Socioeconomic status and adolescent brain responses to peer feedback: Testing the impact on negative affect

Brent I. Rappaport1, James E. Glazer1, Lilian Y. Li1, Madeline M. McGregor1, Lili A. Massac2, Katherine Durham2, Randy P. Auerbach2, & Stewart A. Shankman1

1 Department of Psychiatry, Feinberg School of Medicine, Northwestern University

2 Columbia University

Author note

The authors made the following contributions. Brent I. Rappaport: Conceptualization, Formal analysis, Writing - Original Draft Preparation, Writing - Review & Editing; James E. Glazer: Methodology, Writing - Review & Editing; Lilian Y. Li: Methodology, Writing - Review & Editing; Madeline M. McGregor: Writing - Review & Editing; Lili A. Massac: Writing - Review & Editing; Katherine Durham: Writing - Review & Editing; Randy P. Auerbach: Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing - Review & Editing; Stewart A. Shankman: Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing - Review & Editing.

Correspondence concerning this article should be addressed to Brent I. Rappaport, 680 N. Lakeshore Drive, Suite 1520, Chicago, IL 60611. E-mail: [brent.rappaport@northwestern.edu](mailto:brent.rappaport@northwestern.edu)

Abstract

Background: Lower socioeconomic status (SES) is a potent risk factor for psychopathology in youth, however the mechanisms linking them are yet unknown. One potential neural mechanism is aberrant brain responding to peer acceptance and rejection. Test whether SES (operationalized as area deprivation) is 1) related to brain responses to peer feedback, and 2) moderates the relationship between brain responses to peer feedback and affect. Methods: 159 adolescent participants (ages 13-19) from the Chicago, IL and New York, NY metro areas completed an event-related potential (ERP) version of the Chatroom task, a week of ecological momentary assessment (EMA) reporting on their positive and negative affect, and a self-report of discrimination (adolescent discrimination distress index). Results: lower SES (as well as greater self-reported discrimination distress) was related to blunted responses to acceptance. Moreover, brain responses to rejection interacted with SES to predict EMA reported negative, but not positive, affect. Conclusions: SES may be linked to depression and anxiety disorders via heightened sensitivity to rejection, and/or blunted responses acceptance. Preliminary evidence suggests that discrimination may be one factor of low SES driving this effect. This study uses multiple levels of analysis (objective measure of environment, brain activity, EMA reported affect) to identify a potential brain x environment mechanisms explaining why low SES are at higher risk for internalizing disorders.

*Keywords:* social feedback, socioeconomic status, area deprivation, negative affect, discrimination

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Low socioeconomic status (SES) in youth is a robust correlate of concurrent psychopathology (1,2) and longitudinal predictor of psychopathology and general health problems into adulthood (3,4). However, the mechanisms linking SES to psychopathology remain unknown. This study examines whether one potential mechanism interacts with this sociological stressor to influence individual mental health: anomalous processing of feedback from others. That is, does a greater sensitivity to rejection and/or blunted sensitivity to acceptance from others, in combination with low SES, produce worse mental health outcomes.

Lower SES youth experience greater prejudice, discrimination, and stigma from others than higher SES youth (5,6) leading to biases in how they interpret social situations. Numerous theories (7,8) have argued that discrimination, prejudice, and stigma leads to difficulty being open, trusting and intimate with others (9), along with other social biases. Chronic discriminatory experiences lead to distrustful, cynical relationship schemas (8,10) that is, longstanding beliefs, cognitions, and expectations about social relationships (11). Youth develop these relationship schemas from experience with others. These schemas, in turn, help youth to efficiently identify salient social information (7). Thus, when youth regularly experience discrimination, the schema adapts to expect it in social interactions. Two ways this can manifest in social interactions are: 1) heightened sensitivity to negative feedback (rejection), and 2) blunted sensitivity to positive feedback (acceptance). These biases can have short-term benefits such as leading the individual to safely remove themselves from hostile environments (12,13). Over time, however, chronic heightened rejection sensitivity and blunted acceptance sensitivity can lead to pervasive social withdrawal and depressive and anxiety disorders (14).

