Archival Report

Labeling Emotional Stimuli in Early Childhood Predicts Neural and Behavioral Indicators of Emotion Regulation in Late Adolescence

Nourhan M. Elsayed, Alecia C. Vogel, Joan L. Luby, and Deanna M. Barch

ABSTRACT

BACKGROUND: Effective emotion regulation (ER) may be supported by 1) accurate emotion identification, encoding, and maintenance of emotional states and related brain activity of regions involved in emotional response (i.e., amygdala, ventral/posterior insula) and 2) cognitive processes that implement reframing, supported by activation in cognitive control brain regions (e.g., frontal, insular, and parietal cortices). The purpose of this project was to examine how emotion labeling ability in early childhood is related to ER concurrently and prospectively.

METHODS: Data from a prospective longitudinal study of youths at risk for depression, including measures of emotion labeling (i.e., Facial Affect Comprehension Evaluation) and ER ability (i.e., Emotion Regulation Checklist) and strategy use (i.e., Cognitive Emotion Regulation Questionnaire, Children's Response Style Questionnaire), and functional magnetic resonance imaging data during a sadness ER task (*N* = 139) were examined.

RESULTS: Findings from multilevel modeling and linear regression suggested that greater emotion labeling ability of more difficult emotions in early childhood was associated with enhanced parent-reported ER in adolescence, but not with a tendency to engage in adaptive or maladaptive ER strategies. Recognition of fear and surprise predicted greater activation in cortical regions involved in cognitive control during an ER of sadness task, including in the insula, anterior cingulate cortex, dorsal medial prefrontal cortex, and inferior frontal gyrus.

CONCLUSIONS: These findings suggest that early ability to identify and label difficult facial emotions in early childhood is associated with better ER in adolescence and enhanced activity of cognitive control regions of the brain.

The ability to accurately recognize and label emotions is a critical component of social-emotional competence and has been associated with positive developmental outcomes in youth (1–3). Evidence suggests that interventions designed to teach accurate emotion identification have long-term benefits for enhanced emotion regulation (ER) (4). Furthermore, perturbations in regions of the brain implicated in emotion processing (and thus potentially emotion recognition and labeling) are also implicated in difficulties with ER. Studies prospectively examining the relationship between emotion labeling and ER are limited. Thus, the goal of the current study was to examine how emotion labeling in early childhood prospectively predicts both neural and behavioral indicators of ER in adolescence.

As early as 3 months of age, infants begin to recognize and respond to different emotional states (5–7). By 2 years, children begin to recognize and label happiness and sadness, and by 5 years they begin to recognize and label anger, fear, disgust, and surprise (8,9). Accuracy of recognition follows a similar trajectory; happy and sad facial expressions are recognized at 5 years of age with near adult-level accuracy, but recognition of fear, anger, disgust, and neutral faces have more protracted development (10). The ability to recognize and label emotions, known

as emotion labeling, is an important facet of emotional competence throughout development (11). Izard *et al.* reported that after accounting for gender, verbal ability, and temperament, youths with greater ability to identify and label emotions at 5 years of age had better social skills, better academic competence, and fewer behavioral problems at age 9 years (2). This relationship continues beyond childhood; in a study of early to mid-adolescence, Ciarrochi *et al.* reported that low emotion identification in eighth grade predicted increases in negative affect and decreases in social support 1 year later (12).

The results described above are consistent with the constructionist theory of emotion, which suggests that labeling emotions facilitates ER by enabling access to socially and psychologically constructed information about the consequences of and solutions to similar situations (13–18). As such, constructionist accounts of emotion predict that as emotion labeling capacity improves, so does ER ability. Furthermore, evidence from developmental literature suggests that emotion competence in children is the first step to ER (19). In other words, early emotion labeling competence, such as accurately labeling emotion faces, may be an important precursor to effective ER later in development. This notion is salient in light of literature suggesting that

accurate emotion labeling capacity predicts internalizing and externalizing symptoms and disorders (3,20,21). Models have emerged suggesting that deficits in early emotion knowledge (of which emotion labeling is a facet) may predict psychopathology through disruptions in the development of effective ER abilities (22,23). Consistent with this hypothesis, there is evidence from clinical populations that individuals with deficits in emotion recognition also have lower ER ability (22,24).

There is also overlap between brain regions implicated in ER and those implicated in emotion recognition. Specifically, during emotion recognition, regions of the brain typically implicated in ER (e.g., dorsolateral prefrontal cortex [PFC], dorsal anterior cingulate cortex, ventrolateral PFC, medial temporal gyrus, parietal cortex) and in generating emotional responses (e.g., amygdala) demonstrate similar patterns of activation as during ER (25). Studies have reported that when participants are asked to label an emotion, there is deactivation of the amygdala, as is seen in ER (26–29). As such, deficits in the ability to recognize and label emotions in childhood may reflect alterations in brain regions implicated in not just emotional responses (i.e., amygdala, insula) but also those associated with explicit ER such as the dorsolateral PFC, dorsal anterior cingulate cortex, and ventrolateral PFC.

Given the importance of emotion recognition and ER to adaptive functioning, it is important to understand the development of and relationship between emotion recognition and ER. This project aimed to test three hypotheses, namely that 1) emotion recognition would improve across development as indexed by enhanced ability to label emotional facial expressions correctly, 2) lower emotion recognition early in development would be related to lower scores on measures of ER both concurrently and prospectively, and 3) lower emotion recognition ability early in development would be related to subsequent decreased response in limbic regions (i.e., amygdala, ventral/posterior insula) when viewing negatively valenced stimuli and to less of an increase in activity in a range of cortical regions (anterior/dorsal insula, frontal, and parietal regions) during reappraisal of negative stimuli (reappraise sad vs. view sad condition comparison) during an ER of sadness task.

