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ORIGINAL PAPER

# Parenting an Early Adolescent: a Pilot Study Examining Neural and Relationship Quality Changes of a Mindfulness Intervention

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**Abstract** Relating to adolescent children can be challenging for parents, and yet children's perceptions of positive parent–child relationships are protective against deleterious outcomes. Therefore, it is valuable to understand and explore strategies that can support positive parent–adolescent relationships during adolescence. The present study investigates the effects of mindfulness training on parents' neural activity, children's perceptions of the parent–child relationship, and the relationship between the two. As such, this design allowed us to investigate intervention-induced changes in the parent–child relationship. One parent per family ($N = 18$) completed a task measuring mindful awareness of breathing during functional magnetic resonance imaging before and after attending an 8-week Mindful Families Stress Reduction (MFSR) course with their early-adolescent children. Across the sample, parent neural activation from pre- to post-intervention increased in areas related to self-awareness and evaluation (precuneus, ventromedial prefrontal cortex), emotional awareness and interoception (mid-insula), and emotion regulation (lateral prefrontal cortex). Changes in parents' activation in the left anterior insula/inferior frontal gyrus, an area often related to empathy and emotional processing/regulation, were specifically related to changes in children's reports of the parent–child relationship. The neural regions showing an intervention effect overlapped to a significantly greater degree with emotion regulation-related than attention-related regions. These findings implicate parental empathy and emotion/regulation in children's perceptions of the family relationship and suggest that parent emotion and/or emotion regulation is a potential mechanism by which mindful parenting interventions affect change.

**Keywords** Parenting · Mindfulness · Parent–child relationship · Attention · Emotion regulation

## Introduction

Cultivating positive relationships with adolescent children can be challenging for parents because of the physical, psychological, and social transitions that children go through in this time. Normal adolescents experience changes in mood and emotion related to reproductive hormones (Peper and Dahl 2013) and neural development (Moore et al. 2012; Nelson et al. 2005; Pfeifer et al. 2013) and shift the focus of their social interactions from family to peers as part of a broader quest for autonomy (Nickerson and Nagle 2005). However, the quality of the parent–child relationship appears to be particularly important during this time. A positive parent–child relationship can play a protective role as it is related to reduced risk-taking and delinquent behavior and increased positive outcomes such as academic success (see DeVore and Ginsburg 2005 for review). For these reasons, it is valuable to understand the factors that

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affect the parent–child relationship during adolescence and explore strategies that can support positive relationships.

Mindfulness practice, defined here as "the awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experience moment by moment" (Kabat-Zinn 2003), can contribute to effective parenting interventions. Parenting interventions that include a mindfulness component have been shown to improve parent affective self-regulation (Meamar et al. 2015), increase parent warmth and positive parenting (Duncan et al. 2015), and reduce negative parent emotional expressions and parenting practices (Lippold et al. 2015; Parent et al. 2016; Turpyn and Chaplin 2016) and increase shared parent–child positive emotion (Coatsworth et al. 2015; Lewallen and Neece 2015; Lippold et al. 2015; Turpyn and Chaplin 2016). Though these studies and others (Bögels et al. 2010; Dumas 2005; Duncan et al. 2009; Harnett and Dawe 2012) have suggested potential psychological and interpersonal mechanisms by which mindfulness practices help families, no studies have yet addressed the question of neural mechanism.

Functional neuroimaging has value for exploring the mechanisms of a mindfulness intervention because of its ability to access the neural underpinnings of mental processes that may be beyond introspection. In the case of parenting interventions, the child's perception of relationship quality is a strong predictor of outcomes, even though parents are the primary targets of the intervention (DeVore and Ginsburg 2005). Functional neuroimaging may reveal neural changes that are different from, and perhaps outside the scope of, self-report. Examining the relationship between children's reports of the parent–child relationship and parental functional activation is a robust way to understand the effects of mindfulness training on the parent–child relationship.

This pilot study represents the first functional neuroimaging investigation of the neural correlates of mindfulness in parenting. Parents completed functional magnetic resonance imaging (fMRI) sessions immediately before and after attending a modified mindfulness-based stress reduction (Kabat-Zinn 1990) with their early-adolescent children. Parents completed an existing fMRI-compatible mindful awareness of breathing task, as well as mindfulness and well-being self-report measures. Children completed a measure of parent–child relationship measure before and after the 8-week course. We had three sets of hypotheses relating to the self-report measures, the neural measures, and the relationships between the two. First, because we were interested in the effect of mindfulness training on the parent–child relationship, we predicted that the child's perception of the parent–child relationship would improve from before to after the Mindful Families Stress Reduction (MFSR) course. Second, because change in attention-related processing is a known effect of mindfulness training (Chiesa et al. 2011) and because our previous work (Dickenson et al. 2012) found an effect of the mindful awareness of breathing task we used here on frontoparietal attention network activation, we predicted parents to have task-dependent increases in activation in frontoparietal regions from pre- to post-intervention. Third, we predicted that the improvements in the parent–child relationship would be related to the increases in the parents' neural activity in areas related to attention and/or emotion regulation. Given the lack of previous data relevant to this third hypothesis, we reasoned that there were at least two possibilities. We expected that a measure of the parent–child relationship could relate to increases in activation in the frontoparietal attention network, suggesting improvements to the parent–child relationship via parent attention processing. Alternatively, we expected that a measure of the parent–child relationship could relate to increases in activation in regions associated with emotion regulation such as dorsomedial prefrontal cortex, ventrolateral prefrontal cortex, and dorsal anterior cingulate cortex (Ochsner et al. 2012), suggesting improvements to the parent–child relationship via parent emotion regulation.

