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Sticky criticism? Affective and neural responses to parental criticism and praise in adolescents with depression

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Original Article

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Abstract

Background. Parent-adolescent interactions, particularly parental criticism and praise, have previously been identified as factors relevant to self-concept development and, when negative, to adolescent depression. Yet, whether adolescents with depression show aberrant emotional and neural *reactivity* to parental criticism and praise is understudied.

Methods. Adolescents with depression ($n = 20$) and healthy controls ($n = 59$) received feedback supposedly provided by their mother or father in the form of negative ('untrustworthy'), neutral ('chaotic'), and positive ('respectful') personality evaluations while in an MRI-scanner. After each feedback word, adolescents reported their mood. Beforehand, adolescents had rated whether these personality evaluations matched their self-views.

Results. In both groups, mood decreased after criticism and increased after praise. Adolescents with depression reported blunted mood responses after praise, whereas there were no mood differences after criticism. Neuroimaging analyses revealed that adolescents with depression (*v.* healthy controls) exhibited increased activity in response to criticism in the subgenual anterior cingulate cortex, temporal pole, hippocampus, and parahippocampal gyrus. Praise consistent with adolescents' self-views improved mood independent of depression status, while criticism matching self-views resulted in *smaller* mood increases in adolescents with depression (*v.* healthy controls). Exploratory analyses indicated that adolescents with depression recalled criticism (*v.* praise) more.

Conclusions. Adolescents with depression might be especially attentive to parental criticism, as indexed by increased sgACC and hippocampus activity, and memorize this criticism more. Together with lower positive impact of praise, these findings suggest that cognitive biases in adolescent depression may affect how parental feedback is processed, and may be fed into their self-views.

Introduction

Adolescent depression is a major mental health issue due to its high prevalence (Ormel et al., 2015), substantial burden of illness (World Health Organization, 2019), and high recurrence rate (Curry et al., 2011). Key features of depression are a negative self-concept and low self-esteem (Rappaport & Barch, 2020; Sowislo & Orth, 2013). Prior meta-analyses on both self-report and observational studies have shown that negative parent-child interactions are linked to adolescent depression (Pinquart, 2017; Yap, Pilkington, Ryan, & Jorm, 2014). Moreover, receiving both negative and positive feedback (i.e. criticism and praise) from parents is important for the formation of adolescents' self-concept and self-esteem (Brummelman & Thomaes, 2017; Harter, 2015; Jacquez, Cole, & Searle, 2004). However, it is also known that depression is characterized by negative biases in cognitive processes, such as attention, interpretation, and memory (Everaert & Koster, 2020). Importantly, these biases may also affect the way adolescents with depression *react* to parental criticism and praise, which thus far has received little attention. The purpose of this study is therefore to elucidate how adolescents with depression process parental criticism and praise (in terms of affective and neural responses) and whether this is affected by their self-views and their parents' view.

Hitherto, only one study examined neural responses to parental feedback in adolescents with depression. In response to auditory maternal criticism, Silk et al. (2017) found increased parahippocampal gyrus activation in adolescents with depression, and decreased activation in the dorsal striatum, ventromedial prefrontal cortex (vmPFC), and precuneus in response to praise, indicating that the neural processing of parental criticism and praise may be

differentially affected in depression. Moreover, in a broader context, negative stimuli have been shown to elicit greater neural reactivity in regions related to social saliency, e.g. dorsal anterior cingulate cortex (dACC), subgenual ACC (sgACC), anterior insula (AI), and the amygdala both in adults (Hamilton et al., 2012; Rappaport & Barch, 2020) and adolescents with depression (Forbes, Eckstrand, Rofey, & Silk, 2020). Also, reduced ventral striatum (VS) responses to rewarding or *positive* stimuli have frequently been linked to depression (Keren et al., 2018; Ng, Alloy, & Smith, 2019).

Using a social feedback design about one's *personality* in healthy participants, we previously found that criticism elicited increased activity in areas supporting salience processing (i.e. AI, ACC) and social cognition (i.e. dorsomedial PFC, inferior frontal gyrus, temporal poles), both in adolescents receiving feedback from one's parent (van Houtum et al., 2022), and in adult women receiving feedback from a stranger (van Schie, Chiu, Rombouts, Heiser, & Elzinga, 2018). Praise elicited increased activity in brain regions supporting socio-cognitive and self-referential processes, including temporoparietal junction (TPJ), posterior cingulate cortex, and precuneus. Aberrant neural responses to parental feedback in these regions may relate to socio-cognitive, self-referential, and/or salience processes, possibly being linked to (self)-negativity biases in adolescent depression (Bradley et al., 2016; Forbes et al., 2020).

The impact of social feedback is greatly dependent on the receiver and moderated by how people view themselves (Sedikides & Gregg, 2008; Stinson et al., 2010; van Schie et al., 2018). In healthy individuals, mood responses to feedback seem to depend both on valence and consistency with self-views, such that criticism elicits negative mood, but criticism *inconsistent* with self-views elicits even more negative mood (van Houtum et al., 2022; van Schie et al., 2018). As depression is characterized by negative self-views (Bradley et al., 2016; Orchard, Pass, & Reynolds, 2019), adolescents with depression may react in a more blunted way to both parental criticism, which matches their self-views, and parental praise – mismatching their self-views (Swann, 2012). Alternatively, adolescents with depression, being generally more sensitive to rejection (Gao, Assink, Cipriani, & Lin, 2017), may feel worse after criticism, regardless of their self-views. Given the bidirectional nature of social interactions, next to self-views, one's parent (i.e. the feedback provider) view might also be an important factor in an adolescent's reactivity to feedback.