METHODS AND MATERIALS

Participants

Participants were recruited as part of the Preschool Depression Study, sampling procedures for which have been previously described (30–32). The Preschool Depression Study is an ongoing prospective longitudinal study examining developmental trajectories of preschool-onset depression. It assesses emotion development as one key component and oversamples for preschoolers at risk for depression (33). All participants in the study have 1 to 9 assessment waves (T1–T9) and 1 to 4 magnetic resonance imaging (MRI) scan waves (Figure 1). There were 348 participants originally recruited at baseline and later, as part of the full data set, with 210 included at the first wave of imaging. From these 210 participants, 171 had behavioral data at scan 4, when the imaging measure of interest to the current study was administered. Given the goals of the study, we focused our analysis on a subset of adolescents from the 171 participants who had useable imaging data

(n = 139) from the most recently completed assessment/scan wave, T9/MRI 4 (Figure 1). Parents provided written informed consent, and children gave either oral or written assent or consent following study description. Methods were reviewed and approved by the Washington University School of Medicine Institutional Review Board. See Supplemental Methods for details.

Emotion Recognition

Facial Affect Comprehension Evaluation. The Facial Affect Comprehension Evaluation (34) is a task that assesses the child's ability to recognize and verbally label 7 different emotions from facial expressions and was administered at T1, T2, and T3 (Figure 1). Stimuli consisted of color photographs of male and female adults and children from different racial groups displaying seven different emotions (i.e., happy, mad [anger], sad, scared [fear], surprised, yucky [disgust], shame). In total, 8 sad trials and 5 trials of the other emotions were presented at each wave. Shame was assessed only at T3 and was excluded from analyses. Children received 1 point for every emotion labeled correctly. Each emotion was treated as its own subscale by summing together all items probing for that emotion. We calculated the correct number of responses for each emotion across all faces at T1, T2, and T3 (Figure 1).

Concurrent Assessment of Emotion Dysregulation

Direct assessments of ER that coincide with emotion recognition assessments (T1, T2, and T3) were not available. However, assessments of two dimensions of behavior that represent ER deficits, excitability and irritability, were available at T1 and are used here as indices of early emotion dysregulation (35). Specifically, excitability (i.e., dysregulation including positive emotions), a form of positive affect dysregulation previously described by Vogel *et al.* (35), and irritability (i.e., dysregulation of negative emotion), a well-studied form of negative affect dysregulation, were studied. For this analysis, factor scores previously validated and described elsewhere were used as assessments of concurrent early childhood emotion dysregulation (35).

Adolescent Measures of ER

ER was directly assessed by both parent and child reports at T9 (Figure 1).

Emotion Regulation Checklist. The Emotion Regulation Checklist (ERC) is a 24-item parent-report questionnaire assessing intensity, lability, flexibility, and appropriateness of children's positive and negative ER (36). It has two subscales: emotion regulation ($\alpha = .77$, where higher scores indicate better regulation) and negative lability ($\alpha = .77$, where higher scores indicate worse dysregulation).

Children's Emotion Management Scale. The Children's Emotion Management Scale ($\alpha = .71$) is a 30-item child-report questionnaire assessing the likelihood of children to engage in inhibition, dysregulated expression, or coping for the emotions of anger, sadness, and worry (37).
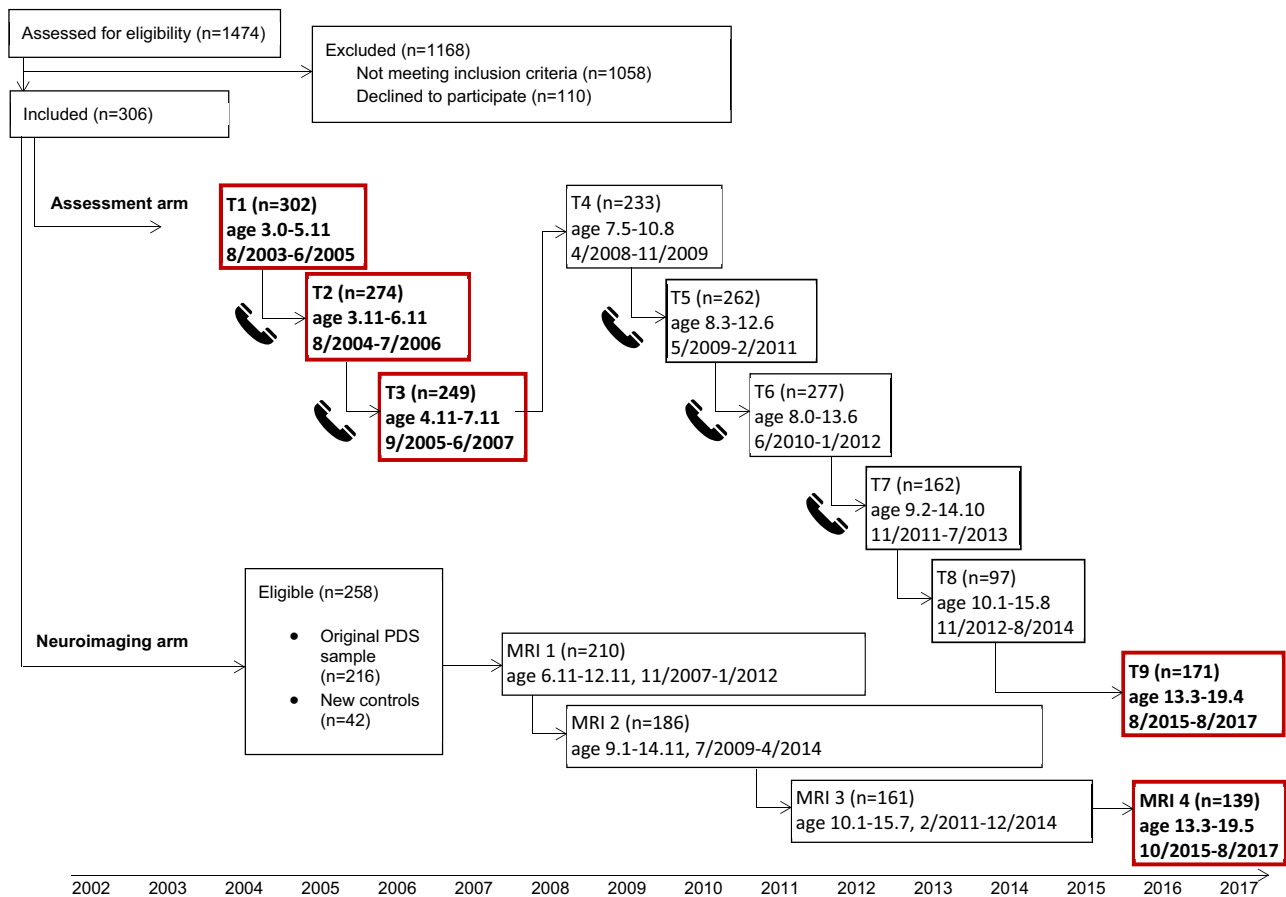
Figure 1. Preschool Depression Study (PDS) timeline and data collection. Boxes outlined in red are time points (T) in which data were reported. MRI, magnetic resonance imaging.