## Method

### Participants

Twenty-eight parents (one parent per child, all Caucasian; M age = 40.51 years, SD = 6.31, range = 29–57, 3 males) and children (M age = 11.00 years, SD = 1.05, range = 9–13, 11 males) were recruited from Eugene, Oregon through fliers posted in the community (e.g., yoga studios, YMCA) and via phone contact from the Psychology Developmental Database of 10–12-year olds. Interested parent–child dyads were screened in a phone conversation with the parent to have normal or corrected to normal vision and hearing, the ability to read, write, and speak in English at an age-appropriate level, and the absence of suicidality and current clinical depression, diagnosis of developmental delay, bipolar disorder, post-traumatic stress disorder, and severe social anxiety that would make it difficult to be in a classroom setting. Parents were further screened for scanner compatibility, and children could not have a history of seizures or epilepsy. All participants provided written informed consent approved by the University of Oregon Institutional Review Board.

The sample was collected in three waves; the course was conducted in the same manner for each wave but each class varied slightly in what percent of class attendees were willing to be scanned. Over all three waves, 28 families met the inclusion criteria and were consented, 24 completed the first scanning session, and 18 completed the class and both scanning sessions. Families who completed the class and both scanning sessions (parent age M = 41.27, SD = 7.42, 2 males, Five Facet Mindfulness Questionnaire (FFMQ) M = 130.99, SD = 21.74, child age M = 10.89, SD = 1.13, 7 males) did not differ significantly in parent age, child age, or parent initial score on the FFMQ from families who did not complete all sessions (parent age M = 39.14, SD = 3.49, 1 male, FFMQ M = 131.39, SD = 13.78, child age M = 11.20, SD = 0.92, 4 males, all $p$ values > .05). One family did not complete all of the questionnaires, reducing the available sample size for some measures (noted in the results section). Of the 18 participants that completed both scanning sessions, most parents had not previously engaged in mindfulness practices ($n = 13$), but a minority were experienced meditators ($n = 5$, range of 3–214 months, 2–21 times per week) presumably participating in the class to introduce mindfulness practices to their children. To control for this, previous meditation experience (as a dichotomous categorical variable) was included as a covariate in all subsequent analyses. Also, because of the gender imbalance in our sample, we included gender as a covariate in each of the statistical tests below; all analyses were substantively unchanged when controlling for gender.

## Procedure

Participants came to the Lewis Center for Neuroimaging within 1 week of the first MFSR class meeting to complete a pre-intervention neuroimaging session. Within 1 week of completion of the 8-week course, participants completed an identical post-intervention neuroimaging session. Self-report measures relating to mindfulness and parenting were completed before and after the course.

## Neuroimaging

Participants completed two runs of a mindful awareness of breathing task that compares present moment interoceptive attentional focus on the breath (one component of mindfulness practice) to mind wandering. Additionally, participants completed three other tasks that will be reported separately (measuring external attention regulation, emotion regulation, and response inhibition). Task order was counterbalanced across subjects, and total scan time was approximately 50 min. Except for counterbalancing order, pre- and post-intervention scanning sessions were identical.

## Mindful Families Stress Reduction Course

The 8-week MFSR mindfulness course was based on Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn 1990) and included adaptations for children (Saltzman and Goldin 2008). Notably, the MFSR course offered no instruction in parenting but instead simply provided opportunities for parents and children to practice mindfulness techniques together. Major modifications of MBSR included removing the silent retreat from week 7, reducing class sessions to 90 min (compared with the standard 150 min of MBSR), and including age-adapted activities (i.e., more experiential and of shorter duration). Home practice assignments were also shorter for the children (e.g., 3–12 min daily), but not for parents (e.g., 40 min daily practice). Each week, participants were asked to practice daily informal mindfulness practices (e.g., eating, brushing teeth, daily transitions). In each of the three cohorts, one of the eight class sessions was canceled due to an issue such as inclement weather or scheduling difficulties.

## Measures

### *Mindful Awareness of Breathing Task*

We used a version of the mindful breathing task described by Arch and Craske (2006) that we previously adapted for the neuroimaging environment (Dickenson et al. 2012). The task compares a focused breathing (FB) condition to a mind-wandering (MW) control condition. In the FB condition, participants were instructed to focus on the physical sensations of breathing such as air entering and leaving the nose and the abdomen rising and falling. Participants were told not to berate themselves if they noticed that their attention had wandered but instead to gently bring awareness back to their breath. In the MW condition, participants were instructed to let their minds wander freely. Each 50 second block was followed by five 6 second questions to assess participant's compliance with instructions (e.g., "In general, I was able to follow the instructions, remaining focused on my breath.") and then 12 seconds of resting fixation. Each condition was presented four times per run for a total of eight blocks or 6:18 per run. The order of the conditions within the runs alternated between FB and MW, and each run started with a different condition. The order of the runs was counterbalanced between participants and between the pre- and post-intervention sessions.

