local (smaller) shapes. When stimuli appeared in either of the bottom two quadrants, children respond based on the local (smaller) shapes, disregarding the global (larger) shape. Children responded via mouse click. Trials with stimuli in the top left or bottom right quadrants involved set shifting (shift trials) because responses required a different rule than the previous trial. Trials with stimuli in the top right or bottom left quadrants did not require shifting because they featured the same rule as the previous trial (non-shift trials). Children completed a total of 60 trials which were divided into 4 consecutive blocks to match the number of outcome variables from the updating and inhibition tasks (Kofler et al., 2019). Fifty percent (50%) of trials require children to shift between rules (global to local, or local to global). To minimize memory demands, visual cues reminding participants of the rule set ("big shape," "small shapes") remained on the screen throughout the task. Children were required to complete three blocks of practice trials before advancing to the full task. During the first practice block, children were required to match shapes to ensure that they could match each shape to the response options. The second practice block included six trials alternating between responding to the global and local shapes (100% correct required for the first two practice trials). The final practice trial included the stimuli rotating (clockwise) through the four quadrants (90% correct required). The shift cost, or the difference between the average reaction time for the shift trials and the average reaction time for the non-shift trials, served as the dependent variable for each of the 4 test blocks. Higher reaction times indicated worse performance. Internal consistency in this sample was $\alpha = 0.86$ for the shift trials and $\alpha = 0.90$ for the non-shift trials (Kofler et al., 2019).

Executive Function Dimension Reduction.: Task impurity was controlled by computing Bartlett maximum likelihood component scores (DiStefano et al., 2009) based on the intercorrelations among all 12 executive function task scores (working memory updating blocks 1–4, inhibitory control blocks 1–4, set shifting blocks 1–4; 47.2% variance accounted; component loadings = .59 – .76; Table 1). These factor-analytically derived component scores provide estimates of reliable, latent/component -level variance attributable to each executive function while controlling for each of the other two executive functions. This formative method for estimating executive functioning was selected because (a) such methods have been shown to provide higher construct stability relative to confirmatory/ reflective approaches (Willoughby et al., 2016); and (b) estimating executive functions at the construct-level rather than measure-level was expected to maximize associations with the study's behavioral outcomes of interest via the removal of task-specific and error variance. Conceptually, this process isolates reliable variance across estimates of each executive function by removing task-specific demands associated with the other two executive functions, time-on-task effects via inclusion of four blocks per task, and non-construct variance attributable to other measured and unmeasured cognitive processes (e.g., short-term memory load). Orthogonal components were specified to derive independent factors and maximally control for task impurity (e.g., Kofler et al., 2016, 2019). The ratio of participants (159) to factors (3) was deemed acceptable (Hogarty, Hines, Kromrey, Ferron, & Mumford, 2005). Loadings for each performance variable on each executive function component are presented in Table 1. By design, the intercorrelations among the varimax-rotated updating, inhibition, and shifting components were $r = .00$. These updating (working memory), inhibition, and set shifting component scores were used in all analyses. Higher scores reflect better updating but worse inhibition and shifting abilities.

Rumination

Children's Response Styles Scale.—Trait sadness rumination was assessed using the Children's Response Styles Scale (CRSS), a 20-item self-report questionnaire of children's tendency to ruminate or distract in response to sad mood. Children were asked to rate the frequency with which they engage in rumination (i.e., "I think, 'Why can't I stop feeling this way?' ") or distracting behaviors (i.e., "I do something I really like to do") on an 11-point Likert scale, ranging from 0 ("never") to 10 ("always"). The Rumination subscale was used for analysis and consists of 10 items. The CRSS was demonstrated to be a reliable and valid measure of response styles in children (Ziegert & Kistner, 2002). Internal consistency for this sample was $\alpha = .86$. Total scores were used for analysis with possible scores ranging from 0–100. Higher scores indicate higher ruminative tendencies.

Children's Anger Rumination Scale.—Trait anger rumination was assessed using the Children's Anger Rumination Scale (CARS), a 19-item self-report questionnaire of children's tendency to ruminate in response to anger (i.e., "I think a lot about other times when I was angry"). Children were asked to rate their response on a 4-point Likert-scale, ranging from 1 ("almost never") to 4 ("almost always"). Total scores were used. The CARS was adapted from the Anger Rumination Scale (Sukhodolsky, Golub, & Cromwell, 2001) to be developmentally appropriate and has been shown to be a reliable and valid measure of anger rumination in children and adolescents (Smith et al., 2016). Internal consistency for this sample was $\alpha = .87$. Total scores were used for analysis with possible scores ranging from 19–76. Higher scores indicate higher ruminative tendencies.

Intellectual Functioning (IQ)

Intellectual functioning was assessed via the Wechsler-V (WISC-V) Short Form (Sattler et al., 2016) or the WISC-V Matrix Reasoning subtest (Wechsler, 2014).

Socioeconomic Status (SES)

SES was assessed via procedures outlined in Hollingshead (1975). Scores are based on caregiver(s)' education and current occupation and range from 8–66, with higher scores indicating a higher socioeconomic status.

Data Analyses

Multivariate regression analyses were conducted to assess associations between rumination and executive function variables, controlling for age and sex. Both sadness and anger rumination were included in each model to assess unique associations between each form of rumination and each executive function (updating, inhibition, shifting). We then conducted a series of sensitivity analyses to probe the extent to which our results were influenced by specific study design choices. Sadness and anger rumination were modeled as predictors of each executive function, rather than vice versa, to allow maximal comparability with the models used in previous studies examining concurrent and longitudinal associations between rumination and executive functions in youth (e.g., Connolly et al., 2014; Hilt, Leitzke, & Pollak, 2014; Wagner, Alloy, & Abramson, 2015; Wilkinson & Goodyer, 2006).

Results

Power Analysis

A priori power analysis for a multiple regression with 4 predictors was conducted using GPower version 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2014). Using an alpha of .05 and power of .80, our sample size of 159 is powered to detect small-to-medium effects of $f^2 = .08$ or larger. Thus, the study is adequately powered to test the effects of interest.