Cognitive Emotion Regulation Questionnaire–Child Version. The Cognitive Emotion Regulation Questionnaire–child version (α = .88) is a 36-item child-report questionnaire assessing children's tendencies to engage in a variety of adaptive ER strategies (i.e., acceptance, positive refocusing, refocus on planning, positive reappraisal, putting it into perspective) or maladaptive ER strategies (i.e., self-blame, rumination, catastrophizing, other-blame) (38). See Supplemental Methods for more details.

Child Response Style Questionnaire. The Child Response Style Questionnaire (α = .82) is a 25-item self-report questionnaire assessing the ER strategies youths use in response to sadness, including scales for rumination, distraction, and problem solving (39).

ER Factors

Principal component analyses (PCAs) were performed on ER variables to reduce data dimensionality and determine the number of ER factors to be retained. In the first attempt at PCA, a four-factor model was suggested, with ERC negative lability comprising its own factor. Thus, we removed ERC

negative lability from the model and reran the PCA. In doing so, the model returned two factors. One corresponded to youths' tendencies to engage in ER skills thought to be adaptive and one corresponded to skills thought to be maladaptive. Items on each subscale and their loadings are listed in Table S1. Given that the ERC scales did not specifically load onto either factor, we also examined ERC negative lability and emotion regulation as more general indices of the efficacy of ER versus the use of specific skills. See Supplemental Methods for details.

Explicit ER of Scenes Functional MRI Task Design

An in-depth description of this task has been provided elsewhere (30,40). Briefly, following prescan training procedure to ensure that children understood how to use reappraisal in response to negative stimuli, children were instructed to passively view either sad or neutral images or to decrease their experience of negative emotions in response to viewing sad images by using cognitive reappraisal strategies such as looking on the bright side and imagining a good outcome to the image. Stimuli were taken from the International Affective Picture Series (41,42) and supplemented with an in-house set of images selected to be appropriate for viewing

by children (e.g., photos of other children crying). International Affective Picture Series stimuli have been rated for valence (1 = extremely negative to 9 = extremely positive) and arousal (1 = no arousal to 9 = extreme arousal). The images used had valence scores less than 4 and arousal scores greater than 4. At the start of each trial, participants fixated on a cross for 500 ms. Next, participants were told to either view or try to decrease their experienced emotion for 2000 ms. Finally, participants were presented with a photo (i.e., neutral or sad) for an 8000-ms interval. Following each picture, children were prompted to answer the question "How do you feel?" Children had 4 seconds to rate their affect on a scale from 1 to 4 using a 4-button box (see Supplemental Results for details). After the affect-rating period, the word RELAX was shown for 4 to 8 seconds. The combinations of neutral and sad photographs with just view versus regulate instructions resulted in three conditions: view neutral (nonemotional photo), view sad (sadness without reappraisal), and reappraise sad (reappraise while viewing a sad photo).

Image Acquisition and Processing

See Supplemental Methods for details.

Statistical Analyses

We tested the hypotheses that emotion recognition improves across development using hierarchical linear modeling (HLM) of growth in emotion recognition for each of the Facial Affect Comprehension Evaluation emotions across each of the first three Preschool Depression Study waves (i.e., T1, T2, T3) using grand mean–centered age at T1 as a covariate. The lme4 and nlme packages in R (43,44) were used, producing models that estimated the intercept of emotion recognition and the slopes of emotion recognition over time (see Supplement for more details).