Therefore, the current study aimed to investigate affective and neural responses to parental criticism and praise in adolescents with depression *v.* healthy controls. We furthermore explored whether these responses are influenced by adolescents' own self-views and/or their parent's view. All study measures, hypotheses, and analyses were preregistered prior to data analyses (https://osf.io/yja3g). We examined whether adolescents with depression show either *blunted* (Bylsma, Morris, & Rottenberg, 2008; Rottenberg, Gross, & Gotlib, 2005) or *potentiated* (Rappaport & Barch, 2020) negative mood to parental criticism (*v.* intermediate feedback and praise), and aberrant activity in regions of the salience network (i.e. AI, dACC, sgACC, and amygdala) and social cognition (i.e. TPJ) (Forbes et al., 2020; Rappaport & Barch, 2020). We further hypothesized that adolescents with depression show blunted positive mood to parental praise (Rappaport & Barch, 2020) as well as aberrant activity in VS and brain regions supporting thinking about self and others (e.g. TPJ) (Forbes et al., 2020; Silk et al., 2017). We further explored whether mood and activation in regions of affective and socio-cognitive networks are influenced by the level of consistency of feedback with self-views. Lastly, we explored whether parents' general view of their child differentially impact affective and neural responses.

Method

Participants

Adolescents and their parent(s) participated in RE-PAIR (*'Relations and Emotions in Parent-Adolescent Interaction Research'*). This Dutch multi-method two-generation study investigates the bidirectional interplay between parent-adolescent interactions and adolescent wellbeing by comparing adolescents with major depressive disorder (MDD) or dysthymia (DEP) to healthy controls (HC). Families with a DEP adolescent were primarily recruited via mental health clinics. Families were also recruited via (social) media. Inclusion criteria for all adolescents were as follows: aged between 11 and 17 years when screened for psychopathology, having started secondary school, living with one or both parents, and good command of the Dutch language. Inclusion criteria specifically for DEP adolescents were: a current MDD or dysthymia diagnosis as determined by the Kiddie-Schedule for Affective Disorders and Schizophrenia–Present and Lifetime Version (K-SADS-PL) (Kaufman, Birmaher, Brent, Rao, & Ryan, 1996), and psychotherapy for their depression did not start yet, or had just started. Exclusion criteria for DEP adolescents were: a primary mental disorder other than MDD/dysthymia, or having a comorbid psychosis, substance use disorder, autism spectrum disorder, and/or mental retardation. For HCs, a lifetime MDD/dysthymia diagnosis or any other psychiatric diagnosis in the 2 years preceding study participation was an exclusion criterion. Families participated in a lab session, completed ecological momentary assessment (EMA; Stone & Shiffman, 1994) for 14 consecutive days, and were invited for an MRI-scanning session (for detailed procedures, see Supplement 1). For the scanning session, MRI contraindications were exclusion criteria.

In total, 22 DEP and 63 HC adolescents took part in the scanning session. The current paper focuses on the impact of depression on responses to parental feedback, whereas data of HCs have previously been published elsewhere (van Houtum et al., 2022). Two HCs were excluded due to scanner artifacts, one due to excessive head motion, and one because of a depression severity score in the clinical range, see also (van Houtum et al., 2022). Furthermore, one DEP adolescent was excluded due to excessive head motion and one due to claustrophobia. This resulted in a final sample of 20 DEP (primary diagnosis MDD: $n = 16$; dysthymia: $n = 4$) and 59 HC adolescents (Table 1 and Supplement 2).

RE-PAIR was approved by the Medical Ethics Review Committee of Leiden University Medical Centre, Leiden, the Netherlands (reference: P17.241; protocol: NL62502.058.17) and carried out in accordance with the Declaration of Helsinki and Dutch Medical Research Involving Human Subjects Act (WMO). Written informed assent and consent were obtained from all adolescents and their parents prior to study procedures.

Clinical assessment

To determine current and lifetime psychopathology adolescents were interviewed based on DSM-IV criteria using the K-SADS-PL (Kaufman et al., 1996). For DEP adolescents,

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Table 1. Participants' demographics and descriptive statistics

Variables	Adolescents with depression (n = 20)		Healthy control adolescents (n = 59)		Between groups t test/χ^2 test
	Mean (s.d.) /n (%)	Range	Mean (s.d.) /n (%)	Range	
Age adolescent (years)	16.2 (1.44)	13.5–18.0	16.2 (1.21)	12.6–18.2	$U = 579$[a], $p = 0.906$
Sex adolescent: n male	5 (25.0%)	–	20 (33.9%)	–	$\chi^2(1) = 0.21$, $p = 0.645$
Sex parent: n male	7 (35.0%)	–	27 (45.8%)	–	$\chi^2(1) = 0.36$, $p = 0.563$
Current educational level, n					$\chi^2(4) = 3.55$, $p = 0.470$
Lower vocational (VMBO)	3 (15.0%)	–	7 (11.9%)	–	
Higher vocational (HAVO)	3 (15.0%)	–	19 (32.2%)	–	
Pre-university (VWO)	9 (45.0%)	–	26 (44.1%)	–	
Secondary vocational (MBO)	4 (20.0%)	–	5 (8.47%)	–	
Higher professional (HBO)	1 (5.00%)	–	2 (3.39%)	–	
Handedness (EHI-score)	74.6 (41.3)	−55.6 to 100	71.0 (52.9)	−100 to 100	$U = 600$[a], $p = 0.912$
Right-handed, n	18 (90.0%)	–	54 (91.5%)	–	$\chi^2(1) = 0.00$, $p = 1$
Pubertal development (PDS score)	3.47 (0.61)	1.2–4	3.25 (0.63)	1–4	$U = 443$[a], $p = 0.093$
Depressive symptoms (PHQ-9-score)	17.8 (4.44)	10–26	4.36 (2.52)	0–12	$U = 2$[a], $\mathbf{p < 0.001}$
Parent-child bonding (PBI-score)[b]					
Care	25.8 (5.92)	14–34	30.8 (5.13)	14–36	$U = 894$[a], $\mathbf{p < 0.001}$
Overprotection	11.4 (7.09)	1–26	7.97 (3.97)	2–21	$U = 412$[a], $p = 0.054$
Parents' general view of their child	0.87 (0.30)	0.32–1.34	1.04 (0.30)	0.21–1.63	$U = 768$[a], $\mathbf{p = 0.045}$

EHI, Edinburgh handedness inventory (Oldfield, 1971); PBI, parental bonding instrument (Parker, Tupling, & Brown, 1979); PDS, pubertal development scale (Petersen, Crockett, Richards, & Boxer, 1988); PHQ-9, patient health questionnaire-9 (Kroenke & Spitzer, 2002).
[a]As assumptions of normality and/or equal variances were not met, a nonparametric Mann–Whitney U test was conducted.
[b]n = 58 healthy control adolescents, as PBI data of one adolescent was missing.

interviews were conducted by a trained psychologist from the mental healthcare institution where the adolescent was (on the waiting list for) being treated. Otherwise, adolescents were interviewed by trained graduate clinical psychology students of Leiden University prior (DEP) or during (HC) the lab session. Final diagnoses were discussed with a registered healthcare psychologist. Additionally, depressive symptoms were assessed using the Patient Health Questionnaire-9 (Kroenke & Spitzer, 2002) as part of the scanning session questionnaire battery.