Preliminary Analyses

Prior to the analyses, all variables were examined for missing values, normality, skewness and kurtosis, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity. The Missing Value Analysis (MVA) in SPSS 25 revealed that 0.60% of data points (k =18) had missing data. To estimate the pattern of missing values, Little's (1988) Missing Completely at Random (MCAR) test was conducted and revealed a MCAR missing data pattern, χ^2 (60) = 66.05, $p = .28$. Missing data were accounted for using an expectation maximization (EM) algorithm that included all available variables (Tabachnick & Fidell, 2013). Inspection of histograms, Q-Q plots, and skewness and kurtosis were used to evaluate the distributions of all study variables for violations of the assumption of normality. Examination of skewness and kurtosis values revealed that all variables were within the acceptable range (skewness = +/− 2; kurtosis = +/−7). Based on recommendations outlined by Tabachnick and Fidell (2013), outliers +/− 3 standard deviations from the mean were winsorized relative to other values within that measure. This process affected 0.43% of data points. Mahalanobis distances suggested that there were no multivariate outliers. Task data from subsets of the current battery have been reported for subsets of the current sample to examine conceptually unrelated hypotheses as follows[1]. Data for the study's primary constructs of interest, sadness rumination and anger rumination, have not been previously reported. Consistent with previous studies (e.g., Harmon et al., 2019; Peled & Moretti, 2007, 2010), sadness and anger rumination were significantly correlated ($r = .48$, $p < .001$). Correlations for all study variables are found in Table 2.

Neurocognitive Correlates of Sadness and Anger Rumination

Results from each regression analysis are presented in Table 3.

Updating.—The results of the regression indicated that better developed working memory updating was associated with lower sadness rumination ($\beta = -.18$, $p = .046$), higher anger rumination ($\beta = .20$, $p = .03$), and older age ($\beta = .25$, $p < .01$). There were no detectable sex differences in updating abilities ($\beta = .11$, $p = .15$).

[1]The work is part of ongoing clinical research investigating the neurocognitive mechanisms underlying pediatric attention and behavioral problems. Performance data on differing subsets of the current study's tasks for subsets of the current sample were included in the datasets used to investigate conceptually-distinct hypotheses as follows: Data were reported in aggregate with other tasks to examine executive function heterogeneity (Kofler et al., 2019) and working memory heterogeneity in ADHD (Fosco et al., 2020), as predictors of social functioning (Kofler, Harmon et al., 2018) and sluggish cognitive tempo (Kofler, Irwin et al., 2019), and to investigate whether children with ADHD have set shifting deficits (Irwin et al., 2019).

Inhibition.—The results of the regression indicated that neither sadness rumination ($\beta = -.04$, $p = .62$) nor anger rumination were associated with inhibition ($\beta = .08$, $p = .35$). Better developed inhibition abilities were associated with older age ($\beta = -.37$, $p < .01$). There were no detectable sex differences in inhibition abilities ($\beta = .14$, $p = .05$).

Shifting.—The results of the regression indicated that shifting difficulties were associated with higher sadness rumination ($\beta = .20$, $p = .03$). Shifting was not associated with anger rumination ($\beta = -.15$, $p = .11$). There were no detectable age ($\beta = -.09$, $p = .26$) or sex ($\beta = -.11$, $p = .17$) differences in shifting abilities.

Sensitivity Analyses

A series of exploratory analyses were conducted to probe the impact of specific *a priori* methodological choices on study results. First, given the relatively broad age range of our sample and mixed evidence for sex differences in rumination (e.g., Harmon et al., 2019), the primary models were repeated, this time including age and sex as two-way interactions (e.g., age x sadness rumination, sex x anger rumination) in relation to each executive function. Results indicated that neither age nor sex moderated associations between anger and sadness rumination and each executive function (all $p > .30$). Second, we tested the extent to which the results were influenced by our data reduction methods. This involved repeating the primary models after specifying an oblique rather than orthogonal rotation when deriving the executive function component scores. The pattern and interpretation of results was unchanged when executive function scores were derived under an oblique model.

Third, we re-ran the primary models separately for anger and sadness rumination to probe the extent to which the results were impacted by our decision to control for domain-general rumination and shared-method factors (i.e., our decision to more precisely assess relations with each form of rumination by controlling for domain-general rumination and confounding variance associated with the questionnaire-based method used to assess each form of rumination). Results failed to support associations between either form of rumination and any assessed executive function (all $p > .12$), supporting the importance of examining the unique neurocognitive correlates of sadness rumination and anger rumination. Fourth, we probed the extent to which the results were affected by our *a priori* decision to oversample for ADHD. This involved re-running the primary models, this time with a) ADHD status (no/yes) added as a covariate and b) examining the moderating effects of ADHD status (sadness rumination x ADHD; anger rumination x ADHD). The pattern of results was unchanged when ADHD was included in each model; ADHD did not moderate associations between anger and sadness rumination and each executive function (all $p > .98$).

Fifth, we probed the extent to which the findings were impacted by our *a priori* decision to model sadness and anger rumination as predictors (IVs) rather than outcomes (DVs) of executive function difficulties. In these exploratory models, we reversed the IVs and DVs. That is, we modeled the three executive functions as predictors, and the rumination constructs as outcomes, controlling for age, sex, and the other form of rumination (i.e., 2 models, one with sadness rumination as the DV and the other with anger rumination as the DV). The results were highly consistent with those reported in the main text, such that worse updating (β=−.15, *p*=.039) and slower set shifting (β=.15, *p*=.026) predicted higher sadness rumination, and better updating (β=.16, *p*=.024) predicted higher anger rumination.

Sixth, we probed the extent to which the findings were impacted by our *a priori* decision to conduct three separate regression analyses. This involved including both forms of rumination (allowed to correlate) as predictors of all three executive functions in a path model using the R package lavaan (Rosseel, 2012). The pattern and interpretation of results was unchanged relative to those obtained via separate regressions (Figure 1).

