Routledge
Taylor & Francis Group

Child Neuropsychology

A Journal on Normal and Abnormal Development in Childhood and Adolescence

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ncny20

Neural correlates of distraction and reappraisal in the family context: Associations with symptoms of anxiety and depression in youth

Alexandra H. Bettis , Rachel E. Siciliano , Baxter P. Rogers , Megan Ichinose & Bruce E. Compas

To cite this article: Alexandra H. Bettis , Rachel E. Siciliano , Baxter P. Rogers , Megan Ichinose & Bruce E. Compas (2021): Neural correlates of distraction and reappraisal in the family context: Associations with symptoms of anxiety and depression in youth, Child Neuropsychology, DOI: 10.1080/09297049.2020.1870675

To link to this article: https://doi.org/10.1080/09297049.2020.1870675

Published online: 18 Jan 2021.

Submit your article to this journal

Article views: 43

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=ncny20

CHILD NEUROPSYCHOLOGY
https://doi.org/10.1080/09297049.2020.1870675

Routledge
Taylor & Francis Group

Check for updates

Neural correlates of distraction and reappraisal in the family context: Associations with symptoms of anxiety and depression in youth

Alexandra H. Bettis[a], Rachel E. Siciliano[b], Baxter P. Rogers[b], Megan Ichinose[b] and Bruce E. Compas[b]

[a]Department of Psychiatry and Behavioral Sciences, Vanderbilt University Medical Center, Nashville, USA; [b]Vanderbilt University, Nashville, USA

ABSTRACT

Objective: Youth coping is consistently associated with risk and resilience for youth internalizing psychopathology. Integrating questionnaire and experimental methods is an important next step in understanding how youth develop, learn, and implement these skills and to identify possible neurobiological mechanisms that underlie these processes. The current study aims to explore associations among youth self-reported and laboratory-based measures of two methods of coping (distraction and reappraisal). Further, the current study aims to examine associations among neural correlates of distraction and reappraisal with symptoms of anxiety and depression in youth.
Methods: Youth (N = 69; M = 12.24, SD = 1.83; 52.9% female) completed self-report measures of secondary control coping (RSQ) and symptoms of anxiety (SCARED) and depression (CES-D) and a laboratory coping task. While completing the task, prefrontal hemodynamic changes were measured using functional near-infrared spectroscopy (fNIRS).
Results: Neural activation during reappraisal was significantly negatively correlated with youth anxiety symptoms, and both neural activation and self-reported coping were significant independent predictors of anxiety. Youth self-reported coping was not associated with neural activation during reappraisal or distraction.
Conclusions: The measurement of possible neural markers of risk and resilience in youth is an important area of continued research. Identification of possible mechanisms of change related to anxiety and depression in youth may inform targets of intervention.

ARTICLE HISTORY
Received 23 September 2019
Accepted 26 December 2020

KEYWORDS
Coping; anxiety; depression; neuroimaging; adolescent

Efforts to cope with stress are important to the development of resilience across the life span. Results of a recent meta-analytic review highlight secondary control coping strategies (i.e., regulatory efforts to adapt to a stressful situation, which include the use of acceptance, distraction, cognitive reappraisal) as promising candidates for target mechanisms in the prevention of anxiety and depression (Compas et al., 2017). Late childhood to early adolescence presents a salient period of risk for adolescent internalizing problems (Costello et al., 2003; Hankin et al., 1998), suggesting the importance of developing skills to manage responses to stress during this developmental frame. The

CONTACT Alexandra H. Bettis alex.bettis@gmail.com 1500 21st Avenue South, Suite 2200, Nashville, TN 37212
© 2021 Informa UK Limited, trading as Taylor & Francis Group

present study builds upon prior coping research by examining neural correlates of distraction and reappraisal and their association with self-reported use of coping skills and internalizing symptoms in youth.

To date, the field has predominantly relied on self- and parent-reports to broadly assess youth coping strategies as they relate to psychopathology (Compas et al., 2017). As research shifts to include the identification of neurobiological markers of risk and resilience, studies have employed laboratory paradigms to assess the implementation of specific coping skills (e.g., reappraisal) and their underlying neural correlates (Drabant et al., 2009; Goldin et al., 2012; Ochsner et al., 2002, 2004). In a recent meta-analysis focused on adult samples, reappraisal was associated with activation in cognitive control regions (i.e., posterior dorsomedial prefrontal cortex [dmPFC], bilateral dorsolateral PFC [dlPFC], ventrolateral PFC [vlPFC], and posterior parietal cortex) and regions supporting semantic and perceptual representations (i.e., lateral temporal cortex) (Buhle et al., 2014). To a lesser degree, studies have also examined distraction (i.e., to distract yourself by thinking about something positive) using laboratory paradigms, identifying both common (dmPFC, dorsal anterior cingulate cortex [dACC]) and distinct (dlPFC, vlPFC) patterns of prefrontal activation during distraction compared to reappraisal (Hermann, Kress, and Stark, 2017; McRae et al., 2010). Child and adolescent studies, while limited in number, have replicated these findings (Belden et al., 2014, 2015; McRae et al., 2012), indicating prefrontal regions are associated with reappraisal and distraction in adults and youth.

Despite these initial important findings, common laboratory paradigms often fail to capture the *context* under which individuals cope with and regulate emotions in response to stress in daily life. This is important, as individuals' coping and emotion regulation responses may vary based on the context under which they are enacting regulation responses, and specific strategies may be more or less effective depending on situational context (Bonanno & Burton, 2013; Compas et al., 2017; Gross, 2015). Children and adolescents often cope with stress within the family context. Family stress, particularly when uncontrollable (e.g., displays of parental negative emotion in the context of parental depression), is linked to poorer child outcomes, including symptoms of both anxiety and depression (Costa et al., 2006; Goodman et al., 2011; van Oort et al., 2010). Youths' ability to effectively adapt to family stressors by utilizing secondary control coping strategies (acceptance, reappraisal, distraction), rather than attempt to change or avoid those stressors, may play a central role in reducing risk for internalizing symptoms during adolescence.