Parental social feedback task

During the parental social feedback task, adolescents received social feedback (i.e. words describing their personality) supposedly given by their parent (van Houtum et al., 2022). During the lab session, adolescents and their parents had rated 49 feedback words in terms of valence ('*What do you think of this personality characteristic?*') from −4 ('*very negative*') to 0 ('*neutral*') to 4 ('*very positive*') and applicability to the adolescent ('*To what extent does this personality characteristic apply to you/your child?*') from 1 ('*not at all*') to 5 ('*very much*'). Questions could be answered with a question mark if a feedback word was unclear. Unclear feedback words were discarded from analyses on a person-based level [excluded words: 16 (0.6%) across 12 HCs; 12 (1.3%) across 7 DEP].

Right before the task, adolescents were informed that their mother/father (HC: n = 32/27; DEP: n = 13/7) was asked to select both positive and negative personality characteristics from a list that they deemed most descriptive of their child, and that they would see these chosen personality characteristics. In reality, each adolescent received the same preprogrammed feedback, split in three predetermined valence categories: 15 positive (e.g. '*Kind*'), 15 intermediate (e.g. '*Chaotic*'), and 15 negative words (e.g. '*Untrustworthy*'; see (van Houtum et al., 2021)). Each trial (online Supplementary Fig. S1) started with a jittered fixation cross and the sentence '*Your mother/father thinks you are:*' [duration: 2000–6000 ms (M = 4000 ms)]. Next, a feedback word appeared (2500 ms), followed by a jittered inter-trial-interval [duration: 1000–3000 ms (M = 2000 ms)]. After each feedback word, adolescents rated their current mood ('*How do you feel right now?*') from 1 ('*very negative*') to 7 ('*very positive*') with MR-compatible button boxes. Participants used their left index- and middle fingers to move from left to right on the scale and their right index-finger to confirm responses. If adolescents did not respond within 8000 ms, the message '*Too late*' appeared (1000 ms), and the trial was excluded from analyses [excluded trials: 4 (0.15%) across 4 HCs; 0 DEP]. Feedback words were pseudo-randomly presented, with the condition that consecutive words were never of similar valence. The task started and ended with two fixed positive feedback fillers, being excluded from analyses. Before and after the task, adolescents filled out visual analog

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scales to assess their current level of self-esteem, sadness, relaxation, and irritation (Supplement 3).

Outside the scanner, we asked adolescents to freely recall as much feedback words as possible within 2 min, using an online questionnaire with a timer. Obvious typos (e.g. 'life' instead of the Dutch word 'lief') were corrected manually. Next, adolescents were interviewed to check the extent to which they believed that their parent provided the feedback. No adolescent disbelieved our cover story (Supplement 4). Hereafter, a thorough debriefing took place about study purposes and to ensure adolescents understood that feedback was preprogrammed and not based on their parent's appraisals. We also informed parents that their child received preprogrammed feedback, ostensibly given by them. Families received a letter explaining the experimental set-up and – if preferred – were contacted later to evaluate experiences (contacted families: $n = 15$). The task was well-received by families, and they were positive about study participation.

The task was programmed using E-Prime 2.0 (Psychological Software Tools, Pittsburgh, PA) and presented on a 32-inch BOLD-screen (Cambridge Research Systems, Cambridge, UK) placed at the end of the scanner bore, which participants could see via a mirror attached to the head coil.

Parents' general view of their child

Parents' general tendency to view their child positively was calculated by multiplying parents' applicability ratings of the feedback words (assessed during the lab session) with within-subject *z*-scored valence ratings of these words. Parents can have different baseline values in valence ratings of words. To account for these differences between parents, we used within-subject *z*-scored valence ratings to ascertain that parents' evaluation of the valence of feedback words are incorporated in the measure, i.e. all feedback words with *z*-scored values >0 were evaluated as more positive than the other words, while feedback words with *z*-scored values <0 were evaluated as more negative by the parent. We averaged these within-subject applicability*z*-scored valence values across all feedback words per parent to create a general view score (van Houtum et al., 2021) (Table 1). A higher score indicated a more positive parental view of the child.

Affective data analysis

We analyzed how mood varied as a function of feedback valence and group (depression yes/no) using multilevel modeling in R-4.0.4 (R Foundation, Vienna, Austria). Intermediate feedback was set as reference category to which the effects of criticism and praise were compared. We specified adolescents' mood after each feedback word as outcome, feedback valence categories on the first level (including random effects), and group on the second level:

$$\begin{aligned}\text{Mood}_{ij} = {} & \gamma_{00} + \gamma_{01}(\text{Depression})_j + \gamma_{10}(\text{Criticism})_{ij} + \gamma_{20}(\text{Praise})_{ij} \\ & + \gamma_{11}(\text{Depression})_j(\text{Criticism})_{ij} + \gamma_{21}(\text{Depression})_j(\text{Praise})_{ij} \\ & + \upsilon_{0j} + \upsilon_{1j}(\text{Criticism})_{ij} + \upsilon_{2j}(\text{Praise})_{ij} + \varepsilon_{ij}\end{aligned}$$

To ascertain whether DEP adolescents have more negative self-views, we included applicability (instead of mood) ratings as outcome.