Finally, we probed the extent to which the results were affected by our change from the comprehensive evaluation to the abbreviated screening procedure for the final 62 participants. This involved re-running the primary models, this time with just the participants who completed comprehensive clinical evaluations (*n*=97). Results were the same as those reported above, with one exception: With the smaller sample size, we were no longer powered to detect relations between shifting abilities and sadness rumination (β changed minimally .20 to .16, whereas the *p*-value crossed the significance threshold from .03 to .17), highlighting the importance of our *a priori* plan to increase the proportion of neurotypical children in the sample to provide a more psychologically diverse sample with a broader range of psychological symptoms and neurocognitive abilities.

Discussion

The current study tested competing model predictions regarding the neurocognitive correlates of rumination in a preadolescent sample by applying current theoretical frameworks drawn from adult samples. To our knowledge, this is the first study to examine these competing frameworks in youth. Differential associations between multiple forms of rumination and executive functions were explored by examining both sadness and anger rumination simultaneously in a clinically heterogeneous sample oversampled for ADHD that was selected in an effort to capture a broader range of internalizing symptoms and executive function abilities. To date, no study has examined the association between anger rumination and executive functions, or simultaneously examined all three primary executive functions in studies of rumination in youth.

Findings from this study offer partial support for the attentional scope and multiple systems models, but only for sadness rumination. That is, sadness rumination was associated with worse updating and shifting abilities as predicted by the attentional scope and multiple systems models, respectively. In contrast, sadness rumination was not associated with inhibition difficulties, which was inconsistent with theoretical predictions from both models. Neither model was supported for anger rumination, which was associated with *better* updating abilities. Together, this study provides novel insights into the differential neurocognitive correlates of sadness and anger rumination in youth. It also highlights the importance of differentiating between anger and sadness rumination given their moderate intercorrelation and distinct neurocognitive correlates. Possible explanations for these findings and implications regarding the associations between rumination and executive function in youth are considered next.

To our knowledge, the current study is the first to examine sadness rumination in relation to updating abilities in youth. Our finding that elevated sadness rumination in youth was associated with difficulty retrieving and replacing new information in working memory replicates previous findings observed in the adult literature (Zetsche, Bürkner, & Schulze, 2018), including larger sorting costs (e.g., Joormann, Levens, & Gotlib, 2011), slower "refreshing" (e.g., Bernblum, & Mor, 2010), and difficulty removing emotion-laden information in working memory (e.g., Joormann & Gotlib, 2008), providing partial evidence for a downward extension of the attentional scope model.

Furthermore, our finding that sadness rumination was associated with shifting difficulties offers partial support for a downward extension of the multiple systems model, such that youth who ruminate to sadness are characterized by difficulty quickly switching their attention and thoughts away from negative stimuli. However, this association is inconsistent with the null findings observed in the majority of previous studies conducted among youth (Connolly et al., 2014; Hilt et al., 2014; Wagner et al., 2015; Wilkinson & Goodyer, 2006). A possible explanation for this inconsistency may reflect differences in the measures used to assess shifting abilities. For instance, the neurocognitive measures used in the current study were selected based on strong construct validity evidence, however, several of the previous studies (Connolly et al., 2014; Wagner et al., 2015; Wilkinson & Goodyer, 2006) examined these relations using traditional neuropsychological measures that may assess gross neuropsychological functioning rather than shifting specifically (for review, see Snyder, Miyake, & Hankin, 2015).

The most surprising finding in our study was that neither sadness nor anger rumination were associated with the ability to inhibit prepotent responses. Instead, these findings suggest that it is difficulty *replacing* negative thoughts and shifting between mental sets, and not difficulty suppressing negative thoughts and automatic responses, that is associated with ruminative tendencies. One possibility for the observed differences between this and previous studies regarding inhibitory control (e.g., Ding et al., 2015; Hilt et al., 2014; Whitmer & Banich, 2010) may be that the current study accounted for task impurity by controlling for concurrent updating and shifting processes. These processes, namely maintaining competing rule sets and flexibly going back and forth between rule sets, are likely involved in successful performance on inhibition tasks (Irwin et al., 2019). Future studies should use measures consistent with recommendations from the cognitive literature that may best capture these specific cognitive abilities (Snyder et al., 2015). Alternatively, differences may be due to variations in how inhibition is operationalized across studies (Vălenaş & Szentágotai-Tătar, 2017). Inhibition is not a unitary construct but is often used interchangeably to describe various processes, including the inhibition of external vs. internal distractions (i.e., cognitive inhibition), inhibition of prepotent responses (e.g., Aker, Harmer, & Landrø, 2014; Friedman & Miyake, 2004; Nigg, 2000), and/or processes associated with cancelling an in-progress action vs. stopping oneself from beginning a prepotent but unwanted behavior (i.e., behavioral inhibition; e.g., Alderson, Rapport, & Kofler, 2007). The inhibition task used in the current study (i.e., stop-signal) assessed behavioral inhibition; however, future studies may care to measure inhibition using tasks that more specifically assess cognitive rather than behavioral inhibition. That is, individuals who ruminate may be most likely have difficulty suppressing thoughts or no-longer-relevant information, rather than difficulty stopping a prepotent behavioral response (e.g., Whitmer & Gotlib, 2013). In addition, future studies may benefit from inclusion of a battery of tasks assessing multiple forms of inhibition, such as the ability to inhibit no-longer-relevant information as well as the ability to inhibit external distractors.

Contrary to the predictions outlined by the attentional scope model, this study found that anger rumination was associated with *better* updating abilities. The direction of this finding was surprising particularly given the negative association between sadness rumination and updating. This finding suggests that anger ruminators, compared to sadness ruminators, are better able to process and sort information necessary for achieving an immediate goal. There are several possibilities that may account for different findings between sadness and anger rumination. One possibility is that working memory may serve different purposes for sadness versus anger rumination. For instance, within the attentional scope framework, because ruminators are characterized by a narrowed attentional scope, the process of rumination is rather automatic when negative mood is experienced (Whitmer & Gotlib, 2013). Therefore, an adequate ability to update negative thoughts with less negative thoughts is necessary to actively break the cycle of repetitive thought within the context of sadness rumination. However, for anger rumination, the process may be less automatic and more cognitively demanding, which would require better updating abilities to maintain task-relevant information (i.e., the task here being to “stay mad”). Also, because anger rumination is often the result of a provocation, youth with better updating abilities may be more capable of maintaining an angry experience through constant mental rehearsal in hopes of future retaliation (e.g., Denson, 2013). However, given that this is the first child study, to our knowledge, to examine anger rumination in relation to updating abilities, hypotheses regarding this relation should be considered tentative. While further investigation is needed to better understand differential associations between sadness and anger rumination, this finding adds to the evidence that these two forms of rumination are in fact different.