Chronic heightened rejection sensitivity and blunted acceptance sensitivity have been tied to internalizing disorders. Enhanced sensitivity to rejection is related to depression (15–18) and socially relevant anxiety (i.e., behavioral inhibition, social anxiety disorder, generalized anxiety) in youth (19–21). Likewise, blunted sensitivity to acceptance is also related to depression (22–24). Such brain patterns can result in functional impairments: fearing social situations or not finding them pleasurable, youth withdraw hampering their ability to form and maintain positive peer relationships. This is a particularly important aspect of healthy adolescent development. Therefore, understanding how low SES confers risk for psychopathology may lead to reduced clinical symptoms and improved functioning.

## Current Study

Despite prior studies showing links between SES and psychopathology, and brain responses to peer feedback and psychopathology, only one study tested a link between SES and brain responses to peer feedback (25). The current study aims to fill this gap by explicitly testing whether an objective and validated measure of SES (area deprivation index [ADI], 26,27,28) is related to brain responses to peer feedback and moderates the association between these brain responses and negative affect in adolescents.

The first aim of the study tests whether low SES relates to brain responses to different kinds of peer feedback (acceptance and rejection). To measure brain responses to peer feedback, this study used event-related potentials (ERPs)—fluctuations in electroencephalography (EEG) signals that are time-locked to particular events. Unlike other neural measures like fMRI, ERPs have high temporal resolution (on the order of milliseconds) making them ideal for detecting separate neuropsychological responses to peer feedback. For example, the reward positivity (RewP)—a positive inflection that occurs around 250-350ms post feedback and is maximal at frontocentral cites (29)—likely reflects the rewarding aspects of acceptance in peer feedback studies (30,31). Alternatively, the P300—a positive inflection occurring around 300ms post feedback and maximal at centroparietal sites—likely reflects the salient aspects of acceptance and rejection in peer feedback studies (31,32). This makes ERP ideal for testing whether low SES is related to a) more blunted sensitivity to acceptance in the RewP, b) heightened salience of rejection in the P300, or c) both.

The second aim of the study was to test whether SES moderates the relationship between brain responses to peer feedback and negative affect assessed via ecological momentary assessment (EMA). Unlike traditional self-report assessments, EMA provides ecologically valid indicators of affect outside of the lab, as adolescents go about their daily lives. Furthermore, as EMA collects multiple samples of affect per participant, it yields more accurate measures of mean affect than single snapshot assessments and is less susceptible to biases associated with retrospective recall (33,34). Critically, showing that SES moderates the relationship between brain responses to peer feedback and negative affect would support heightened neural rejection sensitivity and/or blunted acceptance sensitivity as potential clinical targets for prevention/intervention. For example, targeted interventions aimed at reducing rejection sensitivity could reduce low SES youths’ risk for later life psychopathology.

The third aim of this study was to test the above two aims with a critical correlate of low SES—perceived discrimination. Low SES youth often experience greater discrimination, either directly due to their economic standing or due to other conflated factors[[1]](#footnote-21) (5,6,37). Perceived discrimination, specifically, has been linked to greater negative affect (38). However, no study has tested whether perceived discrimination is related to altered patterns of brain responses to peer feedback. This aim also complements the above aims with SES as it examines a subjective correlate (39), and more specific aspect, of SES. That is, while SES is a broad construct, perceived discrimination is a more specific consequence of low SES that may be particularly relevant to adolescent brain responses to peer feedback and subsequent risk for psychopathology. Indeed, perceived discrimination is as strong a risk factor for psychopathology as other significant life events (e.g., loss of a loved one or job loss), and comparable risk factor for depression and anxiety to traumatic events (e.g., sexual assault and combat, 40).

# Methods

## Participants

Participant data was acquired from a larger, ongoing project examining social processing deficits in adolescent depression. Adolescents, ages 13-18-years-old, were recruited from the community (via ads on public transportation, Facebook, and craigslist) and mental health clinics in New York, NY and Chicago, IL. All study procedures were carried out in accordance with the Declaration of Helsinki and approved by the New York State Psychiatric (NYSPI) (primary) Institutional Review Board (IRB) and the Northwestern University IRB. See supplement for further information regarding participants, including inclusion and exclusion criteria. N=160 participants were available to analyze for the present study. Table 1 summarizes the participant demographic and clinical characteristics.

