

Effect of maternal rumination and disengagement during childhood on offspring neural response to reward in late adolescence



Judith K. Morgan^{a,*}, Daniel S. Shaw^b, Rachel H. Jacobs^c, Sarah E. Romens^a, Stephanie L. Sitnick^{b,d}, Erika E. Forbes^{a,b}

^a University of Pittsburgh, Department of Psychiatry, United States

^b University of Pittsburgh, Department of Psychology, United States

^c University of Illinois at Chicago, Department of Psychiatry, United States

^d Caldwell University, Department of Psychology, United States

ARTICLE INFO

Keywords:

Rumination
Depression
Reward

ABSTRACT

Maternal rumination is a cognitive-affective trait that could influence offspring's ability to respond flexibly to positive and negative events, depending on the quality of maternal problem-solving behaviors with which rumination co-occurs. As reward circuitry is sensitive to stressors and related to risk for depression, reward circuitry is an appropriate candidate mechanism for how maternal characteristics influence offspring. We evaluated the independent and combined effect of maternal rumination and disengagement on adolescent neural response to reward win and loss. Participants were 122 boys and their mothers from low-income, urban backgrounds followed prospectively in a longitudinal study. The combination of high maternal rumination at child age 6 and high maternal disengagement during problem-solving at child age 10–12 was associated with lower anterior cingulate response to winning reward at age 20, but unrelated to neural response to losing reward. Lower anterior cingulate response to winning reward was associated with fewer anxiety symptoms during late adulthood. Findings suggest that maternal rumination occurring within the context of maternal disengagement during challenging experiences may be related to offspring blunted engagement during positive events. Helping highly ruminative mothers to restructure repetitive negative thoughts and to develop context-appropriate problem-solving behaviors may be important for promoting offspring affective development.

1. Introduction

Rumination is a specific cognitive pattern involving repetitively and passively dwelling on negative feelings and distress that is implicated in the onset and duration of multiple psychiatric disorders, notably depression and anxiety, but also eating and substance disorders (Aldao, Nolen-Hoeksema, and Schweizer, 2010; Nolen-Hoeksema et al., 2008). Rumination is associated with ineffective problem-solving and behavioral disengagement (Aldao et al., 2010, Lyubormirsky & Tkach, 2004) and may interfere with parenting, particularly in the realm of teaching youth how to actively cope with problems. However, empirical research has only begun to explore how maternal rumination may alter offspring affective processing or heighten their risk for psychiatric illness (Waller and Rose, 2010). Initial findings point to a role of maternal rumination in youth affective development via impaired mother-child interactions and teaching of problem-solving skills (e.g., see Grimbois et al., 2013, Muller et al., 2013). Understanding if and how maternal rumination may underlie dis-

rupted affective brain development could advance our understanding of basic child development and identify targets for prevention and intervention.

Highly ruminative parents may model poor emotion coping skills in parenting their offspring that disrupt children's ability to process emotional information and alter their neural functioning. In particular, rumination when combined with outward displays of frustration and disengagement may provide offspring with models of ineffective problem-solving. Specifically, highly ruminative parents may have difficulty shifting their thinking from their own worries during problem-solving discussions with their children. Rather than substantively engaging in these discussions and providing a model of effective problem-solving, mothers high on rumination may be more likely to turn inward and disengage during these discussions (e.g., sit quietly and think about own worries when child is seeking advice). In turn, this coping style may decrease motivation and flexibility needed to shift from negative thinking to pleasurable enjoyment of positive events and result in offspring's difficulty experiencing positive affect in response to

* Corresponding author.

<http://dx.doi.org/10.1016/j.psychresns.2017.02.003>

Received 8 September 2015; Received in revised form 3 February 2017; Accepted 9 February 2017

Available online 11 February 2017

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positive events and difficulty letting go of negative feelings in the context of loss.

Based on prior evidence that maternal depression is associated with altered reward functioning in offspring only in the context of compromised caregiving (Morgan et al., 2014), maternal rumination may also be related to altered response to reward and loss in their offspring, although perhaps only in the context of high levels of outward expressions of poor problem-solving. Prior work has shown that neural circuitry associated with consummatory reward processing (e.g., receiving monetary reward) and loss function (e.g., losing monetary reward) is activated by social cues (Leibenluft et al., 2004), suggesting that early family experiences may play a role in development of the child's ability to appropriately respond to positive and negative information. One critical region in reward circuitry is the ventral striatum (VS), which is thought to be associated with the subjective experience of pleasure. Blunted striatal response has been demonstrated in adults and adolescents with depression (Zhang et al., 2013) and is present in adolescents with familial risk for depression (Gotlib et al., 2010). Furthermore, evidence suggests that function in the ACC and mPFC are heightened in response to loss of reward (Gotlib et al., 2010), a process closely related to rumination, making them important regions likely involved in affective development of youth with highly ruminative parents. Together, these findings point to a diminished capacity to enjoy pleasurable events and a hyper-reactive response to experiencing loss as components of the pathophysiology of depression; thus, evaluating how these reward and loss alterations may develop is warranted.