To test the hypothesis that lower emotion recognition scores early in development would be related to increased emotion dysregulation concurrently, we used linear regressions predicting baseline irritability and excitability scores from baseline (T1) accuracy for recognizing each emotion. To assess whether lower emotion recognition early in development predicted worse ER in adolescence, we examined whether intercepts and slopes extracted from the HLMs (i.e., empirical Bayes estimates) of each emotion related to the two ER factors from the above PCA (i.e., tendency to engage in adaptive/maladaptive skill use) and the two subscales of the ERC (negative lability and emotion regulation), with separate analyses for slopes and intercepts. For each set, we corrected for multiple comparisons using false discovery rate (FDR) at $p < .05$ by ER outcome and controlled for age at the time of scan, sex, and irritability. Throughout, we controlled for irritability rather than excitability because there is a moderate correlation and it more closely aligns with ER constructs currently in the literature.

To test the hypothesis that lower emotion recognition ability early in development relates to decreased response in limbic regions (i.e., amygdala, ventral/posterior insula) when viewing sad images compared with neutral images in adolescence, we used linear regressions predicting activity in these brain regions (i.e., 6 subdivisions of the amygdala, right and left ventral/posterior insula) identified from articles by Roy et al. (45) and Liberzon et al. (46) from the intercepts and slopes of recognition accuracy for

each emotion (see Supplement for methods and results of whole-brain analyses). To test whether lower emotion recognition ability early in development would be related to blunted increases in activity during reappraisal of negative stimuli in adolescence, we used multiple regression predicting activity in each of the regions identified in Diekhof et al.'s meta-analysis of ER (47) from the intercepts and slopes recognition accuracy for each emotion. For each set of tests and follow-up analyses, we corrected for multiple comparisons using FDR at $p < .05$ by brain region (e.g., left dorsomedial PFC [dmPFC], left anterior cingulate cortex) across emotions and controlled for age at time of scan, sex, and irritability.

RESULTS

Demographic and Clinical Characteristics

Youths with and without imaging data did not differ in sex, ethnicity, or age at T1. At T9/MRI 4, youths who had imaging data were slightly older than youths who did not have imaging data (Table S2).

Development of Emotion Recognition

Table S3 shows the results of HLMs across T1, T2, and T3 for each of the emotions, and Figure 2 shows the predicted values of recognition across time. For each of the HLMs, youths developed an enhanced ability to identify emotions over time, and age predicted greater ability to recognize and label emotions.

As shown in Table S3, accuracy for happiness and sadness showed significant linear and quadratic fixed effects and a significant effect of age at T1. For happiness, there was a decrease in recognition between T1 and T2 but steep growth between T2 and T3. Of note, overall accuracy for happiness recognition was very high at baseline and throughout, and thus the effect of development is difficult to assess. For sadness, there was improvement from T1 to T2 but no further improvement at T3. In contrast, the HLMs for anger, fear, disgust, and surprise recognition yielded a significant positive linear effect for time, indicating that youths increased steadily in their ability to recognize these emotions. There were also significant interactions between year and age at baseline for happy and anger recognition, indicating for both emotions that youths who were older at baseline saw less growth in their emotion recognition ability.

In addition, there was significant random variance in both the intercept and linear slope of growth for happiness, sadness, fear, disgust, and surprise as well as significant variation in the intercept for anger. This finding indicates significant variation among participants in their intercepts and linear slopes, thereby supporting the modeling of individual differences in these parameters over time.

Relationship Between Emotion Recognition and Regulation

Concurrent. After controlling for age at baseline and sex, there were no significant associations between emotion recognition for any emotion and excitability and irritability scores (proxies for emotion dysregulation) at T1 (all $rs \leq .17$, all $ps \geq .26$) (Table S4).
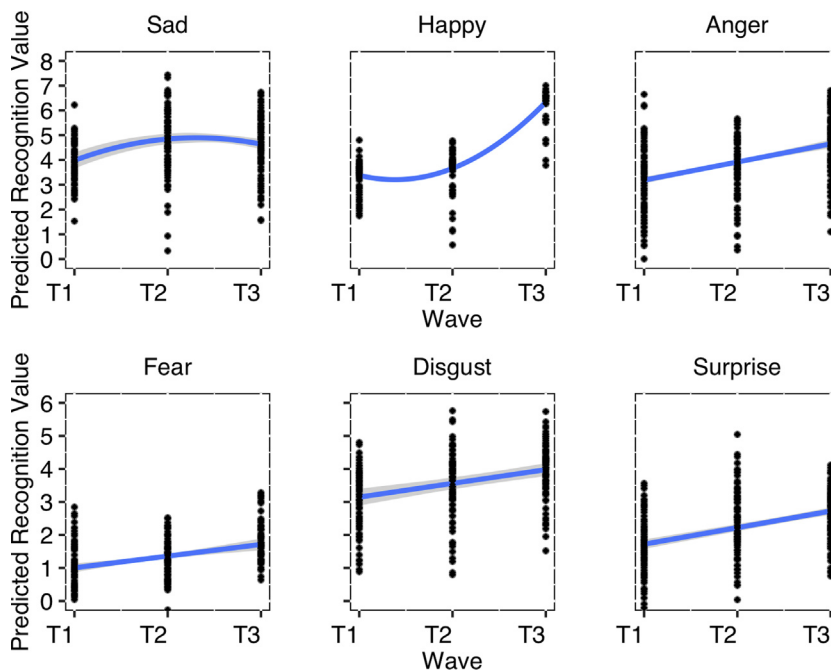
Figure 2. Emotion recognition by wave accounting for centered age at baseline. Blue lines are predicted emotion recognition trajectories derived from hierarchical linear modeling. Gray lines are prediction intervals around those trajectories. Black points are individual raw data points. T, time point.