To explore whether consistency of feedback words with adolescents' self-views differentially impacts mood across groups, applicability ratings were added on the first level (including random effects) to the mood model:

$$\begin{aligned}\text{Mood}_{ij} = {} & \gamma_{00} + \gamma_{01}(\text{Depression})_j + \gamma_{10}(\text{Criticism})_{ij} + \gamma_{20}(\text{Praise})_{ij} \\ & + \gamma_{11}(\text{Depression})_j(\text{Criticism})_{ij} + \gamma_{21}(\text{Depression})_j(\text{Praise})_{ij} \\ & + \gamma_{30}(\text{Applicability})_{ij} + \gamma_{31}(\text{Depression})_j(\text{Applicability})_{ij} \\ & + \gamma_{40}(\text{Criticism} * \text{Applicability})ij + \gamma_{50}(\textit{Praise} * \text{Applicability})_{ij} \\ & + \gamma_{41}(\text{Depression})_j(\text{Criticism} * \text{Applicability})_{ij} \\ & + \gamma_{51}(\text{Depression})_j(\text{Praise} * \text{Applicability})_{ij} \\ & + \upsilon_{0j} + \upsilon_{1j}(\text{Criticism})_{ij} + \upsilon_{2j}(\text{Praise})_{ij} + \upsilon_{3j}(\text{Applicability})_{ij} + \varepsilon_{ij}\end{aligned}$$

To explore whether the impact of parental feedback on adolescents' mood is dependent on parents' general view, general view scores were added on the second level:

$$\begin{aligned}\text{Mood}_{ij} = {} & \gamma_{00} + \gamma_{01}(\text{Depression})_j + \gamma_{02}(\text{Parents}' \text{ general view})_j\gamma_{10}(\text{Criticism})_{ij} \\ & + \gamma_{20}(\text{Praise})_{ij}\gamma_{03}(\text{Depression})\ (\text{Parents}' \text{ general view})_j \\ & + \gamma_{11}(\text{Depression})_j(\text{Criticism})_{ij} + \gamma_{12}(\text{Parents}' \text{ general view})_j(\text{Criticism})_{ij} \\ & + \gamma_{21}(\text{Depression})_j(\text{Praise})_{ij} + \gamma_{22}(\text{Parents}' \text{ general view})_j(\text{Praise})_{ij} \\ & + \gamma_{13}(\text{Depression})_j(\text{Parents}' \text{ general view})_j(\text{Criticism})_{ij} \\ & + \gamma_{23}(\text{Depression})_j(\text{Parents}' \text{ general view})_j(\text{Praise})_{ij} \\ & + \upsilon_{0j} + \upsilon_{1j}(\text{Criticism})_{ij} + \upsilon_{2j} + (\text{Praise})_{ij} + \varepsilon_{ij}\end{aligned}$$

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All continuous variables were *z*-scored at the sample level. χ^2 tests were used to test for significance of effects.

fMRI data acquisition and analysis

We acquired MRI images using a Philips Achieva 3.0-Tesla scanner (Philips Medical Systems, Best, NL) equipped with a SENSE-32 whole-head coil. We collected functional scans with T2*-weighted echo-planar imaging sequence [TR/TE: 2200/30 ms; flip angle: 80°; 38 transverse slices (anterior-to-posterior); FOV: 220 × 220 × 114.68 mm; voxel size: 2.75 mm^3], see Supplement 5 for further details.

fMRI data were preprocessed and analyzed using SPM12 (Wellcome Trust Centre for Neuroimaging, London, UK), following standard procedures including spatial normalization using the DARTEL-toolbox (Ashburner, 2007) (Supplement 5). Next, we defined a general linear model (GLM) including three separate regressors for onsets of criticism, praise, and intermediate feedback (modeled for 2500 ms), and one onset regressor of no interest for the mood question [modeled for the duration questions were displayed (self-paced)]. DEP adolescents answered mood questions significantly faster [$M_{(S.D.)}$ = 1720(984) ms, *range:* 460–7961) than HCs [$M_{(S.D.)}$ = 1906 (969) ms, *range:* 395–7903] [$t(1741) = 5.43$, $p < 0.001$]. The GLM further included six motion regressors accounting for head motion (realignment parameters). For each subject, t-contrasts were generated to compare criticism and praise to each other and to intermediate feedback.

We compared activation patterns across groups in *a priori* preregistered regions of interests (ROIs). For the criticism *v.* praise/intermediate feedback contrasts, we looked at activity in bilateral dACC, sgACC, amygdala, AI, and right TPJ. For the praise *v.* criticism/intermediate contrasts, we looked at activity in bilateral VS and right TPJ. We created an anatomical ROI of bilateral dACC previously used by Dedovic, Slavich, Muscatell, Irwin, and Eisenberger (2016). We obtained anatomical ROIs of bilateral sgACC, amygdala, AI, and VS from Silk et al. (2022). Furthermore, we created an independent functional ROI of right TPJ [i.e. 8-mm sphere MNI-space surrounding peak voxel coordinates ($x = 56$, $y = -42$, $z = 16$) previously found by van Schie, Chiu, Rombouts, Heiser, and Elzinga (2020) in response to criticism, using this paradigm in borderline personality disorder patients]. Parameter estimates for each ROI were extracted and averaged across all voxels per feedback valence using MarsBar toolbox implemented in SPM12. We used independent *t*-tests (two-tailed) to test for significance of each contrast of interest in these ROIs. We corrected for multiple comparisons by applying Bonferroni correction for the number of ROIs per analysis (i.e. criticism contrasts: $p < 0.05/5$; praise contrasts: $p < 0.05/2$).

We explored whether additional brain regions were differentially involved in the processing of parental feedback across groups using exploratory whole-brain analyses. Subject-specific contrast images were submitted to group-level random effects analyses using independent *t*-tests, which were corrected for multiple comparisons as preregistered using Family-wise Error cluster-correction at $p < 0.05$ (cluster-forming threshold of $p < 0.001$).

To explore how neural responses to parental feedback varied as a function of self-rated applicability, we defined a similar GLM, in which feedback regressors were parametrically modulated by applicability ratings. We generated first-level t-contrasts which were entered in a flexible factorial ANOVA design with applicability per valence as within-subject factor (three levels: negative, intermediate, and positive) and depression as group factor (two levels: yes/no) to examine differences in BOLD-responses between groups with respect to the main effect of applicability, and the feedback valence*applicability interaction (Gläscher & Gitelman, 2008).

To explore group differences associated with parents' general view of the adolescent, we ran independent *t*-tests on all feedback contrasts, with a general view score regressor added as interaction term.