Rumination has a heterogeneous presentation (Siegle et al., 2004). Although some forms of rumination are highly associated with depression, rumination is a trait that occurs in and out of episode and is linked to many other psychiatric illnesses (e.g., anxiety, eating disorders, and substance abuse) (Nolen-Hoeksema et al., 2008). In fact, a sizeable portion of healthy people who have never met criteria for psychiatric illness report high trait levels of rumination (although the way in which they ruminate may be slightly different; see Siegle et al., 2004). Although rumination can be thought of as brooding on sad emotions, rumination can also involve perseverating on angry feelings and cognitions, such as being personally slighted or offended (Nolen-Hoeksema et al., 2008). For some people, rumination may interfere with daily functioning and coping, for example through disengagement from the environment because of distraction by their self-related cognitions. This could be particularly evident during interpersonal problem-solving, when they have difficulty focusing on others' needs and concerns rather than their own internal experience. For others, rumination may not be evident in behavior nor may it hinder their ability to interact with others and engage in problem-solving. For these reasons, evaluating rumination separately from depression, testing whether it is independently related to child outcomes above and beyond depression, and measuring interpersonal problem-solving behavior as a moderator of the association between maternal rumination parent and youth outcomes is warranted.

We evaluated whether mothers' rumination during offspring's childhood is linked to their offspring's neural response to reward and loss during late adolescence, a developmental period in which clinical disorders typically begin and often worsen (Paus et al., 2008). Maternal rumination was assessed when sons were age 6, an age in which maternal involvement and influence on child affective development are high. However, based on the trait-like stability of rumination during adulthood (Nolen-Hoeksema et al., 2008), high rumination assessed during the early school-age period was expected to be moderately stable for mothers during their offspring's childhood and adolescence. We were interested in examining associations between maternal rumination and offspring reward and loss circuitry after accounting for levels of maternal depressive symptoms measured concurrently (at age 6) and across childhood. Although rates of depression are higher in women relative to men, depression can have devastating consequences

(higher rates of suicide completion) for boys (Dumais et al., 2005). Risk of depression onset and recurrence of depression is also higher among low- vs. middle-income youth and adults (Kessler et al., 2003). Thus, focusing on a predominantly low-income sample of male youth represents an additional methodological strength.

We hypothesized that maternal rumination during childhood would be associated with dampened neural response in the VS and other reward-related regions when winning reward, and heightened neural response in the anterior cingulate and mPFC when experiencing loss during late adolescence. We controlled for maternal history of depression across childhood to evaluate the putative role of rumination above and beyond its association with depression. We tested a moderation model in which maternal rumination negatively affects child neural processing, depending on the presence of greater maternal disengagement. We predicted that high levels of maternal disengagement during child problem-solving as observed during parent-child interactions during early adolescence would amplify the relationship between maternal rumination and aberrant reward and loss function in the aforementioned neural regions. Finally, we explored how boys' neural response to reward and loss during this transition to adulthood would be associated with neuroticism, a trait highly correlated with rumination (Perkins et al., 2015), at age 20 and with boys' own depressive and anxiety symptoms at age 22.

2. Method

Participants were 122 boys from the Pitt Mother & Child Project, a longitudinal project on vulnerability and resilience in boys from low-income, urban families (Shaw et al., 2012). Families were recruited to the study when boys were between the ages of 6 and 17 months from Women, Infants, and Children (WIC) Nutritional Supplement centers in the greater Pittsburgh area. All participants were boys because of the parent project's focus on the developmental antecedents of antisocial behavior and boys' higher incidence of serious antisocial behavior. Data from this project, including evaluations of the association between boys' neural reward function and maternal affect as well as their own affective functioning, has been published previously (e.g., Morgan et al., 2014). However, in the current study, we uniquely explored how mothers' own internal state, i.e., ruminative style—a dimensional, trans-diagnostic construct, and her problem-solving behavior with her sons, may prospectively be linked to boys' neural response to both reward win and loss.

The sample for this evaluation was 57% European-American, 33% African-American, and 11% other races/ethnicities (e.g., biracial, Hispanic). At age 18 months, average family income for these 122 boys was \$1045.47 per month and mean SES score was 23.87 using the Hollingshead Index, indicating working-class status (Hollingshead, 1975). Approximately 28% of mothers in the study were single, separated, or divorced at child age 18 months, with the remaining 72% married or living with a partner. Average number of years of maternal education was 12.7 years at the 18-month assessment.