Neuroimaging studies have rarely linked performance on these laboratory paradigms (i.e., ability to engage in coping strategies) to reports of adolescents' use of these skills outside of the laboratory. In two studies, findings suggest potential correspondence between neural activation during task-based coping skill use and daily use of these skills (Belden et al., 2015; Drabant et al., 2009). Whether self-reported coping corresponds with neural responses when engaging in these strategies may inform how to select and measure targets of intervention for youth at risk for internalizing psychopathology. To date, studies have largely utilized functional magnetic resonance imaging (fMRI) to elucidate the neural underpinnings of coping processes. Instead, the present study employed functional near infrared spectroscopy (fNIRS), an emerging, noninvasive method, with several benefits for use in children and adolescents. fNIRS offers

comparable motion tolerance to fMRI in a noiseless environment, with increased comfort and compatibility, making the imaging technique an ideal candidate for imaging youth (Quaresima & Farrari, 2019). The fNIRS signal is closely related to fMRI and both measure changes in blood oxygenation via the same physiological mechanism (Fantini, Frederick, & Sassaroli, 2018). In addition, a number of studies have used NIRS to assess brain activation in the prefrontal cortex in response to cognitive tasks with an emotional component and have detected differences between task conditions (Bendall, Eachus, & Thompson, 2016). In studies utilizing fNIRS to examine implicit coping processes (i.e., not directly instructing individuals to engage in regulation), results show participants experience increased VLPFC and DLPFC (Perlman et al., 2014; Tupak et al., 2014).

To our knowledge, no studies have explored whether these neural correlates are important in samples of adolescent with varied levels of internalizing symptoms. Examining these processes in a sample of youth with a range of symptoms of anxiety and depression may inform our understanding of trajectories of risk and resilience in adolescence and clarify whether these neural patterns of activation serve as a marker of risk along the internalizing spectrum or signify clinical levels of symptoms. The present study sought to examine relationships between neural activation associated with coping and symptoms utilizing a laboratory paradigm and integrating self-report and experimental methods.

Current study

The current study examined whether youth show *increased* prefrontal activation when instructed to use distraction and reappraisal while viewing emotional stimuli, and the association of prefrontal activation during coping and internalizing symptoms. First, we hypothesized that (1a) youth would demonstrate greater signal change (i.e., change in oxygenated hemoglobin) in five *a priori* regions of interest (ROIs) that were selected from a meta-analysis of human neuroimaging studies reporting brain regions supporting reappraisal (Buhle et al., 2014) in response to emotional images during the reappraise, distract, and react conditions when compared to baseline activation, and (1b) youth will demonstrate greater signal change (increases) in response to instructions to reappraise and distract versus react trials when presented with emotional stimuli. Second, we examined associations between laboratory and self-report measurement of secondary control coping. We hypothesized that (2) signal change (increases) in prefrontal regions during reappraise and distract trials will be significantly *positively* correlated with self-reported secondary control coping. Third, we also assessed associations between signal change during reappraisal and distraction and symptoms of anxiety and depression in youth. We hypothesized that (3) increased prefrontal activation during reappraise and distract trials would be significantly *negatively* correlated with self-reported symptoms of both anxiety and depression in youth.

Methods

Participants

The sample included 70 youth ages 9 to 15 years old (M = 12.24, SD = 1.83; 52.9% female; 90% right-handed) recruited from a metropolitan area in the southeastern United States.

The sample of youth was 69.1% Euro-American, 20.0% African American, 4.4% Asian, and 5.9% self-identified as more than one race. The sample of youth was predominantly non-Hispanic (88.6%). Participant grade level ranged from 4th to 10th grade (mean = 6th grade). Final analyses included 69 participants with complete data; data was lost for one participant due to fNIRS technical difficulties.

Procedure

Participants were invited to participate in a study that aimed to better understand how youth respond to stress in the family. Participants were recruited through e-mails to a university employee list serve and university web-based methods of advertising research studies. Interested participants were screened via phone prior to study enrollment for exclusion based on parent-report of prior diagnoses of substance abuse, schizophrenia, bipolar disorder, and intellectual disability. Children completed a battery of measures through REDCap about stress, coping, and psychopathology and a computer-based coping task. While completing the task, prefrontal hemodynamic changes were measured using fNIRS. The University Institutional Review Board approved all study procedures. Parents provided consent for youth participation in the study, and youth provided assent.

Measures

Self-reported secondary control coping

Children completed the family stress version of the Responses to Stress Questionnaire (RSQ; Connor-Smith et al., 2000; Wadsworth & Compas, 2002), a self-report questionnaire measure of how youth cope with and regulate their emotions in response to family stress. The RSQ provides scores for three coping scales (i.e., primary control, secondary control, and disengagement coping), and two stress reactivity scales (i.e., involuntary engagement and involuntary disengagement). The RSQ has demonstrated excellent reliability and validity (Connor-Smith et al., 2000). Analyses in the present study focused on youth self-reports of *secondary control coping* in response to family stress to parallel the laboratory task. The secondary control coping scale includes items assessing acceptance, positive thinking, cognitive reappraisal, and distraction as regulation strategies.

Symptoms of anxiety and depression

Youth completed the Screen for Child Anxiety Related Disorders (SCARED; Birmaher et al., 1999), a 41-item self-report measure that captures symptoms associated with panic disorder or somatic complaints, generalized anxiety, separation anxiety, social anxiety, and school avoidance in the past 3 months. Youth also completed the Center for Epidemiologic Studies – Depression Scale (CES-D; Radloff, 1977), a 20-item measure that assesses symptoms of depression in the past week. Both the SCARED and CES-D demonstrate good reliability and validity in youth samples (Hale et al., 2011; Phillips et al., 2006).

