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Children's responses to cognitive challenge and links to self-reported rumination

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We tested the hypothesis that less effective responses during a cognitive challenge would relate to higher levels of self-reported rumination in children. The sample was 100 children (55 boys, 45 girls), aged 7 to 14 years. A portion ($n = 65$) was at high risk for depression due to having a parent with a childhood-onset mood disorder, and 35 were a low-risk comparison group. Using an impossible puzzle task, we assessed children's responses following failure across several domains: emotions (expressed anger, sadness, and negative self-statements), performance (being off-task, the time to solve subsequent puzzles, and the number solved), and physiology (heart rate, respiratory sinus arrhythmia). Results indicated that making negative self-blaming statements during the solvable puzzles and taking more time to solve the puzzles were associated with higher levels of self-reported rumination. Our findings advance the understanding of potential correlates of children's tendency to ruminate and may have implications for children's performance on cognitive tasks.

Keywords: Rumination; Depression; Emotion; Cognition; Problem-solving; Children; Heart rate; Respiratory sinus arrhythmia.

Experiencing difficult or seemingly impossible tasks could be considered a common part of everyday life, but many times it is necessary to persevere on tasks despite failures or feelings of frustration. However, some people may be better than others at managing negative affect and focusing their attention on completing the task. In the present study, we examined individual differences in the extent to which children were able to effectively persevere on cognitive tasks despite experiencing failure. The main goal was to test whether this capacity relates to self-reported rumination, one type of maladaptive emotion regulation response that should be particularly relevant to regulatory responses following failure. Rumination involves repetitive, self-focused thoughts on one's sad emotions and on the causes and implications of those feelings (Nolen-Hoeksema, 1991).

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Rumination is linked to negative affect and a range of psychopathology, most often depression (see Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; Rood, Roelofs, Bögels, Nolen-Hoeksema, & Schouten, 2009; Smith & Alloy, 2009, for reviews). Rumination can also be conceptualised as the tendency to think repetitively about recent negative events (e.g., Siegle, Moore, & Thase, 2004; Watkins, 2008), yet surprisingly little research has linked self-reported rumination to difficulty following a specific stressor, such as failure. In the present study, we investigated whether children who reported generally higher levels of rumination had greater difficulty after failure, as measured in terms of their emotional responses, performance on subsequent tasks, and physiological recovery.

Children who ruminate may find it difficult to work effectively and problem-solve if they are thinking about the prior failure or are overwhelmed from affect stemming from the failure. Our hypothesis follows from Ellis's resource allocation model and supporting findings indicating that when experiencing negative emotions, a person's attention is allocated away from the task at hand and the emotional state produces thoughts irrelevant to the task (Ellis, Moore, Varner, Ottaway, & Becker, 1997; Ellis, Ottaway, Varner, Becker, & Moore, 1997; Meinhardt & Pekrun, 2003). Pertaining specifically to rumination, induced rumination has been found to result in a decreased ability to generate or carry out effective problem-solving and in poorer performance on academic tasks in adult samples, but only for dysphoric individuals (Lyubomirsky, Kasri, Chang, & Chung, 2006; Lyubomirsky, Kasri, & Zehm, 2003; Lyubomirsky, Tucker, Caldwell, & Berg, 1999; Watkins & Moulds, 2005). However, one study has provided evidence that even when controlling for depressive symptoms, adults who tend to ruminate show poorer inhibition for emotional words than adults who do not ruminate (Joorman, 2006). Relevant work with children is limited to a study where children who were asked to suppress sad thoughts and emotions after watching a sad film were better able to remember subsequent information than children who were told to reflect on the film or told nothing in a control condition (Rice, Levine, & Pisarro, 2007). Overall, this body of work supports our hypothesis that children who tend to perseverate on negative experiences may find it difficult to shift attention to allow them to work efficiently on subsequent tasks.

In addition to exhibiting performance decrements, children who tend to ruminate may be more likely to express negative affect during cognitive tasks following failure. Research suggests that rumination is linked to protracted or more intense negative affect (e.g., McLaughlin, Borkovec, & Sibrava, 2007; Nolen-Hoeksema & Morrow, 1993; Wood, Saltzberg, Neale, Stone, & Rachmiel, 1990), including episodes of past and future depression in children (Abela & Hankin, 2011). Also, rumination, especially the brooding type with more negative self-deprecating content, tends to be associated with other types of maladaptive coping or emotion-regulation strategies (Burwell & Shirk, 2007; Connor-Smith, Compas, Wadsworth, Thomsen, & Saltzman, 2000; Garnefski, Rieffe, Jellesma, Meerum Terwogt, & Kraaij, 2007). These findings suggest that children who often ruminate when sad may also ineffectively manage negative affect under a variety of circumstances.