Mothers reported on their ruminative style at child age 6 and their own depressive symptoms on seven occasions between child ages 6–17. At child ages 10, 11 and 12, maternal disengagement when interacting with her son was coded during a series of mother-child discussion tasks. At age 20, the target male youth (now in late adolescence) were invited to participate in an fMRI assessment of their neural response to reward and completed measures of their own affective functioning. All procedures received Institutional Review Board approval at the University of Pittsburgh and all participants provided consent for their participation in the study.

Originally, 310 boys and their families were recruited to participate in the longitudinal project. Of these 310, 186 boys participated in an fMRI scan at age 20 ($n=56$ missed age-20 research visit, $n=25$ past concussion, $n=17$ refused/unavailable to complete scan, $n=17$ metal in body, $n=7$ claustrophobic, $n=1$ drug use prior to scan, and $n=1$ obese).

Of these 186, 166 boys had usable fMRI data ($n=12$ difficulty understanding the task; $n=6$ insufficient VS signal; $n=2$ intoxicated or experiencing psychosis during the scan). Of these 166 boys, 122 boys had data on maternal rumination, disengagement from ages 10–12, and depressive symptoms at ages 6–17 ($n=30$ missing rumination data, $n=24$ missing disengagement data, $n=4$ missing depressive symptoms data at all ages). There were no significant differences in maternal rumination, maternal depressive symptoms, maternal disengagement, maternal education level or family income for participants with usable fMRI data compared to those without these data or for those in the original sample of 310 compared to those 122 in the current study.

2.1. Measures

2.1.1. Maternal ruminative style

Mothers reported on their ruminative style using the 38-item Response Style Questionnaire (RSQ; Nolen-Hoeksema and Morrow, 1991) at child age 6. Participants rate how frequently they engage in particular behaviors when feeling down or sad on a scale of 1 (almost never) to 4 (almost always). We used the rumination subscale of the RSQ. Sample items from the rumination subscale include “think about how sad I feel” and “think about how I feel alone.” The rumination subscale demonstrated strong internal consistency in the current sample ($\alpha=.90$).

2.1.2. Disengagement

Mothers and their sons participated in problem-solving discussion tasks when boys were 10, 11, and 12 years old. At age 10 and 12, the topic of discussion was based on areas of current disagreement and selected by the primary caregiver (e.g., keeping room clean, getting homework done) (Hetherington et al., 1992). At age 11, boys were asked to select a topic for which they need assistance (e.g., a friend is being mean) (Allen et al., 2007). Maternal disengagement and boys’ disengagement were coded separately based on verbal and non-verbal behaviors (e.g., shutting down, looking away) that indicated disengagement or withdrawal from the discussion on a 9-point Likert scale (1=low, 9=high) at all three ages. Intra-class coefficients for coders ranged from .67 to .84, with a mean of .74, indicating adequate reliability. Mothers’ disengagement with her sons was correlated at ages 10 and 11 ($r=.53$, $p < .001$), at 10 and 12 ($r=.30$, $p < .01$) and approached significance in correlating at 11 and 12 ($r=.20$, $p < .09$). Boys’ disengagement was also correlated at ages 10 and 12 ($r=.26$, $p < .05$), at 11 and 12 ($r=.38$, $p < .001$) and approached significance in correlating at 10 and 11 ($r=.20$, $p < .09$). The codes for all three ages were averaged to create a composite maternal disengagement and composite boys’ disengagement score.

2.1.3. Maternal depressive symptoms

Mothers reported on current depressive symptoms using the Beck Depression Inventory (BDI; Beck et al., 1988), a widely-used measure of depressive symptoms, when boys were ages 6, 8, 10, 11, 12, 15, and 17. The scale had strong reliability (mean $\alpha=.88$). The BDI is a 21-item measure that uses a 4-point Likert scale (0–3), for a highest possible score of 63. A score of 10 on the BDI is the clinical cutoff for mild/modest depression (Beck et al., 1988). We computed the number of times that mothers had a score above this clinical cutoff to evaluate whether any observed relationships between maternal ruminative style and disengagement and boys’ reward response remained after accounting for maternal depressive history across boys’ childhood.

2.1.4. Boys’ psychiatric functioning

Boys also reported on their current depressive symptoms using the Beck Depression Inventory (BDI; Beck et al., 1988) at age 22 and on their current anxiety symptoms using the Beck Anxiety Inventory (BAI; Beck et al., 1988) at age 22. Similar to the BDI, the BAI is a 21-item widely used measure of anxiety that uses a 4-point Likert scale. Boys

also reported on their level of neuroticism on the 60-item NEO Five Factor Inventory (NEO-FFI; Costa & MacCrae, 1992) at age 20. The neuroticism subscale has 12 items, with a sample item being “I often feel tense and jittery”. Reliability for all three measures was good ($\alpha=.86$ for BDI, $.88$ for BAI, $.74$ for NEO).