With this task, we aimed to isolate neural activity in the parents associated with mindfulness by comparing it with mind wandering. This comparison accomplishes that because the focused breathing condition contains both the (a) intentional present moment focus and (b) nonjudgmental attitude that characterize mindfulness practice, whereas the mind-wandering condition also involves self-directed thought but without attentional control, present moment focus, and nonjudgment. We set out to explore the neural mechanisms by which mindfulness practice might affect the parent–child relationship by examining how neural activation specific to the focused breathing condition changed over the course of the MFSR intervention, and how those changes related to child's perception of the parent–child relationship.

## Self-Report Measures

Parents and children completed a variety of questionnaires intending to measure personality and behavior related to mindfulness, some of which will be reported separately. Here, we list the questionnaires relevant to the current study.

**Home Mindfulness Practice** We attempted to collect participant reports of time spent on mindfulness practice at home, but the rate of timely completion was very low (less than 50 %). Experimenters observed participants backfilling their at-home minutes practiced prior to the MFSR meetings each week, defeating the key purpose of the home record to overcome retrospective bias. The fact that these retrospective reports of minutes practiced did not correlate with pre- to post-intervention change in mindfulness as measured by standard indices (described below) casts further doubt on the veracity of the reports. Thus, record of home practice is not included in the results discussed here.

**Perceived Stress** Parents completed the Perceived Stress Scale (PSS; Cohen et al. 1983), a ten-item scale (baseline $\alpha = .89$, endpoint $\alpha = .87$) which measures the degree to which situations in one's life are appraised as stressful on a 5-point Likert scale.

**Mindfulness** Parent mindfulness was measured via the FFMQ (Baer 2006; Baer et al. 2008), a 39-item questionnaire (baseline $\alpha = .95$, endpoint $\alpha = .93$) that uses a 5-point Likert scale to measure mindfulness according to five factors: eight items for observing (baseline $\alpha = .80$, endpoint $\alpha = .67$), eight items for describing (baseline $\alpha = .97$, endpoint $\alpha = .94$), eight items for acting with awareness (baseline $\alpha = .95$, endpoint $\alpha = .88$), eight items for nonjudging of inner experience (baseline $\alpha = .85$, endpoint $\alpha = .90$), and seven items for nonreactivity to inner experience (baseline $\alpha = .86$, endpoint $\alpha = .86$). Example item: "I pay attention to how my emotions affect my thoughts and behavior." Child mindfulness was measured via the Child and Adolescent Mindfulness Measure (CAMM; Greco et al. 2011), a 25-item scale that uses a 5-point Likert scale to yield a single overall score of the child's acceptance and mindfulness (baseline $\alpha = .87$, endpoint $\alpha = .91$). Example item: "I think about things that happened in the past instead of thinking about things that are happening right now" (reverse coded).

**Child Reports of Family Relationship** Children reported on parenting practices and parent–child relationship with the Community Action for Successful Youth (CASY) Parenting and Family Measures (Metzler et al. 1998). This measure is designed to assess the role of conflict, monitoring, positive family relations, discipline, and positive reinforcement in the development of problem behaviors in children and adolescents. Children completed two subscales: the six-item positive family relations subscale (e.g., "My parents trusted my judgment." baseline $\alpha = .84$, endpoint $\alpha = .74$) and the five-item parental monitoring subscale (e.g., "How often does at least one of your parents know what you are doing when you are away from home?" baseline $\alpha = .89$, endpoint $\alpha = .84$).

### fMRI Data Acquisition and Analysis

Data were acquired using a Siemens Allegra 3.0 Tesla MRI scanner at the Lewis Center for Neuroimaging at the University of Oregon. Two whole-brain blood oxygenation-level-dependent functional scans lasting 6:18 min each were acquired during presentation of the paradigm (echo planar T2*-weighted gradient-echo, TR = 2000 ms, TE = 30 ms, flip angle = 80°, matrix size 64 × 64, FOV = 200 mm, 32 slices, 3.1 mm in-plane resolution, 4 mm thick). A total of 378 whole-brain volumes were acquired in the functional scans (189 per run of the focused breathing task). In addition, an 8:08 high-resolution structural scan was acquired using an inversion recovery T1-weighted 3D MP-RAGE pulse sequence (TR = 2500 ms, TE = 4.38 ms, TI = 1100 ms, flip angle = 8°, 256 × 192 voxel matrix, 256 × 192 rectangular field of view, 160 contiguous axial slices coplanar to the functional scans, bandwidth = 130 Hz/pixel, slice thickness = 1 mm, and in-plane resolution of 1 × 1 mm) for functional image registration during fMRI analysis preprocessing. Prior to each run, field map scans were acquired to obtain magnetization values used to correct for field inhomogeneity.