Importantly, part of our sample included children at high risk for depression due to having a parent with a childhood-onset mood disorder. Children with a familial history of depression are at an increased risk for developing maladaptive emotion regulation responses (Gentzler, Santucci, Kovacs, & Fox, 2009; Silk, Shaw, Skuban, Oland, & Kovacs, 2006). In general, children who may be prone to mood disorders respond more negatively to failure experiences in maladaptive ways, such as showing learned helplessness (Hayden, Klein, Durbin, & Olino, 2006). Therefore, in this study we tested whether our hypothesis held only for high-risk youth, or whether it generalised to a low-risk group as well.

Because ruminators process negative and likely arousing thoughts in a sustained fashion, physiological recovery to baseline levels of autonomic function may be extended. A few studies have focused on autonomic nervous system activity to

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understand physiological underpinnings of rumination (e.g., Ottaviani, Shapiro, Davydov, & Goldstein, 2009). Heart rate is affected by both sympathetic and parasympathetic systems, and high-frequency heart rate variability (also called vagal tone or respiratory sinus arrhythmia, RSA, depending on how it is measured) largely reflects the influence of the parasympathetic system (Berntson et al., 1997). Slower recovery could therefore be evident through either faster heart rate or lower RSA during a post-task recovery period. Support for this hypothesis has been found with some adults using rumination-induction tasks (Key, Campbell, Bacon, & Gerin, 2008; Low, Stanton, & Bower, 2008; Ottaviani, Shapiro, Davydov, & Goldstein, 2008; Verkuil, Brosschot, de Beurs, & Thayer, 2009).

No studies have linked heart rate or RSA to rumination in children with one possible exception. In an earlier article that stems from the same larger study that the present article also derives its data from, lack of recovery in RSA was associated with displaying more sadness in a waiting task and focusing on a desired object (Santucci, Silk, Shaw, Gentzler, Fox, & Kovacs, 2008). This tendency to passively focus on a desired object may reflect a proclivity toward rumination (Silk et al., 2006); thus the results of Santucci et al. (2008) could offer preliminary evidence for a link between rumination and lack of recovery in RSA in children. The present study directly examined the associations between HR and RSA in a novel problem-solving task and children's self-reported rumination.

The present study

To summarise, we hypothesised that children who exhibit poorer regulation and performance following failure would report higher levels of rumination. Specifically, we expected that self-reported rumination would be correlated with children's: (1) affect (i.e., more intense sadness and anger displays, and a greater number of negative self-blaming statements); (2) performance (i.e., less task persistence, solving fewer puzzles post-failure, and taking longer to solve the puzzles); and (3) physiology (i.e., higher heart rate measured by lower inter-beat interval, IBI, and lower RSA).

We also investigated the role of children's sex and risk status for depression (high vs. low risk). Women, and sometimes girls, tend to report higher levels of rumination than their male counterparts (Jose & Brown, 2008; Nolen-Hoeksema & Girgus, 1994; Ziegert & Kistner, 2002). As mentioned, children with a familial history of depression are at higher risk for maladaptive emotion regulation than are children at low risk for depression (Silk et al., 2006). In addition, because children's level of depressive symptoms is a confound given its link to impaired attention (e.g., Gotlib & Joorman, 2010; Kovacs & Goldston, 1991), rumination (e.g., Abela & Hankin, 2011), and low resting RSA (e.g., Dietrich et al., 2007), we included children's self-reported depressive symptoms as a covariate in our analyses.

METHOD

Sample

The sample was part of a larger programme project focused on risk factors in childhood-onset mood disorders (COMD). This sample of 100 children was selected because they completed a certain protocol within the psychophysiology study of the project (that includes the puzzle task and a self-reported measure of depressive symptoms) and a psychiatric appointment (when the rumination questionnaire was administered). We selected those youth whose psychiatric appointment was either concurrent with (e.g., 15 children had their appointments within the same week, including 10 on the same day) or following the psychophysiology appointment. The average interval between psychophysiology and psychiatric appointments was 197.44 days ($SD = 184.96$, range = 0 to 791 days). The sample (55 boys and 45 girls) was aged 6.75 to 14.17 years ($M = 9.67$, $SD = 2.26$) at the psychophysiology appointment and aged 7.00 to 15.25 years ($M = 10.13$, $SD = 2.33$) at the psychiatric appointment.