2.1.5. Neural response to reward

Boys completed a reward-related fMRI paradigm at age 20. The fMRI paradigm was an 8-min slow event-related card-guessing game that evaluates neural response to the anticipation and receipt of monetary reward feedback (Forbes et al., 2010). Participants completed trials in which they could win (or break even), “possible-win” trials, and trials in which they could lose (or break even), “possible lose” trials. Participants were told that their performance would determine a monetary reward after the scan, with \$1 for each win trial and 50 cents deducted for each loss trial. Trials were presented in pseudorandom order with predetermined outcomes. Earnings totaled \$6. Trials were presented in a single run, with 24 trials total and a balanced number of trial types within runs (i.e., 12 possible-win vs. no-change and 12 possible-loss trials). Only trials in which participants received win feedback (6 trials) and trials in which participants received loss feedback (6 trials) were used in analyses for this paper. The length of this task is optimal for reliably inducing a reward response without fatigue as could be experienced with a longer task, and has been widely-used with healthy and various clinical populations. During each trial, participants guessed via button press whether the value of a visually presented card was high or low (4 s), learned the trial type (possible-win or possible-loss), anticipated feedback (6 s), and received feedback (1 s plus 6 s inter-trial interval). Baseline was considered to be the last 3 s of the inter-trial interval, as the hemodynamic response is likely to have resolved by this point in trial. Participants were unaware of fixed outcome probabilities (i.e., that all participants received the same trials and outcome), and all received \$10 after the scan. Based on post-scan interviews, most (98%) participants indicated that they believed that their performance on the task determined the outcome and the remaining 2% believed there to be some fixed aspect of the task but were incorrect about the nature of it. Because we were interested in how rumination may affect boys’ ability to respond flexibly to rewarding events and respond adaptively when experiencing loss, we used the reward win > baseline and loss outcome > baseline contrasts.

2.2. fMRI acquisition, preprocessing

Each participant was scanned using a Siemens 3T Trio scanner. BOLD functional images were acquired with a gradient echo planar imaging (EPI) sequence and covered 39 axial slices (3.1 mm thick) beginning at the cerebral vertex and encompassing the entire cerebrum and the majority of the cerebellum (TR/TE=2000/29 ms, FOV=200 mm x 200 mm, matrix=64x64, Flip angle=90). All scanning parameters were selected to optimize the quality of the BOLD signal while maintaining a sufficient number of slices to acquire whole-brain data. Before the collection of fMRI data for each participant, we acquired a reference EPI scan that we visually inspected for artifacts (e.g., ghosting) and for good signal across the entire volume of acquisition. The fMRI data from all included participants were cleared of such problems. In the same session, a 160-slice high resolution sagittally-acquired T1-weighted anatomical image was acquired for coregistration and normalization of functional images (TR/TE=2300/2.98 ms, FOV=25.6cmx24 cm, matrix=256x240, Flip angle=9). Preprocessing and whole-brain image analyses were completed using SPM8 (<http://www.fil.ion.ucl.ac.uk/spm>). Prior to analysis, structural images for each participant were segmented to focus on grey matter. Functional image preprocessing included (1) spatial realignment to correct for head motion (2) spatial normalization into standard stereotaxic space (Montreal Neurological Institute template) using a

12-parameter affine model and nonlinear warping, and (3) image smoothing with a 6 mm full-width at half-maximum Gaussian filter to minimize noise and individual differences in anatomy. Preprocessed data were analyzed using first-level random effects models that account for scan-to-scan variability and second level random effects models that account for participant-to-participant variability to determine task-specific regional responses. Preprocessed data were analyzed using first-level random effects models that account for scan-to-scan variability and second level random effects models that account for participant-to-participant variability to determine task-specific regional responses. All 122 participants had movement < 2 mm in each plane.

Following pre-processing, we ensured adequate signal in the whole brain and regions of interest (i.e., the VS, as ventral regions can be subject to significant signal loss due to their anatomical location) by counting voxels with adequate signal in a given ROI in SPM (“ROI Count voxels”) and ensuring that the number was above 80%. This procedure uses Matlab code based on an anatomical mask (i.e., nucleus accumbens and ventral caudate for VS ROI) to compute percent of voxels in that region with signal.