Results

Affective responses to parental feedback

We found no differences in valence ratings of negative [$b = 0.01$, $_{S.E.} = 0.07$, $t(95.9) = 0.17$, $p = 0.869$], intermediate [$b = -0.03$, $_{S.E.} = 0.05$, $t(83.3) = -0.65$, $p = 0.517$], and positive [$b = -0.06$, $_{S.E.} = 0.07$, $t(87.5) = -0.85$, $p = 0.395$] feedback words between groups [depression*feedback valence categories on valence ratings: $\chi^2(2) = 0.73$, $p = 0.693$], indicating that DEP adolescents did not view the valence of feedback words differently than HCs.

As expected, we found an interaction effect between depression and feedback valence on adolescents' applicability ratings [$\chi^2(2) = 46.1$, $p < 0.001$]. Post-hoc analyses showed that DEP adolescents rated positive feedback words as less applicable [$b = -0.46$, $_{S.E.} = 0.10$, $t(80.7) = -4.77$, $p < 0.001$], while negative [$b = 0.47$, $_{S.E.} = 0.10$, $t(81.1) = 4.88$, $p < 0.001$] and intermediate [$b = 0.28$, $_{S.E.} = 0.09$, $t(80.8) = 3.08$, $p = 0.003$] feedback words were rated as more applicable to the self *v.* HCs, illustrating that DEP adolescents have more negative self-views.

Throughout the task, DEP adolescents (*v.* HCs) reported a lower mood after receiving parental feedback [$\chi^2(1) = 37.8$, $p < 0.001$]. This was further specified by a depression*feedback valence interaction on adolescents' mood [$\chi^2(2) = 6.09$, $p = 0.048$]. Post-hoc analyses revealed that mood did not differ from HCs after criticism [$b = -0.40$, $_{S.E.} = 0.22$, $t(81.1) = -1.82$, $p = 0.073$], while DEP adolescents (*v.* HCs) reported lower mood after praise [$b = -0.91$, $_{S.E.} = 0.14$, $t(81) = -6.50$, $p < 0.001$] and intermediate parental feedback [$b = -0.67$, $_{S.E.} = 0.15$, $t(80.9) = -4.44$, $p < 0.001$]. Furthermore, in each group separately, parental criticism resulted in a significantly lower mood [HC: ($b = -0.68$, $_{S.E.} = 0.06$, $t(80.5) = -10.6$, $p < 0.001$); DEP: ($b = -0.41$, $_{S.E.} = 0.11$, $t(80.8) = -3.76$, $p < 0.001$), and praise in higher mood [HC: ($b = 0.53$, $_{S.E.} = 0.05$, $t(80.2) = 10.0$, $p < 0.001$); DEP: ($b = 0.28$, $_{S.E.} = 0.09$, $t(80.3) = 3.12$, $p = 0.007$)]] relative to intermediate feedback (Fig. 1*a*).

Associations with consistency of feedback with self-views (i.e. applicability)

To examine whether consistency of feedback words with adolescents' self-views differentially impacted mood across groups, we performed a multilevel analysis with main effects of depression, feedback valence, applicability, and their interactions on adolescents' mood (online Supplementary Table S3). We found a main effect of applicability, indicating that feedback more consistent with self-views (i.e. more applicable *v.* more inapplicable), resulted in relative increases in mood [$\chi^2(1) = 61.3$, $p < 0.001$]. Furthermore, we found a depression*applicability interaction on adolescents' mood [$\chi^2(1) = 5.79$, $p = 0.016$]. Post-hoc analyses

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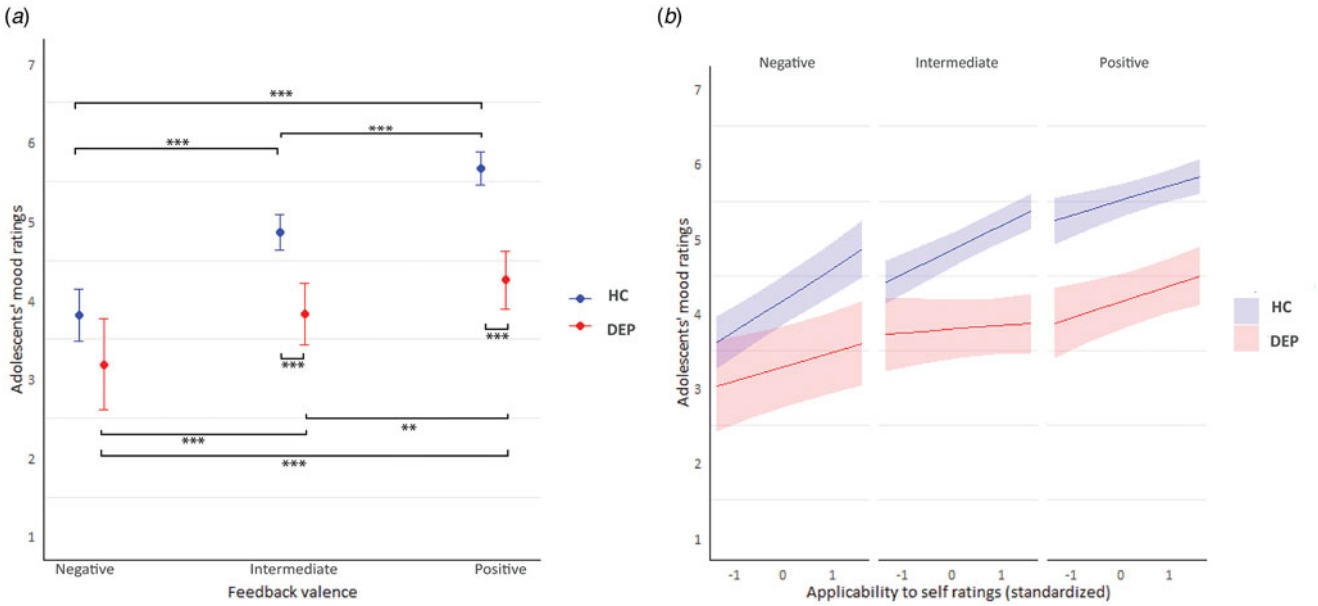