There were 65 high-risk children, who were offspring of a parent with a COMD (21 with bipolar and 44 with major depressive disorder), and 35 low-risk children, whose parents had no history of major psychopathology. The sample was racially diverse: 54% White, 22% Biracial, 21% Black, and 3% other. The sample included 45 siblings (16 sets of sibling pairs, 3 sets of 3 siblings, and 1 set of four siblings).

Sample recruitment and case ascertainment. Participants were children whose parents were enrolled in a programme project, for which parents were categorised as positive or negative for history of COMD. Parents were included in the COMD group if they were diagnosed with major depressive disorder and/or dysthymic disorder prior to age 15 years or with bipolar disorder or cyclothymic disorder before 18 years of age. Participants were excluded if they had any pre-existing major systemic medical disorders or showed evidence of significant intellectual impairment. Trained clinicians from the psychiatric evaluation core of the project interviewed the parents and their evaluations were reviewed by blinded psychiatrists to assure validity of diagnoses. Diagnoses were determined based on criteria set forth in the *Diagnostic and Statistical Manual* (DSM-III, DSM-IV; American Psychiatric Association, 1980, 1994).

Participants' parents with COMD were originally recruited for the programme project through adult out-patient mental health clinics, advertising in the general community, or their participation in past clinical research. A number of individuals in the latter group had participated in a longitudinal 20-year follow-up study of COMD (e.g., Kovacs, Feinberg, Crouse-Novak, Paulauskas, & Finkelstein, 1984). Diagnoses for these participants were made using the Interview Schedule for Children and Adolescents (or the Young Adult version) during childhood and adolescence (Sherrill & Kovacs, 2000). Adulthood diagnoses were made later using the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID; First, Spitzer, Gibbon, & Williams, 1995), which was adapted to include some childhood-onset disorders and Axis II disorders. Clinicians also interviewed a second informant (e.g., parent or partner), and pediatric medical records or third-party corroboration were utilised to validate emotional problems in childhood. In contrast, control parents were required to have no history of any major psychiatric disorder at intake to qualify for inclusion, but were recruited with similar methods (e.g., through prior research studies where they served as control participants, or advertising in the community).

Procedure

At the psychophysiology appointment, children completed a task where they were instructed to replicate a series of designs using blocks (Nolen-Hoeksema, Wolfson, Mumme, & Guskin, 1995). Specifically, each child was given seven block design puzzles from the WISC-R (Wechsler, 1974) in a standardised order (as well as two initial practice trials). Four of the puzzles were age-appropriate and solvable with the given blocks, and three of the puzzles (2nd, 4th, and 5th) were unsolvable using the given blocks. During the task, a computer-generated copy of each design (5 cm × 5 cm) was presented on laminated cards. The children were asked to replicate the picture using the actual blocks and were given up to two minutes to work on each puzzle. If the child asked for more blocks or expressed that he or she could not complete it, the experimenter stated, "Some of the puzzles are easy and some of them are more difficult. I just want you to try your best".

We report on behavioural and affective responses during the solvable puzzles that followed the unsolvable puzzles (the 3rd, 6th, and 7th puzzles). Data for HR and RSA were continuously collected throughout the appointment, but we report on the recovery period, which was the one-minute post-task baseline immediately following the entire block design task. We could not use RSA during the solvable puzzles because children solved the puzzles in varying amounts of time, some of which were too short to provide reliable estimates of RSA (Task Force of the ESC & NASPE, 1996). Also during this session,

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children completed a measure of depressive symptoms.

Psychophysiology appointments were one component of the larger programme project, with an additional component being yearly psychiatric appointments beginning when children were seven years of age. During these psychiatric visits, the child and a parent completed questionnaires as well as semi-structured clinical interviews. We report on children's self-reported levels of rumination as assessed during these study visits.