2.3. Data analytic strategy

Data analysis was completed in two steps. First, we evaluated main effect of task using reward and loss masks from Neurosynth (<http://neurosynth.org/>) at a height threshold of $p < .005$ (FWE corrected at $p < .05$ at peak-level).¹ Resulting clusters were used as regions of interest for our regression models. Second, multiple regression models were conducted in SPM8 and included maternal depressive symptoms from child age 6–17, maternal rumination (child age 6), maternal disengagement when with her son (ages 10–12), and the 2-way multiplicative interaction between maternal rumination and maternal disengagement as predictors of reward outcome and loss outcome. Both maternal disengagement and maternal rumination were centered prior to creating interaction terms. For our regression models, height thresholds were set to a threshold of $p < .005$ and then corrected for multiple comparisons using small volume corrections at $pFWE < .05$ at peak level, statistical methods for thresholding that are considered appropriate for balancing Type I error, Type II error, and spatial resolution (Carter et al., 2016; Flandin and Friston, 2016).¹ Small volume corrections use family wise error within constrained regions (Forman et al., 1995; Poldrack, 2007; Worsley et al., 1996). In our case, regions were empirically-derived from our independent task effects (Nichols et al., 2005) and are conceptually sound based on prior evidence implicating the striatum, ACC, and mPFC in reward processing (Haber & Knutson, 2010; Rogers et al., 2004). We used height thresholds of $p < .005$ ¹ and findings were analyzed using peak-level inferences (as opposed to cluster-level inferences, which have been debated in fMRI methodology literature; see Eklund et al., 2016; Flandin and Friston, 2016) and were significant a $pFWE < .05$ at the peak-level. We explored interactive findings using simple slopes analyses, in which we probed the effect of maternal rumination on neural response by re-centering maternal disengagement at 1 SD above and below the mean for maternal disengagement and then re-running our linear regression models within SPM8 (Preacher et al., 2006). Once again, for these post-hoc analyses, we corrected for multiple comparisons using small volume corrections at $pFWE < .05$ (peak-level).

Next, correlations evaluated whether neural response to reward and

¹ Although we present findings at a height threshold of $p < .005$, findings remain significant when using a height threshold of $p < .001$ for both our within-sample t-tests for task effects (VS and caudate, 575 voxels, $t=8.33$, $pFWE=.000$; ACC, 365 voxels, $[-2, 46, 10]$, $t=5.17$, $pFWE=.021$; mPFC, 284 voxels, $[2, 40, 32]$, $t=7.73$, $pFWE < .000$) and for our regression model (ventral anterior cingulate, 6 voxels, $[2, 36, -8]$, $t=3.41$, $pFWE=.038$).

loss was correlated with boys’ disengagement during the interaction at age 10–12, neuroticism at age 20, depressive symptoms at age 22, and anxiety symptoms at age 22.

3. Results

Table 1 shows means, standard deviations, and intercorrelations of our predictor and outcome variables. There was wide variability in maternal depressive history on the BDI across child ages 6–17, with 51% of mothers never exceeding the clinical cutoff for mild/modest depression and 31% of mothers reporting above threshold scores 2 or more times. Average level of rumination in our sample was elevated compared to mean scores reported in clinical samples (Watkins and Brown, 2002). Maternal rumination was significantly and positively correlated with number of times above clinical cutoff of depressive symptoms ($r=.43$, $p < .001$), but not with maternal disengagement.

Within-sample t-tests revealed significant clusters in the VS and caudate head, anterior cingulate and insula, and medial prefrontal cortex for reward win > baseline and a significant cluster encompassing the striatum and the anterior cingulate for reward loss > baseline (see Table 2, Fig. 1).

For our regression models, we found that, after accounting for maternal depressive history, higher maternal rumination at age 6 interacted with maternal disengagement to predict less activation in the ventral ACC at age 20 for late adolescent boys when winning reward ($[2, 36, -8]$, 41 voxels, $t=3.42$, $pFWE=.05$; Cohen’s $d=.63$).¹ As predicted, maternal rumination was associated with less vACC activation when winning reward only for boys with mothers who were highly disengaged when discussing her son’s problems ($[2, 36, -8]$, 34 voxels, $t=3.46$, $pFWE=.04$) (Fig. 2). There was no association between maternal rumination and boys’ neural response to reward, for mothers low on disengagement. There was also no association between maternal rumination, maternal disengagement, and their two-way multiplicative interaction and boys’ neural response to loss.

Correlation analyses with boys’ psychiatric symptoms and functioning demonstrated that greater response in the vACC to winning reward was associated with boys’ greater anxiety symptoms at age 22 ($r=.20$, $p < .03$), but was unrelated to boys’ depressive symptoms and neuroticism ($ps=.22-.47$). Boys’ disengagement during the interaction task was unrelated to neural response to reward ($p=.89$), but was positively correlated with mothers’ disengagement ($r=.40$, $p < .001$) and boys’ neuroticism ($r=.23$, $p < .05$).