Laboratory paradigm

Youth completed a laboratory assessment of reappraisal and distraction that was designed to depict family stress, including parental displays of sadness and anger/irritability (see *masked citation* for more detail). The task was modeled after prior studies utilizing

emotion paradigms to assess reappraisal and distraction in adults and youth (Belden et al., 2014, 2015; McRae et al., 2012; Ochsner et al., 2002). During the task, youth were instructed to view images of angry or sad adults displayed for 10 seconds, and rate their own negative emotion after each image was presented. Presentation of stimuli and collection of responses was controlled by EPrime 2.0 (Schneider et al., 2012). The task included four conditions: three conditions (reappraise, distract, and react-negative) presented images of adults displaying emotions, with the instruction to imagine the image was their parent, and one condition (react-neutral) presented neutral pictures. Conditions were block randomized, and images were randomly presented within each block such that no image was shown more than once throughout the entirety of the task. In the reappraise condition, youth were instructed to reappraise the image to make it *more* positive. In the distract condition, youth were instructed to think about something *else* that makes them feel good to make the image *less* negative. In the react conditions, youth were instructed to look at the image as they normally would. Prior to each block, research assistants provided instruction on reappraisal and distraction using age-appropriate language. Youth then completed a practice trial, where the instructor asked them to say out loud what they were thinking in order to assess whether youth understood the task instructions and how to employ each strategy. Children received corrective feedback if necessary. Prior to the stimulus presentation, the words "Make Positive" (reappraise), "Distract Yourself" (distract), or "Just Look" (react-negative, react-neutral) were presented for 1 second. Within each condition, youth saw a series of 10 images, immediately followed by negative emotion ratings on scale from 1 (not at all negative) to 5 (very negative). Mean negative emotion ratings and mean prefrontal activation during reappraise (10 total trials), distract (10 total trials), react-negative (10 total trials), and react-neutral (10 total trials) conditions were used in analyses. The implicit baseline for all conditions included in analyses was comprised of a fixation cross on a blank screen at the start of the task.

fNIRS data acquisition

fNIRS was performed with a 24-channel Hitachi ETG-4000 spectrometer to record relative changes of cortical oxy and deoxy-Hb concentrations using a 3 × 5 probeset consisting of 8 emitters and 7 detectors (interoptode distance = 30 mm; light penetration = 20 mm; sampling rate = 10 Hz). Emitters consisted of two laser diodes (3 mW ± 0.15 mW) with wavelengths of 695 nm and 830 nm that were amplitude modulated (0.6 and 1.5 KHz). We used the international 10–20 system of EEG electrode placement guideline with the central optode placed at Fz; however, a crucial difference is that NIRS optodes are held in a fixed holder, with 30 mm spacing between optodes. Despite anatomical variations among individuals, this method assures standardization across both individuals and time. Right side probes approximately covered Fp2, F4, and F8 and left side probes covered Fp1, F5 and F7; with this configuration, probes were restricted to dorsal frontal cortical regions and the task was expected to activate prefrontal regions targeted by this NIRS configuration.

fNIRS data analyses

Preprocessing. NIRS data pre-processing was done using a combination of in-house code from Vanderbilt University Institute of Imaging Science XNAT (Harrigan et al., 2016;

http://www.nitrc.org/projects/masimatlab) and portions of code from NIRS-SPM (Ye et al., 2009). Data were visually inspected for motion and the spline filtering method was utilized to reduce movement artifacts and increase signal quality (adapted from Scholkmann et al., 2010;; Cooper et al., 2012). Cardiac signal strength across channels for each participant was examined as an additional quality parameter (adapted from Pollonini et al., 2014). Optode locations in MNI space were estimated using the MNI space 10/20 positions described in Jurcak et al. (2005). The modified Beer-Lambert law (Cope et al., 1989; Kocsis et al., 2006) was applied to calculate changes in oxygenated and deoxygenated hemoglobin concentration for each channel in each condition. Oxygenated and de-oxygenated concentrations were projected into 3D MNI voxel space, and the oxygenated signal was further analyzed for the present analyses. When transformed into 3D MNI voxel space, separate regressors were constructed for the task conditions of interest (reappraise, distract, react-negative, react-neutral), and contrast images for single conditions against the baseline were calculated for each subject using a block-related design specifying the task conditions as regressors of interest.

Region of interest construction

We used a ROI approach to analyze the task-related fNIRS activation, focusing our selection of regions on the prefrontal cortex. ROIs were chosen from coordinates reported in a meta-analysis of human neuroimaging studies corresponding to maximum *z*-values for brain regions supporting reappraisal (reappraise > emotional baseline conditions) (Buhle et al., 2014). Though whole brain activation was reported in the aforementioned meta-analysis, consideration was limited to regions falling within voxels with available NIRS signal, which is restricted to dorsal frontal cortical regions. Three local maxima from the meta-analysis fit this criterion and were used to create our ROIs; one in the right middle frontal gyrus, one in the left middle frontal gyrus, and one centrally located in the superior frontal gyrus. The two middle frontal gyri coordinates represented distinct regions, therefore symmetrical homologues were created by flipping the sign of the X axis, as we did not have specific lateralized hypotheses for these regions. This resulted in a total of five ROIs: two bilateral pairs and one central region (Table 1). The local maxima were then expanded to 12 mm radius spherical ROIs (Figure 1). We labeled each coordinate representing the center of our spherical ROIs from the Harvard-Oxford Cortical Structural Atlas. The final ROIs were the intersection of the 12 mm spheres from Buhle et al. (2014) and voxels with available NIRS signal.

Table 1. Regions of interest selected for analyses.