Measures

Affective codes. We report on *sadness* expressed by the children. To gauge intensity, coders considered: (1) facial expressions (e.g., eyebrows lowered, pouting or frowning mouth); (2) behaviours (e.g., physical passivity, withdrawal); and (3) voice (e.g., volume dropping off at end, heavy sighing, crying). Children were coded for *anger* based on: (1) facial expressions (e.g., eyelids narrowed; lips pressed; brows drawn together; clenched jaw; rolling eyes); (2) behaviours (e.g., pounding blocks, throwing up hands, kicking table); and (3) voice (e.g., loud gruff or hostile tone; sarcastic or defiant comments; swearing). Coding was completed using 7-point scales from 0 = *No emotion* to 6 = *Very intense expressions*. Reliability was good for sadness ($ICC = .91$) and lower for anger ($ICC = .68$). Codes across the three solvable puzzles were aggregated, so that each child has one score for sadness and one for anger to reflect the intensity of the expressed emotions. The mean intensities were low for both anger ($M = 0.64$, $SD = 0.62$, range 0 to 2.33) and sadness ($M = 0.21$, $SD = 0.73$, range 0 to 4.00). However, the majority of children expressed some amount of anger (67%) whereas fewer children expressed any sadness ($n = 15$, 15% of the sample). Thus, for sadness we created a dichotomous variable to reflect whether or not children expressed any sadness during the solvable puzzles.

We also examined statements reflecting self-blame because these thoughts directly map onto the construct of rumination. Although these negative attributions are not observed expressions of emotion, they likely contribute to experience of sadness (e.g., Abramson, Metalsky, & Alloy, 1989). These *negative self-statements* were counted as they occurred ($ICC = .89$) and included self-critical or self-blaming statements in which the child attributed the inability to complete the task to himself/herself (e.g., "I must be stupid" or "I'm not gonna be able to do that"). We summed the number of negative self-statements across the three solvable puzzles. The range was 0 to 6 ($M = 0.46$, $SD = 1.22$). However, only 17 children (17%) made any self-blaming statements during the solvable puzzles, so a dichotomous variable was analysed to differentiate the children who made any self-blaming statements from those who did not.

Performance codes. We report on three performance indices that reflect an inability to effectively complete the remaining puzzles. We first coded task persistence defined by the time spent on the solvable block puzzles. Evidence for persistence included behaviours such as manipulating the blocks, asking questions about the task (e.g., "Can you give me more blocks?") and looking at the blocks or the picture. The 7-point scale used was from 0 = *Not working on the puzzle at all* to 6 = *Working the entire time* ($ICC = .77$). Most children persisted the whole time across the three solvable puzzles ($M = 5.90$, $SD = 0.27$, range = 4.33 to 6). As a result, we dichotomised this variable, *off-task*, with 0 representing children ($n = 84$) who persisted the entire time during the solvable puzzles, and 1 representing children ($n = 16$) who were off-task. The *number of puzzles solved* (based on the three solvable puzzles) was recorded for most participants ($n = 91$). The range of this variable was 0 to 3 ($M = 2.25$, $SD = 1.00$). Finally, the *time length* to solve the three puzzles also was analysed. This variable was simply the sum of the three durations. The range was 33.37 to 362.37 seconds ($M = 150.63$, $SD = 93.35$).

Physiological indices. To measure heart rate and RSA, electrodes were positioned at the heart level

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on the participant's rib cage. Equipment and software from the James Long Company (Caroga Lake, NY) were utilised for data collection and processing. A 0.01–1000 Hz bandpass filter was used and data were amplified by a gain of 500. A sampling rate of 512 Hz (Berntson et al., 1997) was implemented for digitisation of the data and also was re-sampled off line at 1000 Hz. In examining the data off line, we utilised a multi-pass algorithm to identify R-waves, and data were manually analysed for erroneous or missing R-waves. Original R-wave data were converted to inter-beat intervals (IBIs) and were resampled into 125 ms time intervals. Fast Fourier transform analysis was used to calculate RSA within the frequency range corresponding to respiration rates between 9 and 30 breaths per minute (.15–0.50 Hz), which is age-appropriate for the current sample to obtain heart rate variability due to respiration. RSA data were natural log-transformed to increase normality of the distribution. The natural logarithmic values (in ms^2) for RSA reflect parasympathetic contribution to heart rate variability.