The differential neurocognitive correlates observed between sadness and anger rumination underscores the importance of examining multiple forms of rumination together. Similar to the current pattern of results, Harmon and colleagues (2019) found that controlling for both sadness and anger rumination revealed unique behavioral correlates (i.e., anger rumination and not sadness rumination was uniquely associated with children’s depressive symptoms). These associations were unobserved in previous studies as most studies focused on only one type of rumination. Not controlling for the other form of rumination increases the possibility of overlooking significant and unique results. In light of the large body of research examining rumination in relation to executive function, to our knowledge, the current study was the first to examine sadness and anger rumination concurrently. Future research is necessary to replicate and investigate these associations further.

Limitations and Future Directions

The current study addressed a gap in the literature by providing the largest and most complete test to date of the relations between different forms of rumination and executive function in youth, using gold standard neurocognitive tests and a modeling approach that allowed us to differentiate among the executive functions as well as among two distinct forms of rumination (which in turn have unique clinical correlates). Additional strengths of the study included our method for estimating component scores to control for process impurity among executive functions, examination of and control for multiple forms of rumination, and inclusion of a relatively large and clinically heterogeneous sample of children that allowed examination of effects across a broader range of ruminative tendencies, executive function abilities, and psychological symptoms. At the same time, several caveats merit consideration when interpreting results. First, funding constraints prevented us from completing comprehensive evaluations with a subset of the participants, which may limit the clinical inferences drawn from these data despite these children completing the same standardized measures and neurocognitive tasks as the children who received the comprehensive evaluation. Second, the study is cross-sectional. Therefore, causal attributions cannot be drawn, and it remains unclear whether ruminative tendencies produce executive function difficulties, whether the reverse is true (executive dysfunction increasing children's risk for rumination), or whether there may be third variable explanations that account for the relations detected herein. Future experimental and longitudinal work is needed to clarify this directionality, particularly in light of conceptual models suggesting that these relations may be bidirectional (e.g., Denson, 2013).

Third, several of our findings stood in contrast to the limited available evidence regarding executive functions and rumination in youth. There are several factors unique to the current study design that may account for the similarities and differences observed between this and previous studies. One possibility is the emotional-valence of previous neurocognitive tasks. For instance, Joormann and Tran (2009) found that high sadness ruminators had more difficulty forgetting positive and negative to-be-forgotten words while others have noted significant associations between rumination and reduced inhibition of negative material (De Lissnyder, Koster, Derakshan, & De Raedt, 2010; Hilt et al., 2014; Joormann & Gotlib, 2010). Additionally, sadness rumination has been associated with intrusions from task-irrelevant negative material (Joormann & Gotlib, 2008), difficulty removing task-irrelevant negative material (Joormann & Gotlib, 2008) and larger sorting costs for negative words (Joormann et al., 2011). Interestingly, these associations were not observed for positive (Joormann & Gotlib, 2008; Joormann et al., 2011) or neutral material (Joormann & Gotlib, 2008) and only among depressed participants and not controls (non-depressed high ruminators; Joormann & Gotlib, 2008). However, our use of non-emotional stimuli, which is consistent with previous studies among youth (e.g., Connolly et al., 2014; Wagner et al., 2015; Wilkinson & Goodyer, 2006), is likely a strength rather than a limitation given that using emotional stimuli may confound results by evoking additional cognitive processes independent of executive functioning (e.g., Whitmer & Gotlib, 2013). Additionally, within the framework of the attentional scope model, high ruminators should demonstrate a constricted attentional scope regardless of the type of information presented to them (Whitmer & Gotlib, 2013). Together, these findings suggest that the difficulties observed among high ruminators in previous studies may be a byproduct of processing emotional (negative) stimuli rather than difficulties associated with broader cognitive abilities *per se*. Future studies using an experimental, dual-dissociation paradigm (low/high executive function demands x negative/positive/neutral stimuli) are warranted to assess whether negative stimuli reduce task performance for ruminators generally or specifically on high executive function tasks within this age group.

Similarly, it is important to consider differences in the measures used to assess sadness and anger rumination as an alternative explanation for our findings. Given that the study focused on children rather than adults, measures were selected that were developmentally sensitive. The measures of sadness and anger rumination used in this study were adapted from the well-validated measures frequently used in the adult literature (i.e., Response Styles Questionnaire; RSQ; Butler & Nolen-Hoeksema, 1994; Anger Rumination Scale, ARS; Sukhodolsky et al., 2001, respectively). Importantly, however, both adapted rumination measures have been found previously to be reliable and valid indicators of children's tendencies to ruminate in response to sadness (Ziegert & Kistner, 2002) and anger (Smith et al., 2016). Additionally, sadness and anger rumination were significantly correlated in our sample ($r = .48$) and the magnitude of this association is very similar to what Harmon et al. (2019) found in their study of similarly aged children. While we cannot completely rule out this explanation for discrepant results, it does not seem likely for the reasons noted above.

Another difference in methods that might help to explain discrepant results across studies is our oversampling of children diagnosed with ADHD. As noted previously, this was done purposely to capture a broader range of executive function abilities given the well documented heterogeneity of executive functioning observed in pediatric ADHD (Kofler et al., 2019). Because the unique and shared neurocognitive correlates between rumination and ADHD are not well understood, it is possible that impairments observed in our study were a byproduct of impairments associated with ADHD. To explore this idea, we re-examined our primary regression models controlling for ADHD status. If our oversampling for ADHD accounted for our findings, one would expect the links between rumination and executive dysfunction to disappear once we controlled for ADHD status. This is not what we found. Results indicated that doing so did not change the previously reported associations. Additionally, in a separate analysis, we also examined the moderating effects of ADHD status. Again, results did not change when examining these interactions. Finally, we probed for potential differences in rumination tendencies between children with and without ADHD, and found no evidence to suggest that ADHD is associated with increased risk for rumination (Table 1). Together, these findings suggest that among youth who ruminate, similar impairments of executive functions are observed regardless of ADHD diagnosis.