	Hem	X	Y	Z	BA
Middle frontal gyrus (MFG)	R	42	30	39	9
Middle frontal gyrus (MFG)	L	−42	30	39	9
Middle frontal gyrus (MFG)	R	36	15	57	8
Middle frontal gyrus (MFG)	L	−36	15	57	6
Superior frontal gyrus (SFG)	C	0	15	63	6

Note. L, left; R, right; C, Central; x, y, z, center of mass coordinates in Montreal Neurological Institute (MNI) standard space; BA, Brodmann area. ROIs were labeled from the Harvard-Oxford Atlas as implemented within FSL (Smith et al., 2004; http://www.fmrib.ox.ac.uk/fsl) and Brodmann's Areas were labeled using Yale BioImage Suite (http://www.bioimagesuite.org).

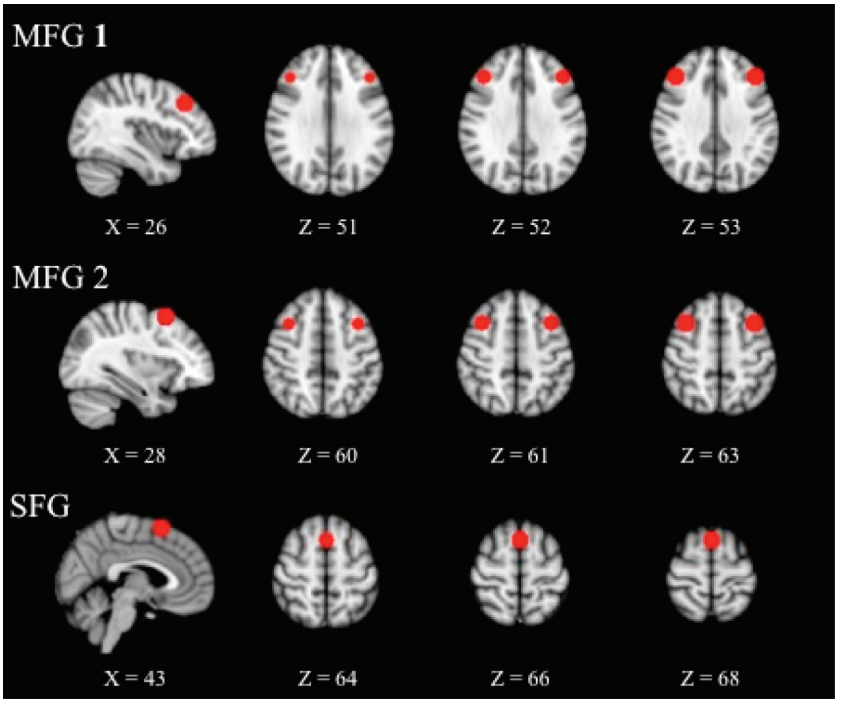

Figure 1. The local maxima expanded to 12 mm radius spherical ROIs.

Activation within regions of interest

All analyses were conducted using SPM12 (http://www.fil.ion.ucl.ac.uk/spm/software/spm12/) within MATLAB (2017; The Mathworks Inc., Natick, MA, USA). At the first level, each event was modeled by a 10 second box function convolved with the hemodynamic response (i.e., a sum of two discretized, or double, gamma functions) as implemented in SPM12 software for each participant (Glover, 1999). This accounts for hemodynamic delay. Oxygenated levels were measured the entire duration of the stimuli and the peak of the double gamma function was five seconds after stimulus onset. The GLM design matrix included seven events modeled at the first level: Reappraise of sad images, reappraise of mad images, distract from sad images, distract from mad images, react to sad images, react to mad images, and react to neutral objects, all relative to an implicit baseline. We modeled two comparisons of interest for each participant: reappraise > react and distract > react, averaged across sad and mad images, to investigate differences in secondary control coping (reappraise and distract) as compared to only reacting (react-negative), averaged across sad and mad trials.

At the second level, the contrast images generated, reappraise > baseline, distract > baseline, react > baseline, reappraise > react-negative, distract > react-negative, as described above, were averaged within each of the five a priori ROIs for each participant. The resulting signal change values for each participant, for each contrast, for each ROI were used in subsequent analyses. Outliers in the fNIRS data were identified as signal change values greater than or less than three standard deviations from the average signal change for each contrast and were excluded from analyses. Less than one percent of all imaging data met this criterion.

Data analytic approach

One-sample *t*-tests were conducted to compare task conditions (Hypotheses 1a and 1b). As we had specific hypotheses that each ROI would correspond to signal change as a result of the task, the Bonferroni method was adopted to address multiple comparisons within each ROI (i.e., three comparisons: reappraise > baseline, distract > baseline, react-negative > baseline, which yielded an adjusted *p*-value of .017). Bivariate correlations were conducted between fNIRS activation in *a priori* ROIs and self-reported secondary control coping (hypothesis 2). Bivariate correlations were conducted between fNIRS activation and symptoms of anxiety and depression (Hypothesis 3). Based on the bivariate results, exploratory hierarchical linear regression models were tested to examine whether self-reported secondary control coping and fNIRS activation in ROIs were independent significant predictors of symptoms.

Results

Means and standard deviations for the self-report measures of anxiety, depression, and secondary control coping are reported in Table 2. Negative emotion ratings differed by task condition, such that participants reported lower negative emotion when engaging in reappraisal and distraction compared to no regulation trials (for more detail, see *masked manuscript)*. In all three conditions (reappraise, distract, react-negative) activation in each of the five ROIs was significantly greater than implicit baseline, $p < .017$ (two-tailed; Bonferroni corrected). However, all contrast differences between active conditions (reappraise > react-negative, distract > react-negative) were non-significant, $p > .017$ (two-tailed). Overall, signal change differed from baseline but did not differ based on coping instructions.

fNIRS activation in all five *a priori* ROIs during the reappraise or distract conditions of the laboratory task was not significantly correlated with self-reported secondary control coping in response to family stress (Table 3). fNIRS activation during reappraise in all five *a priori* ROIs was significantly negatively correlated with self-reported anxiety, but not depressive symptoms (all $p < .01$). Greater signal change in the middle frontal gyrus (BA 6, 8) and superior frontal gyrus (BA 9) when instructed to use reappraisal was associated with lower levels of anxiety symptoms. Signal change in these regions during distract trials was not correlated with anxiety or depressive symptoms in youth.