The recovery scores used in the analyses were computed by subtracting the one-minute pre-task baseline from the one-minute post-task baseline. Thus, higher IBI recovery scores indicate greater return to baseline levels in IBI ($M = 0.02$, $SD = 0.04$; *range* = −0.07 to 0.11). Similarly, higher RSA recovery scores indicate greater return to pre-task baseline levels ($M = 0.19$, $SD = 86$; *range* = −2.63 to 2.83).

Children's depressive symptoms. Children completed the short version of the Children's Depression Inventory (Kovacs, 1992). This is a 10-item measure ($\alpha = .69$) that children answer based on their feelings during the past two weeks. Items are scored from 0–2 and then summed. Higher aggregate scores indicate higher levels of depressive symptoms ($M = 2.16$, $SD = 2.78$).

Rumination. Children reported on their general tendency to ruminate using the *Responses to Depression Questionnaire – Youth version* (RDQ-Y). The RDQ-Y is a modified version of the Response Styles Questionnaire (RSQ; Nolen-Hoeksema, 1991; Nolen-Hoeksema & Morrow, 1993). The RDQ-Y was developed in collaboration with Dr. Nolen-Hoeksema to make the RSQ age-appropriate for youth. Specifically, we modified the wording of several items and eliminated the dangerous activity subscale, one problem-solving item, and one rumination item due to their lack of relevance to children. Children were instructed to respond to items based on what they usually do when feeling sad using a 4-point scale. The measure included an 18-item *rumination* subscale ($\alpha = .87$). However, due to concerns that 10 of these items had been previously identified as potentially confounded with depression in adults, we analysed only the eight items that had loaded onto the brooding and reflection subscales (see Treynor, Gonzalez, & Nolen-Hoeksema, 2003). Example items in our rumination scale included "When I feel sad, I try to figure out why I feel that way" (reflection) and "When I feel sad, I think 'Why do I have problems that other kids don't have?'" (brooding). This 8-item rumination scale had adequate reliability ($\alpha = .79$) and range (8–32, $M = 14.71$, $SD = 5.00$).

RESULTS

Preliminary analyses

We first examined whether children's risk status, sex, or age at the psychophysiology appointment were related to any variables of interest (see Table 1). Low- and high-risk children only differed significantly on the time length to solve puzzles, indicating that low-risk children took more time to solve the puzzles ($M = 177.23$, $SD = 96.95$) than did high-risk children ($M = 136.30$, $SD = 88.84$). There were only two sex differences. Boys solved the puzzles in less time ($M = 132.64$, $SD = 87.92$) than girls ($M = 172.61$, $SD = 96.04$). Also, girls had higher RSA recovery scores ($M = 0.40$, $SD = 0.81$) than did boys ($M = 0.02$, $SD = 0.87$), indicating better recovery following the task. Children's age was associated with most variables. Specifically, older children expressed less intense anger and less

Table 1. *Associations between children's background characteristics and major variables of interest*

	Depressive risk group	*Sex*	*Age*
	t or χ^2	*t or* χ^2	*r*
Affective indices			
Anger intensity	1.22	−1.55	−.43***
Sadness expression dichotomised (dich.)	$\chi^2 = 1.06$	$\chi^2 = 3.35$	−.32**
Negative self-statements (dich.)	$\chi^2 = 2.90$	$\chi^2 = 0.04$	−.34***
Performance indices			
Off-task (dich.)	$\chi^2 = 0.64$	$\chi^2 = 0.01$	−.28**
No. puzzles solved	−1.62	1.96	.53***
Time to solve puzzles	2.13*	−2.17*	−.62***
Physiological indices			
IBI recovery	−0.24	−0.33	−.02
RSA recovery	−0.64	−2.06*	−.10
Self-reported depressive symptoms	−0.58	−0.27	−.44***
Self-reported rumination	−1.21	0.16	−.24*

Notes: Risk Group: 0 = low risk; 1 = high risk. Sex: 0 = boys; 1 = girls. Sadness: 0 = none; 1 = expressed sadness. Negative self-statements: 0 = None; 1 = one or more. Off-task: 0 = persisted; 1 = off-task. dich. = dichotomised; IBI = inter-beat interval; RSA = respiratory sinus arrhythmia. $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

sadness, were less likely to make negative self-statements or be off-task, and solved a greater number of puzzles and in less time. Older children also reported fewer depressive symptoms and lower levels of rumination.