4. Discussion

Our longitudinal study showed that maternal rumination during childhood is associated with boys’ neural response to reward, but not loss, in late adolescence, however this effect was qualified by maternal disengagement during problem-solving with her sons. Specifically, greater maternal rumination was associated with less activation in ventral ACC, a region implicated in emotional response, arousal, and regulation (Etkin et al., 2011), but only when mothers were high on disengagement during problem-solving. This finding suggests that maternal rumination, even when accounting for mothers’ history of depressive symptoms, may be related to offspring disrupted response to reward function, but not to loss. Maternal rumination, when accompanied by high levels of maternal disengagement, may compromise parenting in regard to modeling effective problem-solving skills, with this compromised relationship style impacting their offspring’s ability to respond to pleasant events in the external world.

Although our findings may point to an inherited association between maternal rumination and boys’ own response to environmental stimuli (i.e., winning rewards), another possibility is that lack of maternal engagement during problem-solving discussions may prevent boys from developing healthy regulatory skills that facilitate enjoyment of positive events. Our interactive findings showed that maternal

Table 1
Means, standard deviations, range, and correlations of demographic and predictor variables.

Variable	M	SD	Range	1	2	3	4	5	6	7	8
1. Family Income	1057.47	595.22	300.00–3000.00	–	–	–	–	–	–	–	–
2. Maternal Education Level	12.66	1.57	8.00–18.00	.32**	–	–	–	–	–	–	–
3. Maternal Rumination (age 6)	32.50	8.46	16.00–56.00	–.09	.14	–	–	–	–	–	–
4. Maternal Depression (age 6–17)	1.48	2.10	.00–7.00	.02	.17*	.43**	–	–	–	–	–
5. Maternal Disengagement (age 10–12)	2.64	.93	1.33–6.17	–.17*	–.14	–.01	.10	–	–	–	–
6. Boys' Disengagement (age 10–12)	3.37	.93	1.50–5.83	.01	–.15	.03	.05	.40**	–	–	–
7. Boys' Neuroticism (age 20)	19.02	5.91	7.00–37.00	.05	.19*	.07	.13	–.02	.23*	–	–
8. Boys' Depressive Symptoms (age 22)	5.23	5.48	.00–36.00	–.04	.24*	.07	–.09	–.18*	.07	.36**	–
9. Boys' Anxiety Symptoms (age 22)	5.67	7.12	.00–49.00	.06	.21*	.03	.07	–.02	.12	.45**	.62**

Family Income=Dollars per month at 18 month assessment. Maternal Education Level=Years of schooling completed at 18 month assessment. Maternal Depression=Number of times above clinical cutoff for minimal to moderate depression on BDI from boys' age 6–17. $p < .01$ ** $p < .05$ * $p < .10$ †

Table 2
Main effect of task for reward and loss outcome.

Variable	Region	x	y	z	t	Voxels 2x2x2 mm	p_{FWE} peak-level
<u>Reward Outcome</u> > Baseline	VS and Caudate	6	20	0	8.33	897	.000
	Anterior Cingulate	–2	46	10	5.17	531	.003
	Medial Prefrontal Cortex	2	40	32	7.73	331	.040
<u>Loss Outcome</u> > Baseline	Striatum and Anterior Cingulate	18	28	0	7.67	353	.040

rumination appeared to influence boys' vACC response to reward only in the context of high levels of maternal disengagement when problem-solving with her son. Mothers who are more focused on their own internal world, rather than aiding their child in solving a problem may be more likely to have sons who have trouble enjoying positive events when they do occur. Possibly, these boys have learned from this parenting style to disengage during intensely emotional events, including positive events, perhaps because of greater preoccupation with their negative feelings and worries or because of desire for self-preservation in the face of potential threat. Indeed, we found that boys were also likely to disengage from the difficult discussion at ages 10–12 if their mothers were more likely to disengage, and that boys' disengagement was associated with boys' trait neuroticism. In contrast, when mothers high on rumination are able to distract themselves from their own worries during parent-child interactions and engage more fully with their children, parental rumination might not have the same negative