A significant negative association between self-reported secondary control coping and anxiety symptoms in this sample has previously been reported (*masked citation*). Hierarchical linear regression analyses were conducted in the current study to examine whether fNIRS

Table 2. Means, standard deviations, and bivariate correlations among self-report measures.

Measure	Mean (SD)	RSQ SCC	SCARED	CES-D
RSQ SCC	.25 (.05)	–		
SCARED	20.04 (11.49)	−.50***	–	
CES-D	11.18 (7.87)	−.40**	.56***	–

Note: * = p < .05, ** = p < .01; RSQ SCC = Responses to Stress Questionnaire Secondary Control Coping scale (proportion scored); SCARED = Screen for Child Anxiety and Related Emotional Disorders total score; CES-D = Center for Epidemiologic Studies – Depression Scale total score.

Table 3. Bivariate correlations among self-report measures and brain activation.

	Reappraise Condition				
	R MFG1 (BA 9)	L MFG1 (BA 9)	R MFG2 (BA 8)	L MFG2 (BA 6)	SFG
RSQ SCC	.24^{+}	.12	.18	.11	.18
SCARED	−.46**	−.39**	−.40**	−.35**	−.40**
CES-D	−.09	−.09	−.10	−.08	−.09
	Distract Condition				
	R MFG1 (BA 9)	L MFG1 (BA 9)	R MFG2 (BA 8)	L MFG2 (BA 6)	SFG
RSQ SCC	−.02	−.10	−.02	−.08	.02
SCARED	−.23	−.11	−.15	−.14	−.21
CES-D	.02	.16	.06	.12	.04

Note: $^{+}$ = $p < .10$, * = $p < .05$, ** = $p < .01$; RSQ SCC = Responses to Stress Questionnaire Secondary Control Coping scale; SCARED = Screen for Child Anxiety and Related Emotional Disorders total score; CES-D = Center for Epidemiologic Studies – Depression Scale total score; R = right; L = left, MFG = middle frontal gyrus; SFG = superior frontal gyrus; BA = Brodmann Area

activation and self-reported secondary control coping were significant independent predictors of symptoms of anxiety in youth. Depressive symptoms were controlled for in the model. In three of the five tested models, *both* self-reported secondary control coping and fNIRS activation were significant independent predictors of anxiety symptoms in youth, above the variance accounted for by depressive symptoms (Table 4).

Discussion

Research has consistently found moderate cross-sectional associations between coping and internalizing psychopathology in children and adolescents when using self-report measures (Compas et al., 2017). There is an increasing effort to identify neural and biological markers of these processes, which may inform and refine targets for intervention. The current study builds upon previous research in this area by both replicating prior findings in identifying neural correlates of reappraisal and distraction and linking these neural correlates to symptoms in a sample of adolescents.

The current study found that adolescents demonstrated activation in prefrontal regions associated with cognitive control when implementing reappraisal and distraction compared to baseline. These regions, Brodmann's areas 8 and 9 in the prefrontal cortex, have been linked to executive functioning and working memory skills and are implicated in a broad range of functions including language, motor, and memory (e.g., Kubler, Dixon, & Garavan, 2006). In contrast to prior studies utilizing similar paradigms (Buhle et al., 2014), there were no significant differences between activation in the three task conditions utilizing emotional images. Reasons for these discrepant findings may be due, in part, to differences in task design.

In an effort to address limitations of prior research, the current paradigm was designed to assess how youth are able to regulate their emotions in response to images of one source of family stress; i.e., parental distress. Previous studies have utilized images that are effective in evoking negative emotion but may not be directly relevant to daily stressful experiences of participants (see Goldin et al., 2014, for an exception). The current study attempted to address this by instructing participants to imagine the images of adults in distress were their parent. Importantly, however, this inherently required a form of reappraisal of the images of adult distress. Thus, even during the react trials of the task, it is likely that youth were employing cognitive resources to reinterpret the

Table 4. Hierarchical linear regression analyses.

DV = Anxiety symptoms	β	t value	Total R^2
Condition: Reappraise			.48
1. RSQ SCC	−.21	−1.64	
2. R MFG1	−.30*	−2.53	
3. CES-D	.46***	3.80	
DV = Anxiety symptoms	β	t value	Total R^2
Condition: Reappraise			.46
1. RSQ SCC	−.27*	−2.25	
2. L MFG1	−.25*	−2.22	
3. CES-D	.45**	3.70	
DV = Anxiety symptoms	β	t value	Total R^2
Condition: Reappraise			.46
1. RSQ SCC	−.26*	−2.12	
2. R MFG2	−.25**	−2.18	
3. CES-D	.46*	3.75	
DV = Anxiety symptoms	β	t value	Total R^2
Condition: Reappraise			.45
1. RSQ SCC	−.27*	−2.21	
2. L MFG2	$-.22^{+}$	−1.94	
3. CES-D	.46**	3.73	
DV = Anxiety symptoms	β	t value	Total R^2
Condition: Reappraise			.46
1. RSQ SCC	−.26*	−2.11	
2. SFG	−.25*	−2.23	
3. CES-D	.46**	3.76	

Note: * = $p < .05$, ** = $p < .01$; RSQ SCC = Responses to Stress Questionnaire Secondary Control Coping scale; SCARED = Screen for Child Anxiety and Related Emotional Disorders total score; CES-D = Center for Epidemiologic Studies – Depression Scale total score; R = right; L = left, MFG = middle frontal gyrus; SFG = superior frontal gyrus.

image as their own caregiver. Consequently, differences in levels of brain activation between conditions may have been difficult to detect, as they would be present in all negative image trials. Future research should adapt the present design to eliminate this possibility. In addition, it is important to note that, given the lack of specificity between active conditions of the task, hemodynamic differences between active trials and the implicit baseline may be attributable to simply detecting visual information.