All images were skull stripped using FSL's Brain Extraction Tool (BET; FMRIB Software Library, Oxford University, Oxford, UK). In SPM8 (Wellcome Department of Cognitive Neurology, Institute for Neurology), field maps were used to unwarp magnetic field distortions. Functional images were realigned within and between runs to correct for residual head motion and co-registered to the matched-bandwidth structural scan using a six-parameter rigid body transformation. All functional and anatomical images were then reoriented to set the origin to the anterior commissure and the horizontal ($y$)-axis parallel to the AC-PC line. The co-registered structural scan was then normalized to the Montreal Neurological Institute (MNI) standard stereotactic template, and these parameters were applied to all functional images. Finally, the normalized functional images were smoothed using a 6-mm full-width at half-maximum Gaussian kernel. Preprocessed images were manually inspected, and no subjects showed greater than 1 mm motion.

Fully preprocessed images were entered into subject level, fixed effects models with an explicit mask made from an average of first functional run and a 256 second high pass filter, which removed low-frequency noise without removing signal related to the blocks of interest. Contrasts were created for each participant for the primary contrast that captures increases over time during the FB > MW comparison: (FB (post-intervention) > MW (post-intervention)) > (FB (pre-intervention) > MW (pre-intervention)) and then averaged in a group level, random effects model where previous experience was entered as a covariate of no interest. As in the previous study using this task (Dickenson et al. 2012), global normalization was used at the subject level to account for differences in total BOLD signal between the FB and MW tasks. A gray matter mask, based on the SPM a priori gray matter mask thresholded at 30 % probability, was explicitly specified during analysis. Family-wise false discovery rate (FDR) was set at 0.05 using a Monte-Carlo simulation as implemented in AlphaSim (AFNI; Cox 1996), which yielded a joint voxel-wise threshold of 0.005 and cluster extent of 49 voxels. All functional imaging results are reported in MNI coordinates.

Functional MRI results from an attention task (The Attention Network Test; Fan et al. 2002) and a cognitive reappraisal-based emotion regulation task (Burklund et al. 2014) completed by the same participants were used as functional localizers to generate regions-of-interest (ROIs) with the Marsbar toolbox for SPM (http://marsbar.sourceforge.net). Thus, the resulting ROIs were not only in line with patterns of activation seen in meta-analyses (Buhle et al. 2014; Wager et al. 2004) but also specific to these participants. The attention and emotion regulation maps are available from the first author by request.

## Results

### Intervention Effects: Self-Report Measures

Parents showed significant increases in mindfulness and decreases in stress from before to after the MFSR course (Table 1). The changes in mindfulness and stress were highly negatively correlated ($r = -.66$, $p = .004$) meaning that those who increased the most in mindfulness decreased the most in stress. Of the five FFMQ subscales, four increased significantly (observing, describing, nonjudging of inner experience, and nonreactivity to inner experience) but the Act with Awareness subscale did not (Table 1).

Children reported a significant increase in the amount of parental monitoring, but, on average, reported no significant changes in positive family relationship (Table 1). Change in parent mindfulness was significantly correlated with change in child-perceived positive family relationship ($r = 0.49$, $p = .045$), meaning that parents who increased the most in mindfulness had children who perceived the most improvement in their family relationship. There was no relationship between change in parent mindfulness and change in child-perceived parental monitoring ($r = 0.34$, $p = 0.19$).

Other treatment effects of MFSR are reporter elsewhere (Felver 2012; Felver et al. 2014).

### Intervention Effects: Neuroimaging

*In-Scanner Attention Check Questions*

We created a composite of the five scanner questions to verify that participants were equally able to comply with the instructions of the two conditions of the scanner task. There were no significant differences in these items between FB (baseline M = 2.61, SD = 0.55, endpoint M = 2.59, SD = 0.64) and MW (baseline M = 2.55 SD = 0.50, endpoint M = 2.63, SD = 0.65) at either time point, nor from before to after the intervention, baseline FB vs. MW $t(17) = 0.90$, $p = 0.38$; endpoint FB v. MW $t(17) = 0.85$, $p = 0.40$; FB baseline vs. endpoint $t(17) = 0.10$, $p = 0.92$; MW baseline vs. endpoint $t(17) = 0.79$, $p = 0.44$.

### Increases in FB > MW Over Time

We examined the interaction between condition (FB vs. MW) and time (pre- to post-intervention) to identify regions that changed during focused breathing as a function of the MFSR course, controlling for previous meditation experience. Figure 1 and Table 2 show regions that increased from pre- to post-intervention during the FB > MW task. We observed increases in cortical midline structures related to self-processing (Precuneus, vmPFC), emotion awareness and interoception (subgenual ACC, mid-insula, and lateral PFC), and emotion regulation (dmPFC extending into preSMA and lateral PFC). When we decomposed the interaction, it was clear that the effects were driven by increases in activation in the FB condition from pre- to post-intervention. The comparison of the MW condition pre- to post-intervention yielded no significant increases or decreases, but the comparison of the FB condition pre- to post-intervention yielded all of the same anatomical regions and 20 out of 22 submaxima reported here. The pre-intervention FB vs. MW contrast is reported in Supplementary Table 1 and replicates our previous study (Dickenson et al. 2012) using this task.