Figure 1. (*a*) Main and interaction effects of depression status (yes/no) ($p < 0.001$) and feedback valence ($p < 0.001$) (interaction: $p = 0.048$) on adolescents' mood (raw scores). Mood of adolescents with depression was lower after praise (i.e. positive feedback) and intermediate parental feedback as compared to healthy controls, whereas the groups did not differ in mood responses to criticism (i.e. negative feedback). (*b*) Three-way interaction effect of depression, feedback valence, and applicability ($p = 0.005$) on adolescents' mood (raw scores). Adolescents with depression (*v.* HCs) showed *smaller* increases in mood when specifically criticism and intermediate parental feedback were more applicable (i.e. consistent with self-views). For praise, consistency with self-views did not moderate mood responses of adolescents with depression and healthy controls differently. *Note.* ** $p < 0.01$; *** $p < 0.001$. Error bars represent CIs (i.e. ±1.96*standard error). HC, healthy control adolescents; DEP, adolescents with depression.

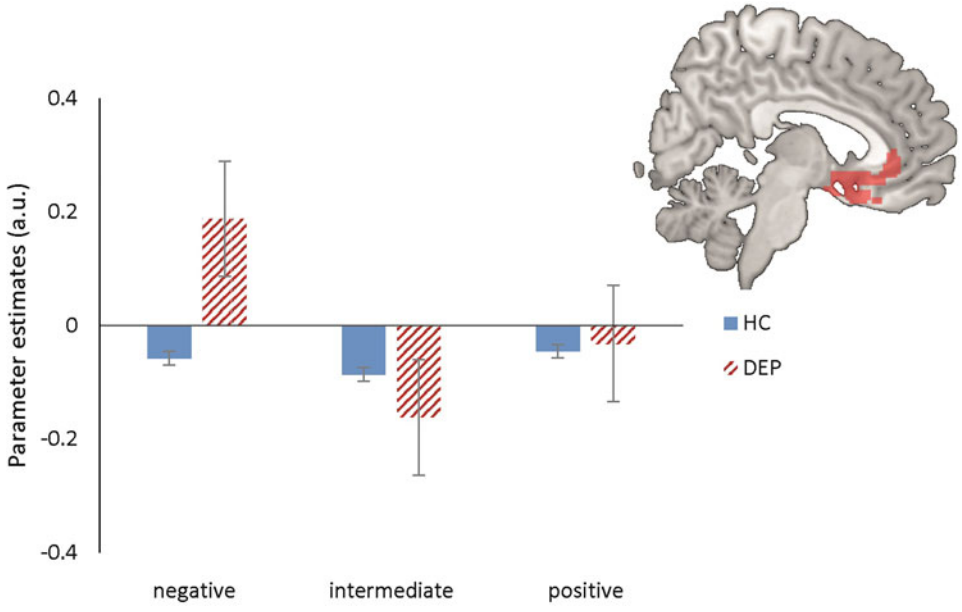

Figure 2. Increased subgenual anterior cingulate cortex (Silk et al., 2022) activity in response to criticism (i.e. negative *v.* intermediate parental feedback) in adolescents with depression compared to healthy control adolescents ($p = 0.002$). *Note.* Error bars represent standard error of the mean. HC, healthy control adolescents; DEP, adolescents with depression.

revealed that DEP adolescents (*v.* HCs) showed *smaller* increases in mood when feedback was more consistent with self-views [$b = -0.11$, *S.E.* = 0.05, $t(76.8) = -2.12$, $p = 0.038$]. We additionally found a three-way interaction effect between depression, feedback valence, and applicability on adolescents' mood [$\chi^2(2) = 10.7$, $p = 0.005$]. In other words, DEP adolescents (*v.* HCs) showed *smaller* increases in mood when specifically criticism [$b = -0.15$, *S.E.* = 0.06, $t(205) = -2.29$, $p = 0.023$] and intermediate feedback [$b = -0.18$, *S.E.* = 0.06, $t(121) = -3.20$, $p = 0.002$] were more applicable (*v.* more inapplicable). The groups did not differ in mood increases when praise was more applicable (*v.* more inapplicable) [$b = 0.01$, *S.E.* = 0.06, $t(185) = 0.13$, $p = 0.895$] (Fig. 1*b*).

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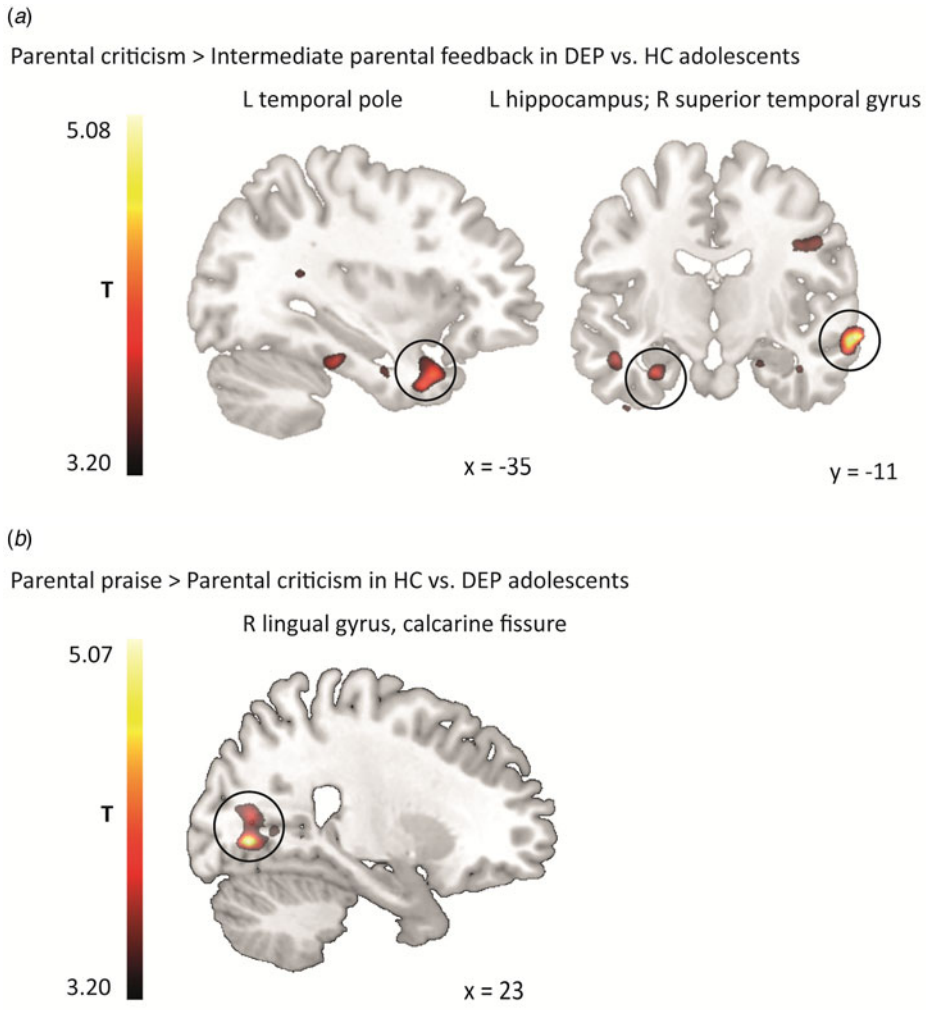