## Procedure

### Chatroom task.

The Chatroom Task (41,42) was completed over two visits. At consent, participants were told that they were participating in a multi-site study on adolescent interactions in online chat rooms. Participants created profiles including their likes/dislikes and a photograph taken in the lab; they were told that other participants would review their profile and indicate interest (acceptance) or not (rejection) in chatting. Next, participants viewed photographs of 100 same-sex peers and selected 50 that they were ‘interested’ (high value) and 50 that they were ‘not interested’ (low value) in chatting with online following the EEG task. On each of 100 trials during EEG recording (~1 week later; Figure 1A), a peer photograph was displayed with a reminder of participants’ prior choice: ‘You were [not] interested’, followed by a fixation cross for a jittered inter-stimulus interval. Next, peer acceptance or rejection feedback was displayed: ‘Interested’ or ‘Not Interested’ (feedback type) and participants rated their emotional response (rating). Participants received 50 acceptance and 50 rejection trials (split by participant interest, e.g., 25 trials when participants were interested and accepted), pseudo-randomized with no more than three sequential acceptances/rejections. After completing the task, participants were assessed to gauge their belief that they would chat with the peers after the task (“While you were doing the chatroom, did you believe that you would really be chatting with one of these people on the computer after your EEG?”), as well as “why not” if they endorsed not believing that they would be able to chat with them. Finally, participants were debriefed on the deception.

Importantly, the structure of the task results in four within-subject conditions: 1) acceptance from high-value peers (i.e., peers that participants were interested in talking to), 2) rejection from high-value peers, 3) acceptance from low-value peers (i.e., peers that participants were not interested in talking to), and 4) rejection from low-value peers.

### EEG recording and processing.

Continuous EEG data were recorded during the Chatroom task using the 32-channel ActiCHamp from Brain Products (Brain Products, Munich, Germany), digitized at a 500 Hz sampling rate, and referenced online to FCz. Vertical and horizontal EOG data were recorded, and electrode impedances were maintained below 20 K. EEG data were processed offline using EEGLAB version 2022.1 (43) and ERPLAB version 9.00 (44) toolboxes in MATLAB version r2022b. Independent component analysis (ICA) and automated identification (ICLabel version 1.4) was used to identify and correct for ocular artifacts prior to artifact rejection. Data were re-referenced offline using an average mastoid reference. A notch filter (60 Hz) and a second-order digital Butterworth filter with a bandpass from 0.1 to 30 Hz were applied. Trials were epoched from -200 to 2000ms and baseline-adjusted by subtracting the average amplitude for 200 ms prior to the stimulus onset (-200 to 0ms).

Stimulus-locked ERPs were averaged separately for each combination of peer value (high, low) and feedback type (acceptance, rejection). Grand averages were inspected to determine time windows to be extracted (see Figure 1B). Time windows were chosen based on those windows which showed substantial difference between condition, and/or were consistent with prior literature (31,32,45). For the N1, a time window of 50-150ms was used, for the RewP: 150-275ms, and for the P300: 275-425ms. Mean amplitude within each time window was computed at Cz electrode. Because this is the first study to examine ERP components of the Chatroom task, we sought to use the same electrode for all ERP components for consistency. Twelve subjects were excluded for having too few clean trials following artifact rejection. This resulted in a sample of N= 172 with clean N1 data, 159 with clean RewP data, and N= 161 with clean P300 data.

### Ecological momentary assessment (EMA).

Ecological momentary assessment data was collected using the Effortless Assessment of Risk States (EARS) app (46,47). For seven days after consenting into the study, participants received three notifications each day prompting them to complete a set of 11-items regarding their current mood and social interactions. These notifications were sent between 6:30am-8:30am, 3:00pm-5:00pm, and 7:00-10:00pm. Surveys were available for 90 minutes after the initial notification and participants were able to decline answering any question. Participants were compensated $1 for every completed set of questions for a maximum of $3 per day and $21 total. Participants rated 11 items on a scale from 0 (*not at all*)-100 (*extremely*). They rated how happy, excited, supported, angry, anxious, sad, and rejected they felt. The first three were averaged into a positive affect composite, and the latter four in a negative affect composite. For both composites, list-wise deletion was used (i.e., if subjects were missing a value for “sad” their negative affect composite score was missing for that time point).