### ROI Analysis of Increases in FB > MW Over Time

Based on the results of this whole-brain analysis and to further test our prediction that parents would have task-dependent increases in activation in frontoparietal regions from pre- to post-intervention, we conducted a ROI analysis using functionally derived ROIs from the attention and emotion regulation tasks completed by these participants. The emotion regulation ROI contained 15,411 voxels and the attention ROI contained 11,633 voxels. Of these, significantly more voxels of the emotion regulation voxels (47 %) demonstrated the increase in FB > MW over time than attention voxels (35 %), $X^2(1) = 447.14$, $p < .001$. Furthermore, comparison of the unique (i.e., non-overlapping) voxels in each ROI again demonstrated that significantly more voxels within the emotion regulation ROI (56 % of 4987 voxels) showed the FB > MW increase over time than within the attention ROI (23 % of 4286 voxels) $X^2(1) = 1057.7$, $p < .001$, suggesting that the emotion regulation voxels fit the pattern to a greater extent than the attention voxels.

**Table 1** Intervention effects on self-report measures: M (SD)

| Measure | Baseline | Endpoint | Change *t* value | *d* |
|---|---|---|---|---|
| Parent report | | | | |
| FFMQ | | | | |
| Total | 132.70 (21.13) | 146.74 (16.57) | 4.45*** | 1.08 |
| Observing | 29.14 (4.74) | 31.94 (3.25) | 3.33** | 0.81 |
| Describing | 27.24 (7.81) | 30.06 (6.53) | 2.89* | 0.70 |
| Acting with awareness | 25.55 (6.76) | 26.82 (4.60) | 1.12 | 0.27 |
| Nonjudging of inner experience | 29.05 (4.60) | 32.65 (4.46) | 6.05*** | 1.47 |
| Nonreactivity to inner experience | 21.82 (4.29) | 25.26 (3.72) | 3.8** | 0.92 |
| PSS | 19.03 (5.04) | 14.22 (4.31) | 4.12*** | 1.00 |
| Child report | | | | |
| CASEY | | | | |
| Parental monitoring | 3.91 (0.92) | 4.38 (0.72) | 2.17* | 0.53 |
| Positive family relationship | 3.35 (0.89) | 3.53 (0.60) | 0.98 | 0.24 |

*Note.* $N = 17$.
$*p < .05$; $**p < .01$; $***p < .001$

We utilized automated meta-analyses found on Neurosynth.org (Yarkoni et al. 2011) as an additional, more data-driven way to test our hypotheses about parental attention and emotion regulation in connection with this result. Meta-analyses of the words "emotion," "regulation," and "empathy" each yielded clusters of activation within 10 mm of our left anterior insula/inferior frontal gyrus cluster, while the words "attention" and "attend" did not, suggesting that this region is indeed recruited during emotion/regulation and empathy more frequently than it is during attention.

## Correlations Between Parent Neural Changes and Child Report of Family Relationship

Our final set of hypotheses was about the relationship between changes in reports of the parent–child relationship and changes in neural activity. Thus, the next analyses investigated how neural activity measured in the contrast reported above (i.e., change in FB > MW from pre- to post-intervention) correlated with children's reports of relationship quality with both parents as operationalized by the CASEY parental monitoring and positive family relationship subscales. Even though there was no

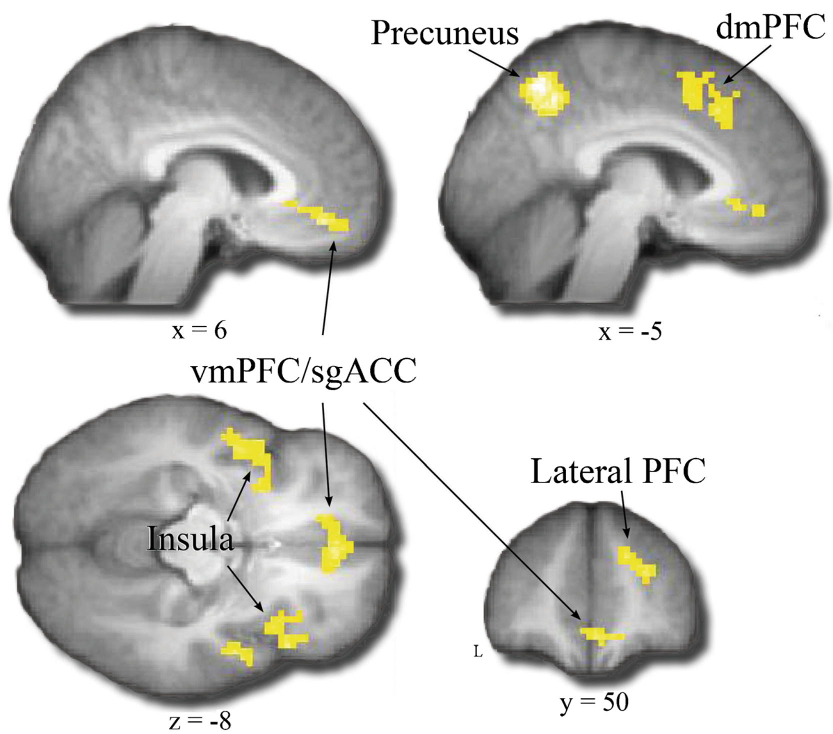


**Fig. 1** Regions showing pre- to post-intervention increase in the FB > MW contrast, controlling for previous meditation experience. *dmPFC* dorsomedial prefrontal cortex, *vmPFC* ventromedial prefrontal cortex, *PFC* prefrontal cortex, *sgACC* subgenual anterior cingulate cortex. FDR corrected at .05