Figure 3. (*a*) A whole-brain analysis contrasting parental criticism with intermediate parental feedback when comparing adolescents with depression *v.* healthy control adolescents resulted in increased activation in a right superior/middle temporal gyrus cluster and left temporal pole/inferior temporal gyrus cluster extending into the left hippocampus, left parahippocampal gyrus, and left fusiform gyrus. (*b*) A whole-brain analysis contrasting parental praise with criticism when comparing healthy control *v.* adolescents with depression resulted in increased activation in a right lingual gyrus/calcarine fissure cluster extending into the right fusiform gyrus. *Note.* Results are thresholded at $p < 0.05$ using Family-wise Error cluster correction with a cluster-forming threshold of $p < 0.001$. HC, healthy control adolescents; DEP, adolescents with depression; L, left; R, right.

Neural responses to parental feedback

ROI findings

DEP adolescents exhibited significantly increased BOLD responses when receiving parental *criticism v.* intermediate feedback in sgACC ($p = 0.002$; Fig. 2) and amygdala ($p = 0.019$) compared to HCs. However, the amygdala finding did not survive Bonferroni correction ($p = 0.05/5$). Receiving criticism *v.* praise resulted in increased activity in sgACC ($p = 0.029$) and right TPJ ($p = 0.034$) in DEP *v.* HC adolescents, but neither finding remained significant after Bonferroni correction. No significant differences were found in AI and dACC activity when adolescents received parental criticism *v.* praise/intermediate feedback (all p's > 0.074).

When receiving *praise v.* criticism, DEP adolescents (*v.* HCs) exhibited decreased activity in the right TPJ ($p = 0.034$), although not surviving Bonferroni correction. No significant group differences in VS and right TPJ activity in response to praise *v.* intermediate feedback were found (all p's > 0.122).

Whole-brain findings

Whole-brain analyses showed that DEP adolescents (*v.* HCs) receiving parental criticism *v.* intermediate feedback, exhibited increased activity in a right superior/middle temporal gyrus cluster and a left temporal pole/inferior temporal gyrus cluster extending into left hippocampus, parahippocampal gyrus, and fusiform gyrus (Fig. 3*a* and online Supplementary Table S4). Compared to praise, receiving criticism elicited no significant differences in activations between groups.

Moreover, receiving praise *v.* criticism increased activity in a right lingual gyrus/calcarine fissure cluster extending into the right fusiform gyrus in HC *v.* DEP adolescents (Fig. 3*b* and online Supplementary Table S4). Receiving praise *v.* intermediate feedback revealed no significant differences in activations between groups.

Next, we explored whether consistency of feedback with self-views (i.e. applicability) differently impacted neural responses across groups. Whole-brain analyses testing for differences in brain activity associated with parametric increases or decreases in applicability across feedback valence categories in DEP *v.* HC

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adolescents did not result in any significant clusters that survived multiple comparison corrections. An analysis testing for an interaction between feedback valence, applicability, and depression did not result in significant clusters either.

Finally, we explored differences between groups with regard to one's parent general view of them. Parents of DEP adolescents viewed their childless positively compared to parents of HCs ($U = 768$, $p = 0.045$). Parental views did not differentially impact affective and neural responses (Supplement 6).

Recall of feedback words

Given that receiving parental criticism (*v.* intermediate feedback) increased activity in memory-related areas in DEP *v.* HC adolescents, we additionally explored differences across groups in the amount of recalled negative and positive feedback words *outside* the scanner. Post-hoc analyses revealed that DEP adolescents recalled more negative than positive feedback words ($b = -0.43$, *S.E.* $= 0.18$, $t = 2.40$, $p = 0.043$), whereas HCs recalled a similar amount of negative and positive words ($b = -0.08$, *S.E.* $= 0.11$, $t = -4.50$, $p = .704$) [depression*feedback valence interaction: $\chi^2(2) = 7.16$, $p = 0.028$] (online Supplementary Fig. S2).

Confound analyses

Behavioral nor neural results did change when adding sex, age, pubertal status, parental sex, or strength of belief in the feedback cover story as covariates (Supplement 7).

Discussion

This study investigated affective and neural responses to parental criticism and praise in adolescents with *v.* without depression. Although adolescents with depression are responsive to parental feedback (i.e. their mood significantly increased after praise, and decreased after criticism), they showed blunted mood responses to praise compared to healthy controls, but no differences in mood responses to criticism. Receiving parental criticism (*v.* intermediate feedback) increased activity in sgACC, left temporal pole, and memory-related areas, i.e. left hippocampus, parahippocampal gyrus, and fusiform gyrus, while receiving parental praise (*v.* criticism) was associated with *decreased* activity in right visual cortex in adolescents with depression (*v.* HCs). Regarding the consistency of feedback with self-views, for both groups, mood increased when praise was more applicable (*v.* more inapplicable). However, when criticism was more applicable (*v.* more inapplicable), adolescents with depression (*v.* HCs) showed *smaller* increases in mood. Applicability did not modulate neural responses to feedback. Lastly, parents of adolescents with depression generally viewed their child less positively, but we found no robust evidence of parents' general view modulating adolescents' affective or neural responses to parental feedback.