A final limitation worth noting is our application of the multiple systems model of angry rumination to both sadness and anger rumination. As previously noted, the multiple systems model emerged to explain rumination in response to anger, however, much of the empirical evidence supporting this model was drawn from studies examining sadness rumination. Even so, understanding the presence and regulation of anger is important given that it is one form of negative affect that is present across psychological disorders in youth (American Psychiatric Association, 2013). Given this, results from the current study highlight the importance of developing conceptual models of rumination that specifically assess anger rumination in youth.

Conclusions

The primary aim of this study was to provide the first examination of relations between multiple forms of rumination and executive function in preadolescent youth. Overall, the results were partially consistent with predictions from both conceptual models, in that children who ruminate to sadness cues demonstrated more difficulties with cognitive flexibility (shifting) and updating working memory. Interestingly however, rumination was not associated with difficulty inhibiting, suggesting that the tendency to ruminate has less to do with difficulty suppressing thoughts/responses and more to do with difficulty replacing and shifting between those thoughts – at least with regards to sadness rumination. Unexpectedly, children with *better* working memory updating abilities tended to report higher levels of anger rumination, suggesting that anger rumination may be a more active process than sadness rumination, and highlighting the importance of distinguishing between these correlated but distinct forms of rumination. These findings provide an initial step toward extending and modifying existing conceptual models of rumination to youth, and provide additional evidence that the distinct correlates of sadness rumination vs. anger rumination extend beyond affective symptoms and behaviors in youth.

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References

Aker M, Harmer C, & Landrø NI (2014). More rumination and less effective emotion regulation in previously depressed women with preserved executive functions. BMC Psychiatry, 14. doi: 10.1186/s12888-014-0334-4

Alderson RM, Rapport MD, & Kofler MJ (2007). ADHD and behavioral inhibition: A meta-analytic review of the stop-signal paradigm. Journal of Abnormal Child Psychology, 35, 745–758.

Alderson RM, Rapport MD, Sarver DE, & Kofler MJ (2008). ADHD and behavioral inhibition: A re-examination of the stop-signal task. Journal of Abnormal Child Psychology, 36, 989–998.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). Arlington, VA: American Psychiatric Publishing.

Anestis MD, Anestis JC, Selby EA, & Joiner TE (2009). Anger rumination across forms of aggression. Personality and Individual Differences, 46, 192–196. doi:10.1016/j.paid.2008.09.026

Arbuthnott K & Frank J (2000). Executive control in set switching: Residual switch cost and task-set inhibition. Canadian Journal of Experimental Psychology, 54, 33–41. doi: 10.1037/h0087328

Baer RA, & Sauer SE (2011). Relationships between depressive rumination, anger rumination, and borderline personality features. Personality Disorders: Theory, Research, and Treatment, 2, 142–150. doi:10.1037/a0019478

Bernblum R, & Mor N (2010). Rumination and emotion-related biases in refreshing information. Emotion, 10, 423–432. doi:10.1037/a0018427

Besharat MA, Nia ME, & Farahani H (2013). Anger and major depressive disorder: The mediating role of emotion regulation and anger rumination. Asian Journal of Psychiatry, 6, 35–41. doi:10.1016/j.ajp.2012.07.013

Boll T & Bryant B (1988). Clinical neuropsychology and brain function: Research, measurement, and practice. American Psychological Association, Washington, DC. doi: 10.1037/10063-000

Butler LD, & Nolen-Hoeksema S (1994). Gender differences in responses to depressed mood in a college sample. Sex Roles, 30, 331–346. doi:10.1007/BF01420597

Caprara GV, Paciello M, Gerbino M, & Cugini C (2007). Individual differences conducive to aggression and violence: trajectories and correlates of irritability and hostile rumination through adolescence. Aggressive Behavior, 33, 359–374.

Cohen P, Cohen J, Kasen S, Velez CN, Hartmark C, Johnson J, … Streuning EL (1993). An epidemiological study of disorders in late childhood and adolescence? I. age- and gender-specific prevalence. Journal of Child Psychology and Psychiatry, 34, 851–867.

Connolly SL, Wagner CA, Shapero BG, Pendergast LL, Abramson LY, & Alloy LB (2014). Rumination prospectively predicts executive functioning impairments in adolescents. Journal of Behavior Therapy and Experimental Psychiatry, 45, 46–56.

Davis RN, & Nolen-Hoeksema S (2000). Cognitive inflexibility among ruminators and non-ruminators. Cognitive Therapy & Research, 24, 699–711. doi: 10.1023/A:1005591412406

De Lissnyder E, Derakshan N, De Raedt R, & Koster EHW (2010). Depressive symptoms and cognitive control in a mixed antisaccade task: Specific effects of depressive rumination. Cognition & Emotion, 25, 886–897. doi:10.1080/02699931.2010.514711

De Lissnyder E, Koster EHW, Derakshan N, & De Raedt R (2010). The association between depressive symptoms and executive control impairments in response to emotional and non-emotional information. Cognition and Emotion, 24, 264–280. doi: 10.1080/02699930903378354

Denson TF (2013). The multiple systems model of angry rumination. Personality and Social Psychology Review, 17, 103–123.

Dickerson KS, Ciesla JA, & Zelic K (2017). The role of executive functioning in adolescent rumination and depression. Cognitive Therapy and Research, 41, 62–72. doi:10.1007/s10608-016-9802-0

DiStefano C, Zhu M, & Mîndrilă D (2009). Understanding and using factor scores: Considerations for the applied researcher. Practical Assessment, Research and Evaluation, 14, 1–11.