Associations among our response indices were mostly in line with our expectations in that children who exhibited visible signs of emotional distress during the solvable puzzles also had difficulty staying on task, solving the puzzles, and completing them as quickly as those who were not upset (see Table 2). However, these emotion and performance variables were not correlated with either IBI or RSA recovery. In addition, children who reported higher levels of depressive symptoms exhibited more intense anger during the solvable puzzles, and were more likely to show sadness, make negative self-statements, be off-task during the solvable puzzles, solve fewer puzzles, and take longer to complete puzzles. They also reported higher levels of rumination. Finally, self-reported rumination was correlated with numerous response indices in the predicted directions (more anger, negative self-statements, solving fewer puzzles, and taking longer to solve them). More comprehensive analyses are described below that account for dependency in the data as well as covariates, thereby offering a more stringent test of our hypotheses.

Associations between task responses and rumination

To examine whether task behaviours were linked to self-reported rumination, three linear mixed models were conducted. This multilevel approach was chosen because siblings were included in the sample, and the 2nd level predictor (i.e., parent) did account for significant variance in children's self-reported rumination ($ICC = .26$, $p = .004$). Therefore, by including parent as a random effect, we accounted for the resulting dependency in the data (Luke, 2004). Analyses were run using SAS (Version 9.3) Proc Mixed with maximum likelihood estimation. Each model included children's self-reported rumination as the outcome, and independent variables were either the affective indices, performance indices, or physiological indices of regulation. Additional covariates included depressive risk group, children's sex, and age at the psychophysiological appointment. The interval between the physiological and psychiatric appointment was examined as a covariate, but it did not affect the outcomes and thus is not reported below.

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Table 2. *Correlations among task variables, depressive symptoms, and self-reported rumination*

	Affective indices			*Performance indices*			*Physiological indices*		
	Sad	*Neg. state.*	*Off-task*	*No. solved*	*Time to solve*	*IBI*	*RSA*	*Depr. Sympt.*	*Rumination*
Anger	.32**	.37***	.29**	−.54***	.56***	−.09	−.07	.29**	.24*
Sadness	—	.33**	.35***	−.36***	.32**	−.01	−.15	.34**	−.04
Negative statements		—	.31**	−.58***	.53***	−.05	−.14	.34**	.29**
Off-task			—	−.44***	.46***	−.12	−.02	.28*	.11
No. solved				—	−.80***	.00	−.02	−.30**	−.23*
Time to solve					—	−.01	−.02	.36***	.34**
IBI recovery						—	.35**	−.08	−.06
RSA recovery							—	−.00	−.08
Depressive symptoms								—	.20*
Rumination									—

Notes: IBI = inter-beat interval; RSA = respiratory sinus arrhythmia. *$p < .05$; **$p < .01$; ***$p < .001$.

Affective indices. As shown in Table 3, when including all three affective indices in the model with covariates, only negative self statements were associated with higher levels of self-reported rumination. This finding indicates that children who made negative self-statements during the solvable puzzles also reported higher rumination on average. In addition, even when equating children on the number of puzzles solved by including it as a covariate in the model, children's negative self-statements continued to be significantly associated with rumination, *estimate* = −3.93, $SE = 1.410$, $t(13) = -2.79$, $p = .015$.

Performance indices. Due to the high correlation between the time to solve puzzles and the number solved ($r = .80$) that results in multicollinearity among our predictors, we initially only included the time to solve puzzles and off-task behaviour in the model using performance indices. This model indicated that the off-task variable was unrelated to self-reported rumination, but consistent with hypotheses, the time to solve puzzles was related to rumination scores (see Table 4). Specifically, children who took longer to complete the solvable puzzles following failure reported higher levels of rumination. Also, if we control for the number of puzzles solved, the association between time to solve the puzzles and children's self-reported rumination remained significant, *estimate* = 0.027, $SE = 0.009$, $t(14) = 3.01$, $p = .010$. Therefore, even when equating children on the number of puzzles they solved, children who took longer to

Table 3. *Mixed model predicting self-reported rumination from affective indices during the task*

Predictors	*Estimate*	*SE*	*t*
Intercept	18.22	3.094	5.89***
Risk group	−1.39	1.031	−1.35
Child sex	−0.06	0.928	−0.07
Age	−0.36	0.232	−1.56
CDI-S	0.12	0.190	0.63
Anger	1.12	0.823	1.37
Sad expression	2.78	1.370	2.04
Self-blame statements	−3.45	1.352	−2.55*

Notes: Reference groups are set as: the low-risk group; girls; no sad expressions; and no self-blame statements. CDI-S = Children's Depression Inventory – Short Version. *$p < .05$; ***$p < .001$.