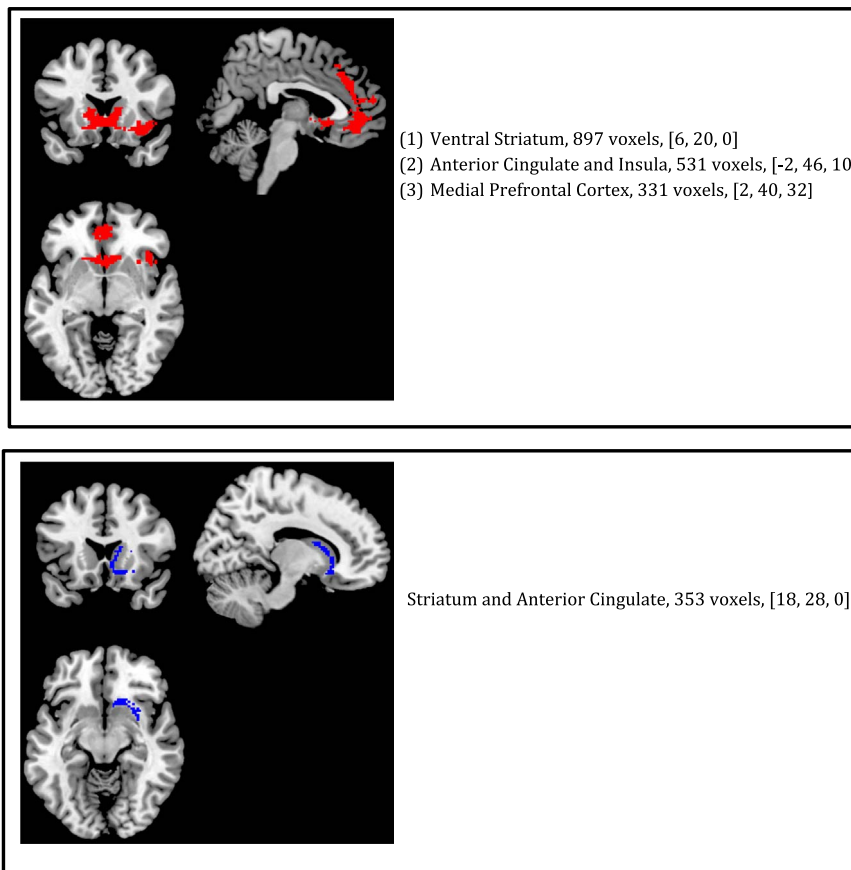


Fig. 1. Main effect of task for reward outcome (top, red) and loss outcome (bottom, blue). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

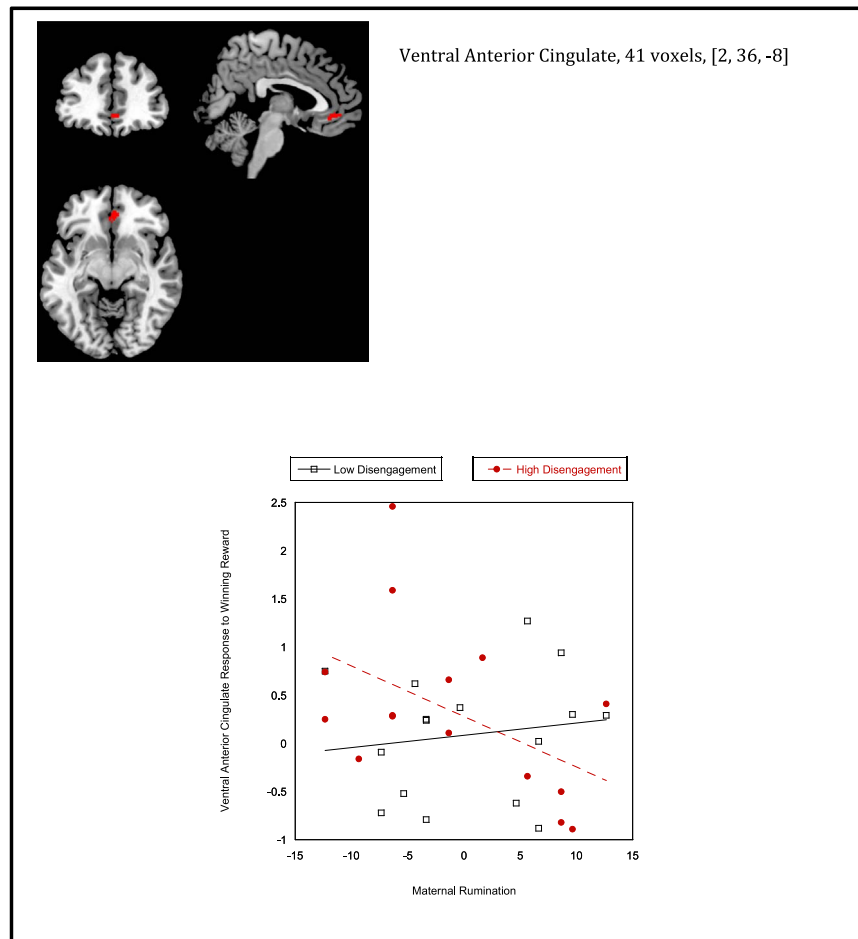


Fig. 2. Interaction between maternal rumination and disengagement during childhood on boys' neural response to reward in the ventral anterior cingulate/mPFC.

impact on child reward processing.

In addition to playing a role in emotion response (Etkin et al., 2011), the vACC has also been implicated in regulating conflict in highly emotional contexts (Kanske and Kotz, 2010) and in modulating amygdalar response to aversive feedback (Etkin et al., 2010). Thus, in addition to less enjoyment of winning reward, boys' lower response in the ventral ACC in the context of receiving positive feedback may also be related to less filtering out of negative thoughts and feelings in the context of a pleasant event, a behavioral pattern characteristic of rumination. As this region was related to maternal rumination in the context of mothers' models of disengagement, it may be that boys may be actively avoiding emotions, even those that are positive, as positive experiences can also generate stress.