**Table 2** Regions with a pre- to post-intervention increase in the FB > MW contrast

| Region | Hemisphere | *x* | *y* | *z* | Cluster size | *T* |
|---|---|---|---|---|---|---|
| Ventromedial PFC | R | 9 | 53 | −14 | 101 | 3.88 |
| | | 3 | 47 | −11 | | 4.16 |
| sgACC | Midline | 9 | 35 | −5 | | 4.76 |
| | | −3 | 32 | −2 | | 3.75 |
| Lateral PFC | | | | | | |
| Superior frontal gyrus | R | 21 | 59 | 16 | 85 | 3.13 |
| | | 27 | 50 | 19 | | 3.67 |
| Medial frontal gyrus | R | 36 | 44 | 22 | | 3.57 |
| Inferior frontal gyrus | R | 36 | 41 | 10 | | 3.36 |
| Dorsomedial PFC | L | −6 | 26 | 40 | 94 | 3.74 |
| | | −6 | 14 | 46 | | 3.46 |
| | | −9 | 23 | 49 | | 3.55 |
| Insula | R | 33 | 29 | −11 | 159 | 3.78 |
| | | 48 | 11 | 1 | | 3.6 |
| | | 39 | 17 | −8 | | 3.51 |
| | | 48 | 2 | 1 | | 4.09 |
| | | 51 | −1 | −5 | | 3.72 |
| Insula | L | −45 | 11 | −2 | 181 | 4.77 |
| | | −30 | 11 | −8 | | 3.66 |
| | | −36 | 11 | 7 | | 3.27 |
| | | −39 | −10 | 4 | | 3.23 |
| Precuneus | L | −6 | −52 | 46 | 165 | 4.44 |
| | | −15 | −64 | 46 | | 4.46 |

*Note.* $N = 18$. All regions FDR corrected at .05. Indents signify submaxima within clusters, and coordinates without an explicit region are the same as the region above.

*PFC* prefrontal cortex, *sgACC* subgenual anterior cingulate cortex.

mean increase across the sample in the positive family relationship subscale, within the sample there was a positive linear relationship between changes in child reports of the family relationship and changes in parent activation in the left anterior insula/inferior frontal gyrus (Table 3; Fig. 2) and was substantively unchanged as a result of controlling for changes in children's mindfulness. This region has been observed in emotional processing, empathy, and emotion regulation (Buhle et al. 2014; Fan et al. 2011; Iacoboni 2009; Jabbi and Keysers 2008; Kober et al. 2008; Lindquist et al. 2012) and responds differentially between meditators and non-meditators during pain (Grant et al. 2011) and empathic accuracy (Mascaro et al. 2013).

## Discussion

The emotional and cognitive benefits of mindfulness training may help parents during the difficult transitions of adolescence. The present study took the first step toward identifying the neural mechanisms underlying the effects of mindfulness practice on the child's perception of the parent–child relationship. Results demonstrate the effectiveness of an 8-week mindfulness-based course for improving both parent and child outcomes and for altering parent functional neural activity during a mindful awareness of breathing task. The pattern of these changes points to emotional processing as a possible mechanism of the improvements in the parent–child relationship.

Parents reported increases in mindfulness and decreases in stress from pre- to post-intervention, and increases in parent mindfulness were significantly related to increases in child-perceived positive family relationship. A comparison of parent neural activation during a mindful awareness of breathing task from before and after the 8-week course revealed changes in areas often related to self-awareness and evaluation, emotional awareness and interoception, and emotion regulation. Critically, children's reports of improvement in the family relationship corresponded to parent changes in activation in the left anterior insula/inferior frontal gyrus, an area often related to empathy and emotional processing/regulation.

We had predicted that the child's perception of the parent–child relationship would improve from before to after the MFSR course. Although there was no significant change in the child's perception of the positive family relationship on average, there was a positive relationship between improvements in parent-reported trait mindfulness and child-reported improvements in

**Table 3** Regions with pre- to post-intervention changes in activation in FB > MW that correlate with child-reported change in positive family relationship

| Region | Hemisphere | *x* | *y* | *z* | Cluster size | *t* |
|---|---|---|---|---|---|---|
| Anterior insula/inferior frontal gyrus | L | −36 | 29 | 10 | 177 | 5.02 |
| | | −39 | 32 | 7 | | 5.04 |
| | | −27 | 26 | 22 | | 4.46 |
| | | −39 | 17 | 13 | | 3.68 |

*Note.* $N = 17$. FDR corrected at .05

positive family relationship. In other words, although children overall did not report improvements in their relationship with their parents, parents who became more mindful had children who felt better about their relationship with their parents.