Table 4. *Mixed model predicting self-reported rumination from performance indices during the task*

Predictors	*Estimate*	*SE*	*t*
Intercept	12.56	3.630	3.46***
Risk group	−1.76	1.055	−1.67
Child sex	−0.86	0.950	−0.90
Age	−0.10	0.259	−0.37
CDI-S	0.11	0.183	0.60
Off-task	0.86	1.370	0.63
Time to complete	0.02	0.007	3.04**

Notes: Reference groups are set as: the low-risk group; girls; and no off-task behaviours. CDI-S = Children's Depression Inventory – Short Version. **$p < .01$; ***$p < .001$.

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solve puzzles after failure tended to report higher levels of rumination.

Physiological recovery. The model including heart rate recovery and heart rate variability recovery (IBI and RSA recovery) indicated that these variables were unrelated to self-reported rumination (these results are not tabled).

DISCUSSION

Overall, we found partial support for our hypothesis that children who exhibit problems during a cognitive task after experiencing failure also report a greater tendency to ruminate when sad. Children's responses following failure were assessed comprehensively using a multi-method approach involving coded emotions, actual behavioural indicators of performance, and physiology. Two variables appeared particularly relevant to rumination: (1) the number of negative self statements that children made; and (2) the length of the time they took to solve the puzzles after failing. Moreover, these results maintained statistical significance when controlling for children's depressive symptoms and other covariates previously linked to rumination. Although small in magnitude, these are the first findings to our knowledge that link difficulty responding to a cognitive challenge and self-reported rumination in children.

Regarding children's affective state during the behavioural task, our coding scheme was designed to detect a range of responses that might result from the task. The majority of children exhibited some amount of anger, but fewer expressed sadness. In the future, researchers may want to use a task that elicits proportionately more sadness, which is more often linked to rumination and is the emotion referenced in our self-report measure. In our study, expressed sadness was not linked to self-reported rumination, and expression of more intense anger was only significantly linked to rumination in bivariate correlations. Another consideration is that we only focused on children's behaviour during the solvable puzzles, which was consistent with earlier research using this task (Hayden et al., 2006; Nolen-Hoeksema et al., 1995). In future research, however, it may be worthwhile to investigate the duration of negative emotions that onset during the impossible puzzles and continue into the solvable puzzles given that rumination is linked to protracted negative affect (at least with depression, e.g., Nolen-Hoeksema et al., 1993), suggesting ineffective recovery processes.

Yet our models revealed that children who made negative self-statements during the solvable puzzles also tended to report more rumination. It is noteworthy that these statements were detected during subsequent solvable puzzles (not the actual impossible puzzles) and that even when controlling for the number of puzzles that were solved, self-blaming statements were still linked to higher levels of rumination. These findings suggest the possibility that children who may be prone to negative thoughts even after such brief failures such as these, also may ruminate more frequently in general when sad. Although we did not specifically ask children to verbalise their thought processes and thus do not know what every child inferred about the puzzles and their abilities, it is possible that we tapped into verbal instances of rumination with the coded negative self-statements. The observed self-deprecating types of comments do fit with the construct of brooding rumination wherein thoughts involve negative implications for the self (Roberts, Gilboa, & Gotlib, 1998; Treynor et al., 2003).

Our results also indicated that children who took longer to solve the puzzles after failure report higher levels of rumination when sad. Time to completion is a critical variable because some of these children may have appeared to be on-task, yet still may not have been fully concentrating on the puzzle. The role of impaired attention is plausible when considering that children were required to shift their attention to a new puzzle immediately after failing, and that experiencing negative affect can further exacerbate the likelihood of off-task thoughts (Ellis, Moore et al., 1997; Ellis, Ottaway et al., 1997; Mikulincer, 1989; Smallwood, Fitzgerald, Miles, & Phillips, 2009). Our results therefore support

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the possibility that these same children who took longer on the puzzles may also have difficulty inhibiting a ruminative response more generally. This association held even when controlling for the number of solvable puzzles that the children completed, indicating this link was not because those children did not solve as many puzzles and were reacting to those additional failures. We also accounted for a critical confounding variable, namely children's depressive symptoms, which suggests it is not simply that depressed youth tend to both ruminate and have problems working efficiently on a task.