Contrary to study hypotheses, self-reported secondary control coping and neural activation when implementing distraction and reappraisal were not related. It is possible that the lack of correspondence between these methods was a result of differences in assessment – the laboratory task assessed reappraisal and distraction separately, while the questionnaire measure assesses these strategies together in a single secondary control coping factor. In addition, due to time limitations for the experimental task, we did not assess acceptance, another component of secondary control coping. In future research, it will be important to consider how to assess the full range of secondary control coping skills in experimental designs. Alternatively, youths' ability to implement those strategies under laboratory conditions may not reflect their experience using these skills in daily life. With an increasing emphasis on identifying neural biomarkers of psychopathology across the lifespan, further research exploring how widely used questionnaire methods, which are more easily administered in clinical settings, and laboratory methods converge or diverge is needed. I

Both decreased prefrontal activation during reappraisal and self-reported secondary control coping were independent predictors of increased anxiety symptoms. These

findings are consistent with studies in anxious adults (Goldin et al., 2009, 2012), and suggest that reduced patterns of neural activation during skill implementation may serve as an indicator of risk for anxiety symptoms. Further, these neural patterns of coping may be an important mechanism to assess over the course of interventions for anxiety. Replication of these findings in a clinically anxious sample of adolescents is needed. In contrast, depressive symptoms were not associated with prefrontal activation during any task condition. Prior studies in both adults and youth have examined differences between clinically depressed and non-depressed samples (Belden et al., 2015; Smoski et al., 2013), with mixed results. In one study of children, neural differences during reappraisal emerged in only one of 23 identified ROIs (Belden et al., 2015), while in an adult sample, depressed participants reported lower levels of neural activation in the middle frontal gyrus (Smoski et al., 2013). It is possible that neural correlates of coping skill use may function differently across the spectrum of depressive psychopathology, such that these mechanisms are only associated with clinical levels of depression and do not provide an indication of risk for the development of depression.

The present study had several limitations that can be addressed in future research. First, the study is cross-sectional in design. Future research examining longitudinal associations among these methods and key study constructs will be important, as limited prospective research in this area suggests neural activity during coping strategy use may change over the course of cognitive-behavioral intervention (Goldin et al., 2014). Longitudinal studies would also help to elucidate any age-related changes in neural activity during distraction and reappraisal. Second, the study used fNIRS, which has limited spatial specificity and captures only cortical brain activation (Woo et al., 2014). There are some notable limitations to fNIRS technology, including limited spatial specificity, though fNIRS is a more cost-effective tool and may be preferable for use in children. Its signal is limited to cortical regions, which precludes examination of other key regions of the brain implicated in the experience of emotion (e.g., amygdala, anterior cingulate cortex). Finally, while this study focused on internalizing psychopathology, research suggests that the use of secondary control coping skills is also significantly correlated with reductions in externalizing psychopathology; research exploring whether neural correlates of coping are associated with externalizing symptoms is an area for future research.

In summary, the measurement of possible neural markers of risk and resilience in childhood and adolescence is an important area of continued research. Identification of mechanisms underlying anxiety and depression in youth may inform targets of intervention. Further research is needed to assess whether experimental coping paradigms may provide clinical utility.

Disclosure statement

The authors report no disclosures or conflicts of interest.

Funding

This study was funded by the Routh Dissertation and Research Award (APA Division 53), a gift from an anonymous donor, and a gift from Patricia and Rodes Hart.

ORCID

Rachel E. Siciliano http://orcid.org/0000-0001-5958-6550

References

Belden, A. C., Luby, J. L., Pagliaccio, D., & Barch, D. M. (2014). Neural activation associated with cognitive regulation of sadness in healthy children. *Developmental Cognitive Neuroscience*, *9*, 136–147. https://doi.org/http://dx.doi.org/10.1016/j.dcn.2014.02.003

Belden, A. C., Pagliaccio, D., Murphy, E. R., Luby, J. L., & Barch, D. M. (2015). Neural activation during cognitive emotion regulation in previously depressed compared to healthy children: Evidence of specific alterations. *Journal of the American Academy of Child and Adolescent Psychiatry*, *54*(9), 771–781. https://doi.org/10.1016/j.jaac.2015.06.014

Bendall, R. C. A.., Eachus, P., & Thompson, C. (2016). A brief review of research using near-infrared spectroscopy to measure activation of the prefrontal cortex during emotional processing: The importance of experimental design. *Frontiers in Human Neuroscience*, *10*, 529. https://doi.org/10.3389/fnhum.2016.00529

Birmaher, B., Brent, D. A., Chiappetta, L., Bridge, J., Monga, S., & Baugher, M. (1999). Psychometric properties of the screen for child anxiety related emotional disorders (SCARED): A replication study. *Journal of the American Academy of Child and Adolescent Psychiatry*, *38*(10), 1230–1236. https://doi.org/10.1097/00004583-199910000-00011

Bonanno, G. A., & Burton, C. L. (2013). Regulatory flexibility: An individual differences perspective on coping and emotion regulation. *Perspectives on Psychological Science*, *8*(6), 591–612. https://doi.org/10.1177/1745691613504116

Buhle, J. T., Silvers, J. A., Wager, T. D., Lopez, R., Onyemekwu, C., Kober, H., Weber, J., & Ochsner, K. N. (2014). Cognitive reappraisal of emotion: A meta-analysis of human neuroimaging studies. *Cerebral Cortex*, *24*(11), 2981–2990. https://doi.org/10.1093/cercor/bht154