Prospective. The ability to recognize happy, sad, angry, disgusted, and surprised faces at baseline predicted ER in early adolescence. Youths who had better emotion recognition ability for these emotions at baseline had lower negative lability in adolescence (Table 1 and Figure S1). Furthermore, youths with better ability to recognize surprise and disgust had greater overall ER ability in adolescence as measured via the ERC emotion regulation subscale (Table 1 and Figure S2). However, the tendency to engage in adaptive or maladaptive ER strategies in adolescence was not predicted by emotion recognition ability (Table 1). Growth in happiness recognition predicted greater negative lability in adolescence, and growth in disgust recognition predicted lower ER in adolescence (Table 1).

Table 1. Prediction of Late Adolescence Emotion Regulation by Emotion Recognition Ability, Controlling for Baseline Negative Emotion Regulation, Age, and Sex

	Adaptive Emotion Regulation	Maladaptive Emotion Regulation	ERC Lability/Negativity	ERC Emotion Regulation
Intercepts				
Happy	0.23 (0.19)	−0.04 (0.18)	−0.62 (0.20)[a]	0.38 (0.21)
Sad	0.07 (0.06)	−0.06 (0.05)	−0.17 (0.06)[a]	0.14 (0.06)
Anger	0.22 (0.25)	−0.20 (0.24)	−0.70 (0.26)[b]	0.62 (0.27)
Fear	−0.33 (0.31)	−0.26 (0.29)	0.04 (0.33)	0.11 (0.35)
Disgust	0.01 (0.09)	−0.14 (0.08)	−0.23 (0.09)[b]	0.27 (0.09)[b]
Surprise	0.26 (0.09)	−0.05 (0.09)	−0.29 (0.10)[a]	0.34 (0.10)[a]
Slopes				
Happy	−0.30 (0.32)	0.02 (0.30)	0.97 (0.33)[b]	−0.62 (0.35)
Sad	0.09 (0.13)	0.16 (0.12)	0.24 (0.13)	−0.29 (0.14)
Anger				
Fear	−0.24 (0.30)	−0.09 (0.28)	−0.07 (0.32)	−0.40 (0.34)
Disgust	−0.04 (0.33)	0.35 (0.30)	0.57 (0.34)	−0.96 (0.35)[b]
Surprise	−0.15 (0.25)	−0.08 (0.23)	−0.37 (0.26)	0.46 (0.27)

Values are B (SE).
ERC, Emotion Regulation Checklist; FDR, false discovery rate.
[a]FDR-corrected $p \leq .01$.
[b]FDR-corrected $p \leq .05$.

Relationship Between Emotion Recognition and Brain Activity In Response to Viewing Sad Pictures

Contrary to our hypotheses, there were no significant relationships after FDR correction between either intercepts or slopes of emotion recognition ability early in development and response in any amygdala or ventral/posterior insula regions in the contrast of viewing negative versus neutral pictures (all Bs ≤ |.12|, all ps ≥ .05) (Table S5).

Relationship Between Emotion Recognition and Cortical Activity in Response to ER of Sad Pictures

The intercepts of early recognition of fear and surprise predicted greater activation in a host of cortical regions implicated in cognitive control. Greater recognition of surprise early in development predicted greater activation in 9 of 23 assessed cortical regions implicated in ER (e.g., dmPFC, left inferior frontal gyrus [LIFG], left anterior insula [LAI], left and right inferior temporal sulcus, left anterior insula frontal operculum [LAIFO]) (see Table 2 for full reporting). Greater recognition of fear predicted greater activation in 5 of 23 regions, including the dmPFC, LIFG, and LAI. Sad

recognition predicted reduced activation in only 1 cortical region of the brain, namely the ventromedial PFC. In contrast to intercepts, the growth (i.e., slope) in emotion recognition did not predict activation in response to ER after FDR correction (Table S6).

Specificity Analyses

The intercepts of surprise predicted ER activity in several regions. For 5 of these regions, surprise was the only significant predictor. For 4 of these regions, intercepts of fear recognition also predicted ER activity. To examine specificity, we conducted additional analyses for any region with more than one emotion predictor where we entered all emotion intercepts simultaneously. In doing so, activity in the LIFG was no longer predicted by either fear or surprise recognition. For the other 3 regions (i.e., dmPFC, LAI), both surprise and fear recognition independently predicted greater cortical activity (Figure 3, Table 3). Conclusions largely did not change when analyses were run without irritability as a covariate (Tables S7–S9).

Table 2. Relationship Between Early Emotion Recognition (Intercepts) and Cortical Activity (Reappraise Negative vs. View Negative), Controlling for Baseline Negative Emotion Regulation, Age, and Sex