Parents reported an increase in trait mindfulness and a decrease in stress upon completion of the course. Moreover, those two measures were inversely related such that individuals who increased in trait mindfulness also had a corresponding decrease in self-perceived stress.

The changes in functional activity during the mindful awareness of breathing task may provide some insights into how the MFSR course altered the parent–child relationship. In our previous work with this task, we observed frontoparietal attention network activation in the FB condition when comparing with MW in a single session with meditation-naïve adults (Dickenson et al. 2012). Based on those results and the task's face-valid manipulation of attentional focus, we expected to find increases in frontoparietal regions when comparing the pre- and post-intervention scans. While the comparison of focused breathing to mind wandering within the pre-intervention scanning session replicated our previous work showing activation in attention-related frontoparietal regions (Supplementary Table 1), intriguingly, and contrary to our hypothesis, the regions whose activation was changed as a function of the intervention are typically associated with self-reference and emotion, not with attention. This finding is consistent with proposed conceptual integrations which argue that the cumulative effects of mindfulness training are on self-processing (Vago and Silbersweig 2012) and emotional systems (Chambers et al. 2009) via a systematic retraining of the process by which one brings awareness/attention to mental and sensory stimuli.

The association between parents' neural alterations and their children's perceptions of relationship change may also be informative. Although children reported significant increases in their parents' monitoring of the children's whereabouts and activities, this increase in parental attention did not correlate with parents' change in neural activation. Instead, parents' change in neural activation in a region implicated in empathy and emotion processing correlated with their children's report of the extent to which their feelings of trust, togetherness, and support changed over the MFSR course. In other words, children of parents who showed the highest increases in activation

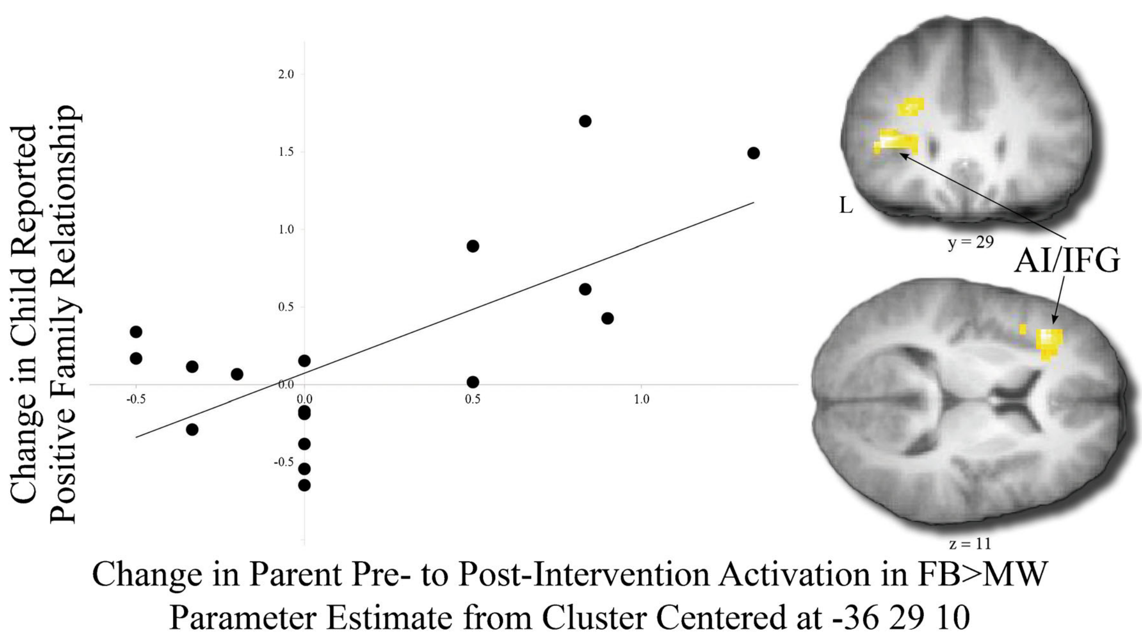


**Fig. 2** Region showing pre- to post-intervention changes in activation in the FB > MW contrast that correlate with child-reported change in positive family relationship, controlling for parent previous meditation experience. *AI* anterior insula, *IFG* inferior frontal gyrus. FDR corrected at .05

during mindful awareness of breathing in the left anterior insula/inferior frontal gyrus reported the highest increases in trust, togetherness, and support from those parents.

The relationship between change in the parents' activation during the mindful awareness of breathing task and change in their children's perception of the parent–child relationship could be explained by a mediating third variable. Though this is always a possibility in correlational research, we took steps to address it to the extent possible using the present data. First, the result was not substantively changed (i.e., all reported clusters were still present) when we controlled for change in the children's mindfulness. This finding reassured us that the link between change in parents' neural activity during mindful practice and their children's reports of the parent–child relationship was not merely a function of the children also increasing in mindfulness. Furthermore, this finding is useful in implicating the children's *perceptions* of the parent–child relationship as an important variable, above and beyond the children's actual level of mindfulness. Second, and with more nuance, we note that the CASY measure asks children about their perceived relationship with their parents and family generally, not just about their relationship with the one parent they attended the class with specifically. Also, it was correlated with change in the parents' neural activation and not self-report. We argue that these two facts together make this measure less vulnerable to demand characteristics because it did not directly ask about the parent with whom the child attended the course and, even if it did, the children were unlikely to be aware of the degree of change in that parent's neural activation during a mindful breathing induction.