Compas, B. E., Jaser, S. S., Bettis, A. H., Watson, K. H., Gruhn, M. A., Dunbar, J. P., … Thigpen, J. C. (2017). Coping, emotion regulation, and psychopathology in childhood and adolescence: A meta-analysis and narrative review. *Psychological Bulletin*, *143*(9), 939. https://doi.org/10.1037/bul0000110

Connor-Smith, J. K., Compas, B. E., Wadsworth, M. E., Thomsen, A. H., & Saltzman, H. (2000). Responses to stress in adolescence: Measurement of coping and involuntary responses to stress. *Journal of Consulting and Clinical Psychology*, *68*(6), 976–992. https://doi.org/10.1037/0022-006X.68.6.976

Cooper, R., Selb, J., Gagnon, L., Phillip, D., Schytz, H. W., Iversen, H. K., Ashina, M., & Boas, D. A. (2012). A systematic comparison of motion artifact correction techniques for functional near-infrared spectroscopy. *Frontiers in Neuroscience*, *6*, 147. https://doi.org/10.3389/fnins.2012.00147

Cope, M., Delpy, D. T., Wray, S., Wyatt, J. S., & Reynolds, E. O. R. (1989). A CCD spectrophotometer to quantitate the concentration of chromophores in living tissue utilising the absorption peak of water at 975 nm. In K. Rakusan, G. P. Biro, T. K. Goldstick, Z. Turek (Eds.), *Oxygen transport to tissue XI* (pp. 33–40). Boston, MA: Springer. https://doi.org/10.1007/978-1-4684-5643-1_4

Costa, N. M., Weems, C. F., Pellerin, K., & Dalton, R. (2006). Parenting stress and childhood psychopathology: An examination of specificity to internalizing and externalizing symptoms.

Journal of Psychopathology and Behavioral Assessment, *28*(2), 113–122. https://doi.org/10.1007/s10862-006-7489-3

Costello, E. J., Mustillo, S., Erkanli, A., Keeler, G., & Angold, A. (2003). Prevalence and development of psychiatric disorders in childhood and adolescence. *Archives of General Psychiatry*, *60* (8), 837–844. https://doi.org/10.1001/archpsyc.60.8.837

Drabant, E. M., McRae, K., Manuck, S. B., Hariri, A. R., & Gross, J. J. (2009). Individual differences in typical reappraisal use predict amygdala and prefrontal responses. *Biological Psychiatry*, *65* (5), 367–373. https://doi.org/10.1016/j.biopsych.2008.09.007

Fantini, S., Frederick, B., & Sassaroli, A. (2018). Perspective: Prospects of non-invasive sensing of the human brain with diffuse optical imaging. *Apl Photonics*, *3*(11), 110901. https://doi.org/10.1063/1.5038571

Glover, G. H. (1999). Deconvolution of impulse response in event-related BOLD fMRI. *Neuroimage, 9*, 416–29. https://doi.org/10.1006/nimg.1998.0419

Goldin, P. R., Maner-Ball, T., Werner, K., Heimberg, R., & Gross, J. J. (2009). Neural mechanisms of cognitive reappraisal of negative self-beliefs in social anxiety disorder. *Biological Psychiatry*, *66*(12), 1091–1099. https://doi.org/10.1016/j.biopsych.2009.07.014

Goldin, P. R., Ziv, M., Jazaieri, H., Weeks, J., Heimberg, R. G., & Gross, J. J. (2014). Impact of cognitive-behavioral therapy for social anxiety disorder on the neural bases of emotional reactivity to and regulation of social evaluation. *Behaviour Research and Therapy*, *62*, 97–106. https://doi.org/http://dx.doi.org/10.1016/j.brat.2014.08.005

Goldin, P. R., Ziv, M., Jazaieri, H., Werner, K., Kraemer, H., Heimberg, R. G., & Gross, J. J. (2012). Cognitive reappraisal self-efficacy mediates the effects of individual cognitive-behavioral therapy for social anxiety disorder. *Journal of Consulting and Clinical Psychology*, *80*(6), 1034. https://doi.org/10.1037/a0028555

Goodman, S. H., Rouse, M. H., Connell, A. M., Broth, M. R., Hall, C. M., & Heyward, D. (2011). Maternal depression and child psychopathology: A meta-analytic review. *Clinical Child and Family Psychology Review*, *14*(1), 1–27. https://doi.org/10.1007/s10567-010-0080-1

Gross, J. J. (2015). The extended process model of emotion regulation: Elaborations, applications, and future directions. *Psychological Inquiry*, *26*(1), 130–137. https://doi.org/10.1080/1047840X.2015.989751

Hale, W. W., Crocetti, E., Raaijmakers, Q. A., & Meeus, W. H. (2011). A meta-analysis of the cross-cultural psychometric properties of the screen for child anxiety related emotional disorders (SCARED). *Journal of Child Psychology and Psychiatry*, *52*(1), 80–90. https://doi.org/10.1111/j.1469-7610.2010.02285.x

Hankin, B. L., Abramson, L. Y., Moffitt, T. E., Silva, P. A., McGee, R., & Angell, K. E. (1998). Development of depression from preadolescence to young adulthood: Emerging gender differences in a 10-year longitudinal study. *Journal of Abnormal Psychology*, *107*(1), 128. https://doi.org/10.1037/0021-843X.107.1.128

Harrigan, et al. 2016; http://www.nitrc.org/projects/masimatlab

Hermann, A., Kress, L., & Stark, R. (2017). Neural correlates of immediate and prolonged effects of cognitive reappraisal and distraction on emotional experience. *Brain Imaging and Behavior*, *11* (5), 1227–1237. https://doi.org/10.1007/s11682-016-9603-9

Jurcak, V., Okamoto, M., Singh, A., & Dan, I. (2005). Virtual 10-20 measurement on MR images for inter-modal linking of transcranial and tomographic neuroimaging methods. *Neuroimage*, *26*(4), 1184–1192. https://doi.org/10.1016/j.neuroimage.2005.03.021

Kocsis, L., Herman, P., & Eke, A. (2006). The modified Beer–Lambert law revisited. *Physics in Medicine and Biology*, *51*(5), N91. https://doi.org/10.1088/0031-9155/51/5/N02

Kübler, A., Dixon, V., & Garavan, H. (2006). Automaticity and reestablishment of executive control—An fMRI study. *Journal of Cognitive Neuroscience*, *18*(8), 1331–1342. https://doi.org/10.1162/jocn.2006.18.8.1331

MATLAB (2017). SPM12. http://www.fil.ion.ucl.ac.uk/spm/software/spm12/.