	MNI			Happy	Anger	Sad	Fear	Disgust	Surprise
	x	y	z						
L/R Dorsomedial PFC/ACC	−6	16	58	0.12 (0.06)	0.14 (0.09)	0.002 (0.02)	0.33 (0.11)[a]	0.02 (0.03)	0.11 (0.03)[a]
L/R Dorsomedial PFC/ACC	2	32	44	0.07 (0.06)	0.07 (0.07)	−0.01 (0.02)	0.31 (0.08)[b]	0.02 (0.02)	0.06 (0.03)
L Middle Frontal Gyrus/Inferior Frontal Sulcus	−42	18	44	0.04 (0.04)	0.08 (0.06)	−0.01 (0.01)	0.17 (0.07)	0.02 (0.02)	0.06 (0.02)
L Middle Frontal Gyrus/Inferior Frontal Sulcus	−42	4	48	0.07 (0.06)	0.16 (0.07)	0.003 (0.02)	0.27 (0.09)[a]	0.01 (0.02)	0.09 (0.03)[b]
R Middle Frontal Gyrus/Inferior Frontal Sulcus	40	22	44	0.001 (0.05)	0.01 (0.06)	0.01 (0.01)	0.14 (0.08)	0.01 (0.02)	−0.01 (0.02)
L Inferior Frontal Gyrus/Anterior Insula	−50	30	−10	0.13 (0.07)	0.09 (0.10)	0.01 (0.02)	0.29 (0.12)	0.06 (0.03)	0.12 (0.04)[a]
L Inferior Frontal Gyrus/Anterior Insula	−54	22	−2	0.12 (0.06)	0.16 (0.08)	0.01 (0.02)	0.35 (0.10)[b]	0.05 (0.03)	0.10 (0.03)[c]
L Inferior Frontal Gyrus/Anterior Insula	−52	42	−6	0.04 (0.05)	0.04 (0.06)	−0.01 (0.01)	0.25 (0.07)[b]	0.01 (0.02)	0.07 (0.02)[a]
R Inferior Frontal Gyrus	50	30	−10	0.11 (0.07)	0.20 (0.09)	0.01 (0.02)	0.16 (0.12)	0.03 (0.03)	0.11 (0.04)[a]
L intraparietal Cortex	−46	−66	36	0.002 (0.06)	0.14 (0.08)	−0.02 (0.02)	0.12 (0.10)	0.02 (0.03)	0.06 (0.03)
L Intraparietal Cortex	−42	−56	38	0.03 (0.04)	0.07 (0.05)	−0.01 (0.01)	0.11 (0.06)	0.01 (0.02)	0.03 (0.02)
L Intraparietal Cortex	−38	−60	30	0.001 (0.03)	0.05 (0.04)	−0.01 (0.01)	0.08 (0.05)	0.01 (0.01)	0.02 (0.02)
R Intraparietal Cortex	50	−58	42	0.01 (0.07)	0.003 (0.09)	−0.01 (0.02)	0.13 (0.11)	−0.01 (0.03)	0.01 (0.04)
L Inferior Temporal Sulcus	−60	−36	−2	0.11 (0.05)	0.10 (0.07)	−0.01 (0.02)	0.20 (0.09)	0.02 (0.02)	0.09 (0.03)[c]
L Anterior Insula/Frontal Operculum	−38	20	−4	0.10 (0.06)	0.11 (0.08)	0.004 (0.02)	0.22 (0.09)	0.03 (0.03)	0.10 (0.03)[b]
R Anterior Insula/Frontal Operculum	46	14	0	0.09 (0.05)	0.08 (0.07)	−0.01 (0.02)	0.19 (0.08)	0.01 (0.02)	0.06 (0.03)
L/R Ventromedial PFC	6	40	−22	−0.09 (0.06)	−0.13 (0.07)	−0.05 (0.02)[a]	0.01 (0.09)	−0.05 (0.02)	−0.03 (0.03)
L/R Ventromedial PFC	0	38	−18	−0.08 (0.05)	−0.02 (0.06)	−0.03 (0.01)	0.10 (0.07)	−0.02 (0.02)	−0.001 (0.02)
L Middle Temporal Gyrus	−64	−4	−22	0.01 (0.04)	−0.02 (0.05)	−0.01 (0.01)	0.11 (0.06)	0.01 (0.02)	0.04 (0.02)
R Frontal Marginal Sulcus	34	60	8	0.02 (0.06)	−0.05 (0.07)	−0.02 (0.02)	0.15 (0.09)	−0.02 (0.02)	−0.005 (0.03)
R Inferior Frontal Gyrus	60	26	6	−0.01 (0.04)	0.07 (0.05)	−0.01 (0.01)	0.17 (0.06)	−0.002 (0.02)	0.03 (0.02)
L ACC	−8	28	28	0.06 (0.04)	0.10 (0.05)	0.003 (0.01)	0.14 (0.06)	0.01 (0.02)	0.07 (0.02)[b]
R Superior Frontal Gyrus	18	24	58	0.03 (0.04)	0.08 (0.05)	0.01 (0.01)	0.13 (0.07)	0.01 (0.02)	0.05 (0.02)

Values are B (SE).
ACC, anterior cingulate cortex; L, left; MNI, Montreal Neurological Institute; PFC, prefrontal cortex; R, right.
[a]FDR-corrected p ≤ .05.
[b]FDR-corrected p ≤ .005.
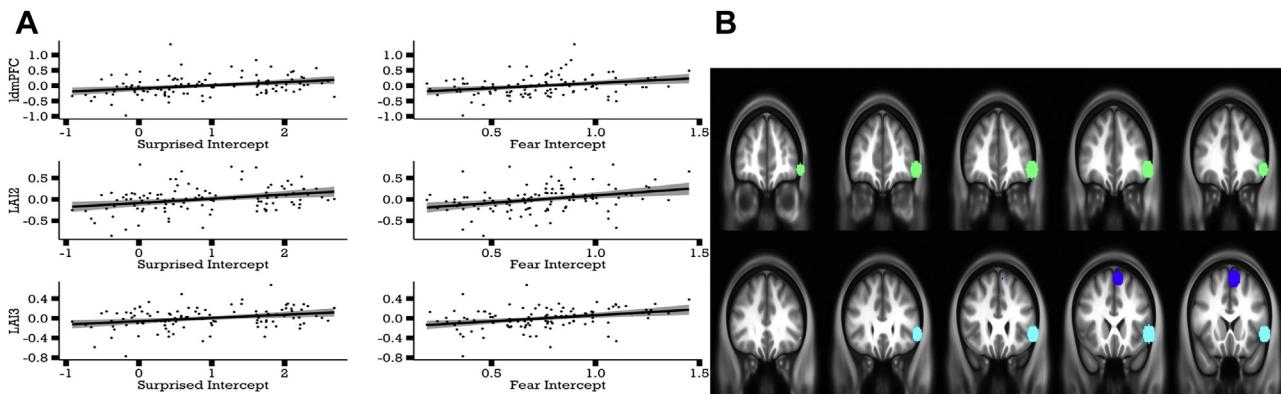[c]FDR-corrected or equal p ≤ .001.