Ding X, Yang Y, Qian M, & Gordon-Hollingsworth A (2015). Specific Effects of Anger Rumination on Particular Executive Functions. Psychological Reports, 117, 825–841. doi:10.2466/02.09.PR0.117c24z8

DuPaul GJ, Power TJ, Anastopoulos AD, & Reid R (2016). ADHD rating scale-5 for children and adolescents: Checklists, norms, and clinical interpretation. New York: Guilford Press.

Faul F, Erdfelder E, Lang AG, & Buchner A (2014). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior Research Methods, 39, 175–191.

Friedman NP, & Miyake A (2004). The relations among inhibition and interference control functions: a latent-variable analysis. Journal of Experimental Psychology: General, 133, 101–135. doi: 10.1037/0096-3445.133.1.101

Gilbert P, Cheung M, Irons C, & McEwan K (2005). An exploration into depression-focused and anger-focused rumination in relation to depression in a student population. Behavioural and Cognitive Psychotherapy, 33, 273–283. doi: 10.1017/S1352465804002048

Gomez R, & Sanson A (1994). Effects of experimenter and mother presence on the attentional performance and activity of hyperactive boys. Journal of Abnormal Child Psychology, 22, 517–529.

Harmon SL, Stephens HF, Repper KK, Driscoll KA, & Kistner JA (2019). Children's rumination to sadness and anger: Implications for depression and aggression. Journal of Clinical Child and Adolescent Psychology, 48, 622–632.

Hilt LM, Leitzke BT, & Pollak SD (2014). Cognitive control and rumination in youth: The importance of emotion. Journal of Experimental Psychopathology, 5, 302–313.

Hilt LM, McLaughlin KA, & Nolen-Hoeksema S (2010). Examination of the response styles theory in a community sample of young adolescents. Journal of Abnormal Child Psychology, 38, 545–556.

Hogarty KY, Hines CV, Kromrey JD, Ferron JM, & Mumford KR (2005). The quality factor solutions in exploratory factor analysis: The influence of sample size, communality, and overdetermination. Educational and Psychological Measurement, 65, 202–226.

Hollingshead AB (1975). Four factor index of social status. Yale: New Haven

Irwin LN, Kofler MJ, Soto EF, & Groves NB (20192019). Do children with attention-deficit/hyperactivity disorder (ADHD) have set shifting deficits? Neuropsychology, 33, 470–481. doi: 10.1037/neu0000546

Jonkman LM, Markus CR, Franklin MS, & Dalfsen JH (2017). Mind wandering during attention performance: Effects of ADHD-inattention symptomatology, negative mood, ruminative response style and working memory capacity. Plos One, 12, doi:10.1371/journal.pone.0181213

Joormann J (2010). Cognitive inhibition and emotional regulation. Current Directions in Psychological Science, 19, 161–166. doi:10.1177/0963721410370293

Joormann J, & Gotlib IH (2008). Updating the contents of working memory in depression: Interference from irrelevant negative material. Journal of Abnormal Psychology, 117, 182–192. doi: 10.1037/0021-843X.117.1.182

Joormann J, & Gotlib IH (2010). Emotion regulation in depression: Relation to cognitive inhibition. Cognition and Emotion, 24, 281–298. doi: 10.1080/02699930903407948

Joormann J, Levens SM, & Gotlib IH (2011). Sticky thoughts: Depression and rumination are associated with difficulties manipulating emotional material in WM. Psychological Science, 22, 979–983. doi: 10.1177/0956797611415539

Joormann J, & Tran TB (2009). Rumination and intentional forgetting of emotional material. Cognition & Emotion, 23, 1233–1246.

Jose PE, & Brown I (2008). When does the gender difference in rumination begin? Gender and age differences in the use of rumination by adolescents. Journal of Youth and Adolescence, 37, 180–192. doi: 10.1007/s10964-006-9166-y

Karr JE, Areshenkoff CN, Rast P, Hofer SM, Iverson GL, & Garcia-Barrera MA (2018). The unity and diversity of executive functions: A systematic review and re-analysis of latent variable studies. Psychological bulletin, 144: 1147–1185. doi: 10.1037/bul0000160

Kaufman J, Birmaher B, Brent D, et al. (1997). Schedule for affective disorders and schizophrenia for school-age children (K-SADS-PL): Initial reliability and validity data. Journal of the American Academy of Child and Adolescent Psychiatry, 36, 980–988.

Kofler MJ, Irwin LN, Soto EF, Groves NB, Harmon SL, & Sarver DE (20192019). Executive Functioning heterogeneity in pediatric ADHD Journal of Abnormal Child Psychology, 47: 273–286.

Kofler MJ, McCart MR, Zajac K, Ruggiero KJ, Saunders BE, & Kilpatrick DG (2011). Depression and delinquency covariation in an accelerated longitudinal sample of adolescents. Journal of Counseling and Clinical Psychology, 79, 458–469.

Kofler MJ, Sarver DE, Spiegel JA, Day TN, Harmon SL, & Wells EL (2016). Heterogeneity in ADHD: Neurocognitive predictors of peer, family, and academic functioning. Child Neuropsychology, 1–27. doi: 10.1080/09297049.2016.1205010

Koster EHW, De Lissnyder ED, Derakshan N, & De Raedt R (2011). Understanding depressive rumination from a cognitive science perspective: perspective: The impaired disengagement hypothesis. Clinical Psychology Review, 31, 138–145. doi:10.1016/j.cpr.2010.08.005

McLaughlin KA, Aldao A, Wisco BE, & Hilt LM (2014). Rumination as a transdiagnostic factor underlying transitions between internalizing symptoms and aggressive behavior in early adolescents. Journal of Abnormal Psychology, 123, 13–23.

McLaughlin KA, & Nolen-Hoeksema S (2011). Rumination as a transdiagnostic factor in depression and anxiety. Behaviour Research and Therapy, 49, 186–193.

Mitchell JT, Benson JW, Knouse LE, Kimbrel NA, & Anastopoulos AD (2013). Are Negative Automatic Thoughts Associated with ADHD in Adulthood? Cognitive Therapy and Research, 37, 851–859. doi:10.1007/s10608-013-9525-4

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

Miyake A, Friedman NP, Emerson MJ, Witzki AH, & Howerter A (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. Cognitive Psychology, 41, 49–100.