The finding that parental criticism elicited increased activity in sgACC in adolescents with depression (*v.* HCs) is consistent with prior research investigating responses to peer rejection in youth with (Silk et al., 2014), or at risk for depression (Silk et al., 2022). The sgACC – having dense connections with both cortical (e.g. PFC) and limbic (e.g. amygdala) areas – is thought to act as a 'gatekeeper' between cognitive and emotion networks, supporting emotion regulation (Scharnowski et al., 2020). This theory fits well with the fact that sgACC is used as deep brain stimulation area to improve treatment-resistant depression (Mayberg et al., 2005). In adolescents with depression, it has been shown that sgACC (and amygdala) activation in response to fearful (*v.* neutral) facial expressions substantially decreases after SSRI-treatment (Tao et al., 2012). Increased sgACC activity may be indicative of attempted coordination of cortical and limbic neural circuits (Mayberg, 1997, 2003). As mood responses to parental criticism did not differ, increased sgACC activity could also reflect *successful* regulation of criticism, but more research is needed to further investigate this.

A second interesting finding is that adolescents with depression (*v.* HCs) receiving parental criticism showed increased activity in temporal pole – involved in representing and retrieving social knowledge (Olson, McCoy, Klobusicky, & Ross, 2013) – and hippocampus, parahippocampal gyrus and fusiform gyrus, areas critical for episodic memory encoding (Squire & Zola-Morgan, 1991). Similarly, Silk et al. (2017) reported increased parahippocampal gyrus activity when adolescents with depression received auditory maternal criticism. Since adolescents with depression also recalled more negative than positive feedback words afterward (whereas HCs did not), our findings may suggest that parental criticism is stored more strongly in adolescents with depression, consistent with both a negative memory bias and attention biases in depression (Everaert & Koster, 2020). Alternatively, previous autobiographical memories of their parent criticizing them may have been elicited. As parental criticism confers heightened risk for adolescent depression, and vice versa (Nelemans, Hale, Branje, Hawk, & Meeus, 2014), adolescents may actually have been exposed more to parental criticism in the past, and consequently have more memories related to parental criticism, that may resurface during the task. This idea is consistent with our finding that parents of adolescents with depression viewed their child less positively *v.* parents of HCs. Either way, negative biases in processing and retrieval of emotional stimuli (via attention, interpretation, and memory), seem to be present in adolescent depression and may affect the processing of parental feedback. Understanding how these cognitive biases emerge, has high clinical importance (Platt, Waters, Schulte-Koerne, Engelmann, & Salemink, 2017).

As expected, adolescents with depression had more negative self-views (Bradley et al., 2016; Orchard et al., 2019). Generally, parental feedback more consistent with adolescents' self-views increased mood. Interestingly, when parental criticism was more consistent with self-views, adolescents with depression (*v.* HCs) showed *smaller* increases in mood. This may indicate that adolescents with depression are especially sensitive to parental criticism: they view themselves already negative, and rely less on their self-views when confronted with parental criticism. Regardless of depression status, however, adolescent's mood increased when *praise* was more consistent with self-views. Although adolescents with depression benefited less from parental praise (i.e. smaller mood increases after receiving compliments), applicable (*v.* inapplicable) praise boosted their mood. Hence, identifying personality characteristics adolescents value about themselves may be key to improving their depressed mood. In the context of an intervention, parents could be taught to identify and acknowledge these valued characteristics of the child, and in doing so support the development of a positive self-view. Furthermore, teaching parents to mix criticism with praise, and to deliver criticism in a specific and constructive way, may reduce negative affect and foster a positive family environment (Peris & Miklowitz, 2015). Actively involving parents in treatment may therefore have added value, which is consistent with findings showing that involvement of parents in adolescents' cognitive behavioral therapy improves therapy outcomes in adolescents with depression

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(Oud et al., 2019). Additionally, providing psycho-education for parents on the typical affect states and cognitive appraisals of adolescents with depression may help parents to better understand the emotional responses of their child and the potential causes of specific behaviors (Jugovac, O'Kearney, Hawes, & Pasalich, 2022; Samen sterk, 2022). Adolescents could, in turn, learn more adaptive ways to communicate their own thoughts and feelings to their parents, making it easier for parents to interpret their child's emotional experiences.

In sum, this study yielded important new insights into the processing of parental criticism and praise in adolescents with depression, using an ecologically-valid and realistic MRI-paradigm. Our findings should also be considered in light of some limitations. First, our sample size of adolescents with depression was relatively small, due to difficulties to get these families to participate in an extensive fMRI study, which was even more challenging during the COVID-19 pandemic. Moreover, quite some adolescents had comorbidities, such as anxiety disorders. While comorbidities are common in adolescent depression (Avenevoli, Swendsen, He, Burstein, & Merikangas, 2015), our findings should be interpreted with this in mind. For instance, receiving social feedback while having social anxiety can be impactful in different ways (Rappaport & Barch, 2020). Lastly, families with more harsh or neglectful parenting styles, which are robustly associated with adolescent depression (Pinquart, 2017), might be underrepresented in our sample (although adolescents with depression reported significantly lower parental care).

In conclusion, our findings show that adolescents, either with or without depression, are reactive to parental criticism and praise, depending on their self-views. Adolescents with depression might have a 'vigilant profile,' as indexed by increased sgACC and hippocampus activity when confronted with parental criticism, and memorize this criticism more, together with a less positive impact of praise. Without the buffer through parental praise, this profile may make these adolescents especially vulnerable to parental criticism. In the clinical realm, it is important that parents and clinicians are made aware of this fact through psycho-education. An urgent question is to what extent this vigilant profile reflects a latent vulnerability that is the expression of an early at-risk environment emerging long before depression-onset (McCrory & Viding, 2015), or whether current depressive symptoms may attune affective and neural responses. Longitudinal designs, starting from early childhood, are necessary to unravel the possible emergence of neural sensitivity to threat contexts – particularly during parent-child interactions –, and relations with depression and other psychiatric conditions.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0033291723002131.

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Conflict of interest. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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