Further, we found that *lower* response in this vACC cluster associated with maternal rumination and disengagement was *also* related to boys' *lower* anxiety symptoms at age 22. This finding was unexpected based on prior research that reduced responding in the vACC during emotional processing has been observed in clinically anxious adults (Etkin et al., 2010). Instead, our finding raises the possibility that disengagement during coping may (temporarily) serve to protect one's self from highly intense emotional experiences through emotional avoidance. Similar to the patterns of disengagement observed in both mother and son during the conflictual discussion at ages 10–12, boys may continue to disengage from highly arousing and emotional events, thereby preventing themselves from experiencing high levels of emotion in everyday life, including anxiety. Thus, it is possible that disengagement during conflict may provide some benefits, for both mothers and her sons, particularly for those prone to repetitive, perseverative thinking about negative events. In this case,

mothers who use this strategy with their sons may help sons to distract themselves from their ruminative and repetitive thoughts as a means of self-preservation to prevent a cycle of negative feelings over a topic or event that is difficult to resolve (Aldao et al., 2010). However, it is likely that this type of benefit may come with a cost. Although emotional avoidance may temporarily help prevent the experience of negative feelings, such as anxiety (Aldao et al., 2010), it may also dampen the experience of positive feelings and pleasant events (commensurate with our finding of lower response in the vACC to winning reward). Furthermore, disengagement during a difficult conversation can hinder communication and ultimately prevent effective problem-solving (Aldao et al., 2010).

In summary, our findings suggest that maternal rumination may be associated with offspring's less pleasurable enjoyment of rewards, but only in the context of disengaged maternal behavior toward the son. Mothers' tendency to focus on their own problems at the expense of helping children with theirs may be more likely to provide their sons with a model of ineffective coping that negatively impacts the ability to enjoy rewarding events and promotes emotional blunting. Specifically, these coping styles may hinder their ability to shift focus from negative moods to positive events around them. Perhaps, mothers who are able to manage their rumination so that it does not extend to a distracted or withdrawn interpersonal style during problem-solving might avoid exerting an influence on their children's responses to pleasant events.

Our study focused on boys from a low SES, urban community. Thus, our findings may not generalize to girls or to boys from other backgrounds. Also, women show higher levels of rumination relative to men and our study focused on boys' relationships with their mothers. Hence, our results may not extend to father-child relationships. One

limitation is that we only measured mothers' rumination style once (at age 6). Repeated assessment would have provided us with a more stable measure of her ruminative style. However, as prior work has demonstrated that ruminative style is a trait (Nolen-Hoeksema et al., 2008), it is likely that mothers high on rumination when their sons were age 6 were also high on rumination when their boys were age 10–12. Another limitation to our study is that we only evaluated neural function at age 20. It is possible that boys in this study showed these reward disruptions prior to their mother's expression of rumination and disengagement, although the likelihood of this directional effect is diminished because we measured maternal rumination at age 6, and some research indicates that rumination is stable (Nolen-Hoeksema et al., 2008). We also cannot rule out that our findings may be a result of a shared genetic tendency for maladaptive cognitive or emotional styles such as disengagement. While small for a behavioral study, our sample was sizeable for a neuroimaging study, particularly one that is part of a longitudinal study of developmental psychopathology in a high-risk sample.

Overall, our findings provide evidence that one specific cognitive-affective characteristic, rumination, may contribute to the development of disrupted reward function in offspring that has been observed in clinical depression and in adolescents at familial risk for depression. Our study is novel for testing and detecting associations (1) longitudinally, across critical developmental periods (2) between maternal cognition/behavior and sons' brain function and (3) with boys' own psychiatric functioning later in life (at age 22). These findings provide an intriguing initial step toward identifying social influences on brain development and underscore the value of a longitudinal, prospective design. Identifying specific symptomatology associated with disrupted development and transmission of risk for psychopathology is important, as these findings can be translated into concrete approaches (e.g., teaching mothers to restructure their negative cognitions, distract themselves from their own ruminative thoughts, and fully engage with their children) and integrated into larger intervention programs.

Acknowledgements

This research was supported by Grant R01 MH050907 from the National Institutes of Health to Daniel S. Shaw and R01 DA02622 to Daniel S. Shaw and Erika E. Forbes. We thank the staff and study families of the Pitt Mother and Child Project. Correspondence should be addressed to Judith K. Morgan, University of Pittsburgh, 3811 O'Hara Street, Pittsburgh, PA 15213, morganjk@upmc.edu.

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