Monsell S (1996). Control of mental processes. In Bruce V (Ed.), Unsolved mysteries of the mind: Tutorial essays in cognition (pp. 93–148). Hove, UK: Erlbaum.

Morris N, & Jones DM (1990). Memory updating in working memory: The role of the central executive. British Journal of Psychology, 81, 111–121.

Navon D (1977). Forest before trees: The precedence of global features in visual perception. Cognitive Psychology, 9, 353–383.

Nigg JT (2000). On inhibition/disinhibition in developmental psychopathology: Views from cognitive and personality psychology and a working inhibition taxonomy. Psychological Bulletin, 126(2), 220–246. doi:10.1037/0033-2909.126.2.220

Nolen-Hoeksema S, Stice E, Wade E, & Bohon C (2007). Reciprocal relations between rumination and bulimic, substance abuse ad depressive symptoms in female adolescents. Journal of Abnormal Psychology, 116, 198–207.

Nolen-Hoeksema S, Wisco BE, & Lyubomirsky S (2008). Rethinking rumination. Perspectives on Psychological Science, 3, 400–424.

Peled M, & Moretti MM (2007). Rumination on anger and sadness in adolescence: Fueling of fury and deepening of despair. Journal of Clinical Child and Adolescent Psychology, 36, 66–75.

Peled M, & Moretti MM (2010). Ruminating on rumination: Are rumination on anger and sadness differentially related to aggression and depressed mood? Journal of Psychopathology and Behavioral Assessment, 32, 108–117.

Raiker JS, Rapport MD, Kofler MJ, & Sarver DE (2012). Objectively-measured impulsivity and ADHD: Testing competing predictions from the working memory and behavioral inhibition models of ADHD. Journal of Abnormal Child Psychology, 40, 699–713.

Reynolds CR, Kamphaus RW (2004) Behavior assessment system for children (2nd ed.). Bloomington, MN: Pearson Assessments.

Reynolds CR, & Kamphaus RW (2015). Behavior assessment system for children (3rd ed.). Bloomington, MN: Pearson Assessments.

Rood L, Roelofs J, Bögels SM, Nolen-Hoeksema S, & Schouten E (2009). The influence of emotion-focused rumination and distraction on depressive symptoms in non-clinical youth: A meta-analytic review. Clinical Psychology Review, 29, 607–616.

Rosseel Y (2012). Iavaan: An R Package for Structural Equation Modeling. Journal of Statistical Software, 48(2), 1–36. http://www.jstatsoft.org/v48/i02/.

Sattler J, Dumont R, & Coalson D (2016). Assessment of Children: WISC-V and WPPSI-IV. San Diego: Sattler Press.

Selby EA, Anestis MD, & Joiner TE (2007). Daydreaming about death: Violent daydreaming as a form of emotion dysregulation in suicidality. Behavior Modification, 31, 867–879. doi:10.1177/0145445507300874

Smith SD, Stephens HF, Repper K, & Kistner JA (2016). The relationship between anger rumination and aggression in typically developing children and high-risk adolescents. Journal of Psychopathology and Behavioral Assessment, 38, 515. doi: 10.1007/s10862-016-9542-1

Snyder HR, Miyake A, & Hankin BL (2015). Advancing understanding of executive function impairments and psychopathology: bridging the gap between clinical and cognitive approaches. Frontiers in Psychology, 6, 328.

Soreni N, Crosbie J, Ickowicz A, & Schachar R (2009). Stop signal and Conners' CPT: Test-retest reliability of two inhibition measures in ADHD children. Journal of Attention Disorders, 13, 137–143.

St Clair-Thompson HL, & Gathercole SE (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. The Quarterly Journal of Experimental Psychology, 59, 745–759.

Sukhodolsky DG, Golub A, & Cromwell EN (2001). Development and validation of the anger rumination scale. Personality and Individual Differences, 31, 689–700. doi:10.1016/S0191-8869(00)00171-9

Tabachnick BG, & Fidell LS (2013). Using multivariate statistics. Boston: Pearson Education.

Vălenaş SP & Szentágotai-Tătar A (2017). The relationship between rumination and executive functions: A meta-analysis. Journal of Evidence-Based Psychotherapies, 17, 23–52.

Vasquez EA, Osman S, & Wood JL (2012). Rumination and the displacement of aggression in United Kingdom gang-affiliated youth. Aggressive Behavior, 38, 89–97.

Wagner CA, Alloy LB, & Abramson LY (2015). Trait rumination, depression, and executive functions in early adolescence. Journal of Youth and Adolescence, 44, 18–36.

Watkins ER (2009). Depressive rumination and co-morbidity: Evidence for brooding as a transdiagnostic process. Journal of Rational-Emotive & Cognitive-Behavior Therapy, 27, 160–175.

Wechsler D (2014). WISC-V: Technical and Interpretive Manual. Bloomington, MN: Pearson.

Whitmer AJ, & Banich MT (2007). Inhibition versus switching deficits in different forms of rumination. Psychological Science, 18, 546–553. doi:10.1111/j.1467-9280.2007.01936.x

Whitmer AJ, & Banich MT (2010). Trait rumination and inhibitory deficits in long-term memory. Cognition & Emotion, 24, 168–179. doi:10.1080/02699930802645762

Whitmer AJ, & Gotlib IH (2013). An attentional scope model of rumination. Psychological Bulletin, 139, 1036–1061.

Wilkinson PO & Goodyer IM (2006). Attention difficulties and mood-related ruminative response style in adolescents with unipolar depression. Journal of Child Psychology and Psychiatry, 47, 1284–1291.

Willoughby MT, Blair CB, & The Family Life Project Investigators. (2016). Measuring executive function in early childhood: A case for formative measurement. Psychological Assessment, 28, 319–330.

Zetsche Bürkner, & Schulze (2018). Shedding light on the association between repetitive negative thinking and deficits in cognitive control – A meta-analysis. Clinical Psychology Review, 63, 56–65. doi: 10.1016/j.cpr.2018.06.001

Ziegert DI, & Kistner JA (2002). Response styles theory: Downward extension to children. Journal of Clinical Child and Adolescent Psychology, 31, 325–334.