McRae, K., Gross, J. J., Weber, J., Robertson, E. R., Sokol-Hessner, P., Ray, R. D., Gabrieli, J. D. E., & Ochsner, K. N. (2012). The development of emotion regulation: An fMRI study of cognitive reappraisal in adolescents and young adults. *SCAN*, *7*(1), 11–22. https://doi.org/10.1093/scan/nsr093

McRae, K., Hughes, B., Chopra, S., Gabrieli, John D. E.., Gross, J. J., & Ochsner, K. N. (2010). The neural bases of distraction and reappraisal. *Journal of Cognitive Neuroscience*, *22*(2), 248–262. https://doi.org/10.1162/jocn.2009.21243

Ochsner, K. N., Bunge, S. A., Gross, J. J., & Gabrieli, J. D. E. (2002). Rethinking feelings: An fMRI study of the cognitive regulation of emotion. *Journal of Cognitive Neuroscience*, *14*(8), 1215–1229. https://doi.org/10.1162/089892902760807212

Ochsner, K. N., Ray, R. D., Cooper, J. C., Robertson, E. R., Chopra, S., Gabrieli, J. D. E., & Gross, J. J. (2004). For better or for worse: Neural systems supporting the cognitive down- and up-regulation of negative emotion. *Neuroimage*, *23*(2), 483–499. https://doi.org/10.1016/j.neuroimage.2004.06.030

Perlman, S. B., Luna, B., Hein, T. C., & Huppert, T. J. (2014). fNIRS evidence of prefrontal regulation of frustration in early childhood. *Neuroimage*, *85*, 326–334. https://doi.org/10.1016/j.neuroimage.2013.04.057

Phillips, G. A., Shadish, W. R., Murray, D. M., Kubik, M., Lytle, L. A., & Birnbaum, A. S. (2006). The center for epidemiologic studies depression scale with a young adolescent population: A confirmatory factor analysis. *Multivariate Behavioral Research*, *41*(2), 147–163. https://doi.org/10.1207/s15327906mbr4102_3

Pollonini, L., Olds, C., Abaya, H., Bortfeld, H., Beauchamp, M. S., & Oghalai, J. S. (2014). Auditory cortex activation to natural speech and simulated cochlear implant speech measured with functional near-infrared spectroscopy. *Hearing Research*, *309*, 84–93. https://doi.org/10.1016/j.heares.2013.11.007

Quaresima, V., & Ferrari, M. (2019). Functional near-infrared spectroscopy (fNIRS) for assessing cerebral cortex function during human behavior in natural/social situations: A concise review. *Organizational Research Methods*, *22*(1), 46–68. https://doi.org/10.1177/1094428116658959

Radloff, L. S. (1977). The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement*, *1*(3), 385–401. https://doi.org/10.1177/014662167700100306

Schneider, W., Eschman, A., & Zuccolotto, A. (2012). *E-Prime User's Guide*. Psychology Software Tools, Inc.

Scholkmann, F., Spichtig, S., Muehlemann, T., & Wolf, M. (2010). How to detect and reduce movement artifacts in near-infrared imaging using moving standard deviation and spline interpolation. *Physiological Measurement*, *31*(5), 649. https://doi.org/10.1088/0967-3334/31/5/004

Smith, S. M., Jenkinson, M., Woolrich, M. W., Beckmann, C. F., Behrens, T. E., Johansen-Berg, H., ... & Niazy, R. K. (2004). Advances in functional and structural MR image analysis and implementation as FSL. *Neuroimage*, *23*, S208–S219.

Smoski, M. J., Keng, S. L., Schiller, C. E., Minkel, J., & Dichter, G. S. (2013). Neural mechanisms of cognitive reappraisal in remitted major depressive disorder. *Journal of Affective Disorders*, *151*(1), 171–177. https://doi.org/10.1016/j.jad.2013.05.073

Tupak, S. V., Dresler, T., Guhn, A., Ehlis, A-C.., Fallgatter, A. J., Pauli, P., & Herrmann, M. J. (2014). Implicit emotion regulation in the presence of threat: Neural and autonomic correlates. *Neuroimage*, *85*, 372–379. https://doi.org/10.1016/j.neuroimage.2013.09.066

Van Oort, F. V., Verhulst, F. C., Ormel, J., & Huizink, A. C. (2010). Prospective community study of family stress and anxiety in (pre) adolescents: The TRAILS study. *European Child & Adolescent Psychiatry*, *19*(6), 483–491.

Wadsworth, M. E., & Compas, B. E. (2002). Coping with family conflict and economic strain: The adolescent perspective. *Journal of Research on Adolescence*, *12*(2), 243–274. https://doi.org/https://doi:10.1111/1532-7795.00033

Woo, C., Krishnan, A., & Wager, T. D. (2014). Cluster-extent based thresholding in fMRI analyses: Pitfalls and recommendations. *Neuroimage*, *1*(91), 412–419. https://doi.org/10.1016/j.neuroimage.2013.12.058

Ye, J. C., Tak, S., Jang, K. E., Jung, J., & Jang, J. (2009). NIRS-SPM: Statistical parametric mapping for near-infrared spectroscopy. *Neuroimage*, *44*(2), 428–447. https://doi.org/10.1016/j.neuroimage.2008.08.036