Figure 3. **(A)** Relationship between emotion recognition and brain activity. **(B)** Regions of interest as plotted in dark blue are the left dorsomedial prefrontal cortex (ldmPFC) (x = −6, y = 16, z = 58), those plotted in light blue are the left anterior insula (LAI2) (x = −54, y = 22, z = −2), and those plotted in green are another part of the left anterior insula (LAI3) (x = −52, y = 42, z = −6).

DISCUSSION

The goal of the current study was to examine the relationship between early childhood emotion recognition and both behavioral and neural indicators of ER in late adolescence. We demonstrated expected developmental increases in ability to recognize emotions across early childhood, for which there were individual differences. The ability to recognize emotion in early childhood, particularly surprise and fear, predicted greater ER in later childhood as well as activity in ER regions such as the dmPFC, LIFG, left middle frontal gyrus (LMFG), and LAIFO measured using functional MRI. Overall, these findings are consistent with theoretical models proposing early emotion recognition as an important early skill for later successful ER development (19,48,49).

Our results suggest that from 3 to 7 years of age, youths' ability to correctly recognize emotion improves across all assessed emotions. Both happiness and sadness recognition have quadratic growth through early development, consistent with previous literature suggesting that recognition of happiness and sadness develops rapidly early in development (10,50,51). Anger, fear, disgust, and surprise recognition were best represented by linear growth, and all assessed emotions except anger showed significant individual differences in youths' recognition ability. Among these emotions, surprise and fear were the most difficult for youths in this sample, as

indicated by a lower ability to identify these emotions throughout the study.

Contrary to our predictions, we did not find that early emotion recognition was associated with early parent-rated childhood dysregulation of positive emotions (i.e., excitability) or negative emotions (i.e., irritability). The existing literature on the relationship between irritability and emotion recognition is mixed, with some studies not finding a relationship (52) but others finding deficits in emotion recognition in youths with irritability compared with healthy control subjects (53–55). Other studies on this topic, however, have assessed older populations with disorders such as bipolar disorder (53–55), while we have studied recognition in samples of preschoolers oversampled for depressive symptoms.

Consistent with our predictions, we found that greater early childhood recognition of happiness, sadness, anger, disgust, and surprise predicted less parent-reported lability and negativity and that greater early childhood disgust and surprise recognition predicted more parent-reported positive ER in late adolescence. Our finding that emotion recognition early in development did not predict early concurrent emotion dysregulation but did predict later ER may indicate that emotion recognition ability serves as a protective factor against lability in later childhood and adolescence but not early in development. This could be explained by younger children having

Table 3. Specificity Analyses for Activation in Cognitive Control, Controlling for Baseline Negative Emotion Regulation, Age, and Sex

	MNI			Fear Intercept	Surprise Intercept
	x	y	z		
L/R Dorsomedial PFC/ACC	−6	16	58	0.31 (0.10)[a]	0.10 (0.03)[a]
L Middle Frontal Gyrus/Inferior Frontal Sulcus/IFJ	−42	4	48	0.07 (0.07)	0.01 (0.02)
L Inferior Frontal Gyrus/Anterior Insula	−54	22	−2	0.33 (0.09)[b]	0.09 (0.03)[a]
L Inferior Frontal Gyrus/Anterior Insula	−52	42	−6	0.23 (0.07)[b]	0.06 (0.02)[a]

Values are B (SE). Fear and surprise correlation: r = .08, p = .40.
ACC, anterior cingulate cortex; IFJ, inferior frontal junction; L, left; MNI, Montreal Neurological Institute; PFC, prefrontal cortex; R, right.
[a]p ≤ .005.
[b]p ≤ .001.

fewer individual regulation strategies and relying heavily on caregivers as external emotion regulators, making ER ratings at this time more dyadically based, while adolescents self-regulate and ER ratings are based on these individual abilities (56,57). It may also reflect the nature of our early childhood dysregulation variables, which may more directly index bottom-up emotion or mood lability rather than top-down ER. We did not find any evidence that early emotion recognition was associated with the tendency to engage in adaptive or maladaptive ER strategies. Our finding that emotion recognition predicts later overall ER abilities (ERC emotion regulation scale) or lack thereof (ERC negative lability scale) rather than the use of adaptive or maladaptive coping strategies is notable. Our measures of ER strategies from the Cognitive Emotion Regulation Questionnaire–child version and Children's Emotion Management Scale do not specifically assess the success of the strategy, only how likely adolescents are to use the strategy. This may indicate that emotion recognition improves the effectiveness of later ER more generally, rather than predisposing to a specific regulation strategy. These findings are consistent with recent work by Kalokerinos et al., who reported that emotion differentiation was not consistently associated with the selection of ER strategies but that low emotion differentiation did impair how effective ER strategies were in reducing negative emotions (58).