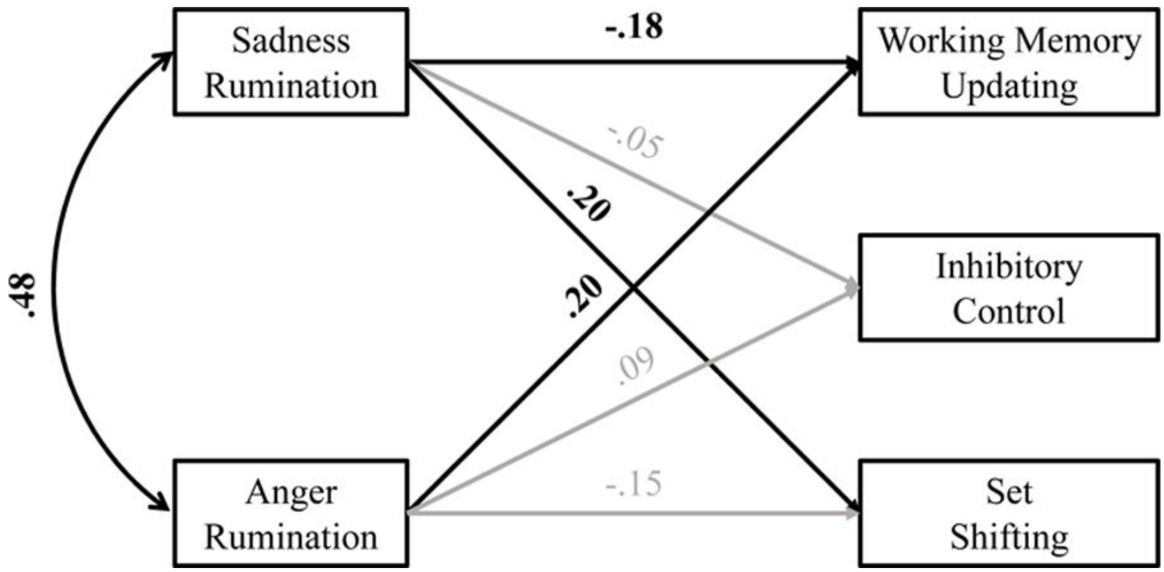

Figure 1.

Path Model of Relations Among Sadness/Anger Rumination and Each Executive Function

Note. Age and sex were controlled but not shown for clarity. Significant paths are bolded (p < .05); non-significant paths are shown in grey font.

Table 1

Loadings of Performance Variables on Executive Function Components

	Updating	Inhibition	Shifting
Letter Updating Block 1	**.64**	−.24	−.15
Letter Updating Block 2	**.70**	−.08	.08
Letter Updating Block 3	**.73**	−.11	−.07
Letter Updating Block 4	**.75**	−.04	−.08
Stop-Signal Block 1	−.02	**.76**	.10
Stop-Signal Block 2	−.01	**.74**	.08
Stop-Signal Block 3	−.26	**.64**	−.15
Stop-Signal Block 4	−.12	**.61**	−.11
Global-Local Block 1	−.14	−.01	**.59**
Global-Local Block 2	.12	−.18	**.59**
Global-Local Block 3	−.07	.16	**.76**
Global-Local Block 4	−.26	−.21	−.16

Note. Component loadings are based on varimax rotation. Loadings equal or greater than .32 shown in bold. All 12 executive function performance variables were included in a single principal components analysis, with component scores saved via the Bartlett method, to maximally control for task impurity (DiStefano et al., 2009).

Table 2

Intercorrelations of Study Variables

		1	2	3	4	5	6	7	8	9	10
1.	Age	--	−.06	.10	−.08	.05	$.19^{*}$	--	$.21^{**}$	$−.39^{***}$	−.05
2.	Sex	−.08	--	.004	.09	$−.27^{**}$	.08	--	.07	$.16^{*}$	−.09
3.	SES	.11	.01	--	$.16^{*}$	−.01	−.08	--	.12	−.07	−.11
4.	IQ	−.06	.09	$.15^{\dagger}$	--	$−.16^{*}$	−.07	--	$.28^{***}$	.05	−.08
5.	ADHD	.06	$−.27^{**}$	−.02	$−.17^{*}$	--	−.09	--	$−.23^{**}$	.05	.06
6.	Sadness Rumination	--	--	--	--	--	--	--	−.12	−.10	$.16^{*}$
7.	Anger Rumination	$−.19^{*}$	.02	.02	−.04	.05	--	--	--	--	--
8.	Updating Component	$.20^{*}$	.12	.12	$.26^{**}$	$−.23^{**}$	--	$.15^{\dagger}$	--	.00	.00
9.	Inhibition Component	$−.39^{***}$	$.17^{*}$	−.08	.04	.05	--	$.15^{\dagger}$	.00	--	.00
10.	Shifting Component	−.06	−.10	−.10	−.06	.07	--	−.12	.00	.00	--

Note. The bottom/left triangle reflects partial correlations with anger rumination, controlling for sadness rumination. The top/right triangle reflects partial correlations with sadness rumination, controlling for anger rumination. The sadness rumination/anger rumination correlation is r=.48, $p < .001$. SES = socioeconomic status; IQ = intellectual functioning; ADHD = ADHD status (no/yes)

$^{\dagger}p < .10$

$^{*}p < .05$

$^{**}p < .01$

$^{***}p < .001$

Table 3

Multiple Regression Analyses Examining Concurrent Associations

	Updating			Inhibition			Shifting		
	b	***SE***	**β**	***b***	***SE***	**β**	***b***	***SE***	**β**
Age	.19	.06	.25**	−.28	.06	−.37***	−.07	.06	−.10
Sex	.22	.16	.11	.29	.15	.14	−.22	.16	−.11
Sadness Rumination	−.01	.00	−.18*	−.00	.00	−.04	.01	.00	.20*
Anger Rumination	.02	.01	.20*	.01	.01	.08	−.01	.01	−.15

Note.

* $p < .05$

** $p < .01$

*** $p < .001$