Taken together, then, the change in the parents' neural activation and the link between this and change in their children's perceptions of relationship implicate parental empathy and emotion/regulation as potentially important to the child's perception of the family relationship and suggest that change in parent emotion and/or emotion regulation may be a mechanism by which mindful parenting interventions affect change.

However, it is not entirely clear from these data whether the intervention operates by changing emotional processing or emotion regulation. The observed pattern of MFSR-related changes in neural activation (Fig. 1; Table 2) is perhaps more consistent with emotional processing than with emotion regulation, though there is substantial overlap between the two. For example, activation in some of the most common regions related to emotion regulation such as anterior dorsomedial prefrontal cortex and dorsal anterior cingulate cortex is missing while activation in areas related to more bottom-up processing such as the insula is present. (However, and interestingly, we note that one region we found here, the vmPFC, has been implicated in several forms of *implicit* emotion regulation such as extinction learning; Phelps et al. 2004). One interpretation of this result is that the improved emotional functioning often associated with mindfulness training is qualitatively different from other forms of cognitive emotion regulation. This makes sense, as mindfulness training invites people to engage with their emotions in a way that is fundamentally different than cognitive reappraisal. While cognitive reappraisal focuses on changing an emotional response, mindfulness practices involve observing and accepting emotional responses just as they are, without trying to change them. This could be why the emotion relevant processing regions we see here are different than the typical emotion regulation profile which has largely been the result of studying emotion regulation using cognitive reappraisal tasks.

## Limitations

One limitation of this study is the lack of a no-intervention group to control for the effects of repeated task performance, time, and class participation. For example, we cannot rule out the possibility that repeated exposure to the mindful awareness of breathing task itself contributed to the parents' increases in activation from the first to the second scanning session. However, we argue that the changes in task-dependent activation were more likely connected to the 8 weeks of mindfulness training than time per se given the concomitant changes in parent stress and parent mindfulness. More importantly, the relationship of children's reports of relationship quality and changes in parent neural activity implicates the involvement of intervention per se in the results reported here (rather than task practice effects), because children participated only in the mindfulness training and not in the scanning sessions or tasks. For this initial study on parent–child mindfulness training, we recruited our participants from an ongoing intervention trial and were thus unable to recruit sufficient participants for a control group; obviously, further studies on this topic will require full-scale randomized controlled trials including an active control group. Nonetheless, we believe the results reported here provide (a) initial evidence of the feasibility of using neuroimaging to study a parent–child mindfulness-based intervention, (b) sufficient reasons for such interventions to warrant further study, and (c) preliminary hypotheses about the nature and direction of the neural results and their correlates.

We also cannot isolate intervention effects from the effects of parents and children attending classes and spending one-on-one time together. However, given the deliberate similarity between MFSR curriculum and that of a standard MBSR course, it is appropriate to compare MFSR parent outcomes to MBSR intervention effects that have been well studied. The reduction in parent stress and increase in mindfulness reported here are consistent with the scope of the results typically reported in MBSR interventions (Keng et al. 2011). More directly, the correlation between parent neural change and child report of the relationship change is within subjects and is thus driven more by individual differences in response to treatment within the treatment group than the main effect of the treatment itself. Nonetheless, future studies that feature an active control class are needed to fully explore these results.

In summary, the current pilot study is the first to explore the neural mechanisms of a mindfulness-based parenting intervention. Following an intervention that targeted parenting behavior only indirectly (i.e., through meditation practice), parents reported significant and correlated increases in mindfulness and reductions in stress, and children reported significant increases in parental monitoring. While children reported no significant increases in positive family relationship, parent mindfulness and parent–child relationship were correlated. What is not yet known is to what extent these positive family changes stem from parents and children learning mindfulness techniques together, vs. how much would result from one or both family members acquiring these skills separately. One possibility is that at least some aspects of mindfulness training are domain general, transferring across contexts. However, it is interesting to consider what might be the added value of learning mindfulness skills together with a family member, especially within the parent–adolescent relationship.

This initial examination of the neural correlates of parent–child mindfulness training expands our knowledge about the mechanism by which mindful parenting works. Instead of the expected increases in attention network activation, the observed increases in areas related to self-reference and emotion begin to emphasize the importance of empathy and emotion processing in mindful parenting, although the classic characterization of emotion regulation in this context may need to be broadened to incorporate processes more involved with emotion perception than reappraisal. The connection between parent change in a region implicated in emotion and empathy with child-perceived change in parent support and trust again points to emotion related processing as a potential "active ingredient" in the parent–child relationship in early adolescence. Based on this, one possible next step for mindful parenting interventions is to leverage meditation practices that have a strong socio-emotional component such as *metta* (Salzburg 1995) and *tonglen* (Chödrön 2001), an implication that illustrates the utility of translational neuroscience in this area.

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**Ethical Approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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