We also hypothesized that lower emotion recognition ability early in development would be related to blunted emotional reactivity as indicated by decreased response in limbic regions (i.e., amygdala, posterior/ventral insula) in adolescence when viewing negatively valenced stimuli, but we did not find such a result. The task used involved sadness, which is one of the first emotions identified by youths and is a low-arousal emotion. We have previously shown that sadness does not elicit amygdala activation to the same extent as may be expected from other high-arousal emotions such as fear (30,40). Thus, we might see more of the relationship between early emotion recognition and adolescent amygdala and insula responsivity if we probed responses to other emotions. Alternatively, these findings may suggest that enhanced ability to recognize emotions is related to the ability to downregulate emotions, but not necessarily with the experience of emotions as reflected in amygdala or insula activation.

Consistent with other hypotheses, we found that early recognition ability, particularly of surprise and fear, predicted greater activation across a host of brain regions implicated in cognitive control during explicit ER. Specifically, greater surprise recognition predicted increased widespread activation in the contrast of reappraisal of sad images relative to viewing sad images in canonical cognitive control regions. Although less widespread, fear also predicted greater activation in the dmPFC, LIFG, LMFG, and LAI. Follow-up analyses suggested that except for the LIFG, in regions where blood oxygen level–dependent activity was predicted by both fear and surprise recognition, each independently predicted enhanced activation in late adolescence. Although the stimuli in this task were of sad images, we anticipate that greater emotion recognition ability would predict enhanced recruitment of cognitive control regions across negative emotions because regions such as the dmPFC, LIFG, LMFG, and

LAIFO function for general cognitive control and not in response to specific emotions (59,60).

Interestingly, the strongest relationships between emotion recognition and ER were found for fear and surprise. This study assessed emotion recognition until 7 years of age, and by then youths likely have reached near adult-level accuracy in happy, sad, and anger recognition but not in surprise and fear recognition (10,61). As reported, at the age ranges assessed in this study, these two emotions were the most difficult for youths in this sample to accurately recognize and label (9,10). It is important to consider our findings within this developmental context. We are not claiming that surprise and fear recognition are the most important emotions to recognize in promoting successful ER. Instead, we believe that enhanced ability to recognize these two emotions simply reflects greater developmentally appropriate emotion recognition and may be particularly sensitive indicators of early emotion recognition abilities in the assessed age range of 3 to 7 years.

Given the overall findings that early emotion recognition ability predicts less emotion dysregulation/lability, greater positive ER, and increased activation of cognitive control/ER regions such as the dmPFC, LIFG, LMFG, and LAIFO in adolescence, this aspect of emotion competence appears to be an indicator of later adaptation and risk. These findings suggest that early emotion recognition should be a target for enhancing the development of ER, thereby potentially reducing impairment and risk of psychopathology. Increasingly, emotion recognition is being used in psychotherapies targeting childhood psychopathology, including in an adaptation of parent–child interaction therapy with an emotion development module addressing depressive symptoms (62). Understanding the effect of interventions supporting emotion recognition for adaptive socioemotional development is not only a potential intervention for preventing or mitigating the effects of psychopathology but also a potential pathway for testing the causal association of early emotion recognition function and later ER deficits.

Unfortunately, our ability to generalize the findings from the current study are limited because the original study was oversampled for preschoolers with symptoms of depression and the related focus on examining the neural response to and regulation of sadness. However, the results presented here do support a role for emotion recognition in the development of ER in children with early-onset psychiatric symptoms, a clinically relevant population. Our results are also hindered by restriction in the range of distributions for both happy and sad intercepts and happy slopes, potentially reducing our ability to find significant associations with ER. Our results are also limited by the racial distribution of stimuli in our task. Most of our stimuli, although not all, were of white faces and, as such, there may have been race-based differences in emotion recognition (63). Future work should aim to assess emotion recognition work across more modalities with more diverse types of stimuli. In addition, this study did not include the same assessments of ER at baseline and late adolescence owing to expected developmental differences in ER. Moreover, this study assessed neural indices of ER only to sadness rather than to high-arousal emotions such as fear, which may have revealed a different pattern of results. Finally, as with many studies examining factors that influence ER, there may be other potential third variables that could explain low emotion recognition and high lability such as

conscientiousness and attention. Despite these limitations, this study has many strengths, including the 15-year longitudinal design that has allowed us to ascertain the long-term relationships of emotion recognition to behavioral and neural indicators of ER and the use of self-report, parent-report, and neural markers of ER as triangulation of our findings.

Overall, we believe that our finding that emotion recognition, specifically of surprise and fear, early in development predicts ER ability in late adolescence underscores the need for greater research outlining the relationship between emotion recognition ability and ER in the development of psychopathology. Given that surprise and fear are more difficult emotions for youths to recognize, this finding, when replicated, may suggest the need for interventions advancing emotion recognition ability in youths as well as public policies and programs targeting emotion development, including emotion recognition skills, in early childhood to reduce impairments in ER in adolescence and beyond.

ARTICLE INFORMATION

From the Department of Psychological & Brain Sciences (NME, DMB), Department of Psychiatry (ACV, JLL, DMB), and Department of Radiology (DMB), Washington University in St. Louis, St. Louis, Missouri.

Address correspondence to Nourhan Elsayed, M.A., at nourhan.elsayed@wustl.edu.

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