An important facet of this sample is that some of the children were at higher risk for depression, and we know that these youth may be more likely to develop maladaptive emotion-regulation strategies (Gentzler et al., 2009; Silk et al., 2006) and show less physiological recovery in heart rate (Forbes, Fox, Cohn, Galles, & Kovacs, 2006) compared to children whose parents do not have a history of a mood disorder. Despite these earlier findings, our results did not reveal a group difference in levels of rumination, and the above task responses were linked to self-reported rumination even when controlling for risk group. Although most previous studies found that inducing rumination only impaired *dysphoric* adults' performance on cognitive tasks (Lyubomirsky et al., 2003), our results suggest otherwise and indicate that *any* child who reports trait-like rumination may be vulnerable to having difficulties recovering from minor stressors. This implication is especially consequential given that rumination emerges as a common regulatory strategy by late childhood in normative samples (Jose & Brown, 2008).

In this study, gender was related to few variables overall. Girls did not report higher levels of rumination than boys. The only task responses that varied by gender were that boys solved the three solvable puzzles in less time than did girls, whereas girls exhibited better RSA recovery following the task than did boys. To be more likely to detect gender differences in rumination in future research, investigators may want to focus on an older sample than ours (see Rood et al., 2009). In addition, because evidence suggests that girls or women may be more reactive to social stressors than achievement ones (Stroud, Salovey, & Epel, 2002), social stressors (e.g., Hayden et al., 2006) may be particularly effective in eliciting reactions in girls that more strongly map onto their proclivity to ruminate.

Also, we did not find that recovery in heart rate or heart rate variability was linked to self-reported rumination. Perhaps if heart rate and heart rate variability during the solvable puzzles could have been meaningfully measured, these data would be more relevant to rumination because their timing would be more immediate to the failures. Future studies also could use a longer recovery period, which may be able to provide a more representative measurement of heart rate variability indices (Task Force of the ESC & NASPE, 1996). Additionally, it might be useful to include a more comprehensive set of physiological indicators that could detect a sustained stress response from a negative experience (e.g., cortisol; Denson, Fabiansson, Creswell, & Pedersen, 2009).

Nevertheless, the general findings may have important implications for children in academic settings. Compared to younger children, by middle childhood youth tend to suppress displays of negative affect more often (e.g., Zeman & Garber, 1996) and show an increased reliance on cognitive strategies (e.g., rumination) to cope with negative events and emotions (Rossman, 1992). Their negative affect and attempts to attenuate it therefore may be less visible. In other words, even though children may appear to be paying attention in class, those who are more ruminative may not be working up to their full potential due to difficulty disengaging from residual negative affect or from earlier experiences. More generally, mind wandering is more likely when in a negative mood (Smallwood et al., 2009) and is hypothesised to have a discernable effect on students' academic performance (Smallwood, Fishman, & Schooler, 2007). This study therefore provides direction for future research to investigate the parameters of this effect, for example, by using different types of cognitive tests or examining if

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children's actual school performance is linked to their tendency to ruminate.

A key limitation of the study is the lack of information that we have about children's conscious thoughts during the task. Although the negative self-statements reflecting self-blame and pessimistic thinking directly map onto rumination, we do not know if we were tapping into ruminative responses during the task or more general dysregulation. Due to the present study's correlational design, an experiment with a rumination-induction condition would be essential to advance this research and understand the direction of effect. A current interpretation of our findings is that common underlying factors likely explain both children's behaviour during the task and the greater reliance on rumination. For example, children's temperament, specifically higher negative emotionality and lower effortful control, may result in their being vulnerable to rumination (Verstraeten, Vasey, Raes, & Bijttebier, 2009) as well as exhibiting difficulty after failure. An additional important limitation of the study is that the modest sample size precluded tests of more complex associations, such as moderated effects.

Despite the limitations, our study offers strong support that rumination is linked to behaviours noted during a cognitive challenge. The findings were examined in a diverse sample of youth and appeared robust despite including essential covariates. Also, the study suggests that the investigation of how children's academic performance might be impacted by rumination could be a critical new direction.

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