## Measures

### SES: Area Deprivation Index (ADI).

The area deprivation index (2021 version 4.0.1, 26,48) is a composite measure based on 17 dimensions of socioeconomic disadvantage including education, employment, housing quality, and poverty-related factors, all measured via the American Community Survey. Neighborhoods are determined based on block groups and are assigned a percentile from 1 to 100, where a higher percentile indicates greater levels of neighborhood disadvantage. In cases when ADI values were missing for subjects (e.g., suppression due to a high group quarter population), it was estimated using the ADI of the nearest block group with available data (often <1 mile from the original address). In cases when youth were attending college and living on college campuses, they provided their most recent non-college address; however in a few cases these addresses were outside of the USA and thus their college address was used. Of note, ADI percentile was reverse scored to create a more interpretable measure of SES (i.e., higher scores represent greater SES/lower ADI).

### Discrimination distress: Adolescent Discrimination Distress Index (ADDI).

Discrimination-related distress was measured using the Adolescent Discrimination Distress Index (ADDI, 49). The ADDI is a 15-item self-report measure that assesses the distress experienced in response to perceived racial-ethnic discrimination across institutional, educational, and peer contexts. Each item includes a statement outlining a common example of discrimination (i.e. “You were called racially insulting names”; “You were wrongly disciplined or given after-school detention”). If a participant endorses that they experienced a given type of discrimination, they are then asked to rate how much the experience upset them on a five-point Likert scale from “not at all” to “extremely”. In the current study, total scores were used, where higher scores indicate greater discrimination-related distress across contexts. Given the format of ADDI, which requires participants to endorse whether an experience occurred in order to report its severity, Cronbach’s alpha could not be measured. However, studies support its psychometric properties (49).

### Covariates.

#### Depression and anxiety symptoms: Inventory of depression and anxiety symptoms (IDAS-II).

The expanded Inventory of Depression and Anxiety Symptoms (IDAS-II, 50) is a 99-item, self-report instrument that measures the severity of depression, anxiety, and bipolar disorder symptoms over the past two weeks. Items are scored on a 5-point scale (1 = not at all; 5 = extremely). For the present study, 52-items were selected to assess current depression and anxiety symptoms. The depression and anxiety (a combination of the panic and social anxiety subscales) both demonstrated excellent internal consistency (Cronbach’s alpha = 0.94, 0.90, respectively).

#### Stressful life events and severity of stressful life events: Stress and adversity inventory (STRAIN).

The Stress and Adversity Inventory for Adolescents (STRAIN, 51) was administered to measure participants’ exposure to acute and lifetime stressors. This interview assesses exposures to 75 different stressors across 12 primary life domains (i.e. Housing, Education, Work, Treatment/Health, Marital/Partner, Reproduction, Financial, Legal/Crime, Other Relationships, Parent/Guardian, Death, Life-Threatening Situations) and five social-psychological characteristics (i.e. Interpersonal Loss, Physical Danger, Humiliation, Entrapment, Role Change/Disruption). If a participant endorses a stressor, they are then asked additional questions about its severity, frequency, timing, and duration. Based on these answers, the STRAIN produces a summary score that notes participants’ total lifetime stressor count and severity for all the acute life events and chronic difficulties experienced, with higher scores indicating more frequent stress exposure. Prior studies support the psychometric properties of the STRAIN, including excellent test-retest reliability ( = 0.90—0.95, 52,53). Given the format of the STRAIN, which requires participants to endorse whether a stressor occurred in order to report its severity, Cronbach’s alpha could not be measured. Although the STRAIN and other commonly used measures of stress life events account for some stressful life experiences, recent work suggests that they do not capture the effects of racism (54), making the STRAIN a useful measure to compare against the ADDI.

## Data analysis

### Behavioral ratings.

Omnibus ANOVAs tested whether in-task behavioral ratings varied as a function of Peer value (high, low) and Feedback type (acceptance and rejection). Post-hoc paired samples t-tests compared levels of Peer value and Feedback type. Multiple regression models (covarying for at least site, age, and sex-assigned-at-birth) tested whether behavioral ratings were associated with SES.

### ERP task effects.

Omnibus MLMs tested whether mean ERP amplitude varied as a function of Peer value (high, low) and Feedback type (acceptance and rejection). These models included random intercept effects of a) subject and b) study site.

### Multilevel multiple regression models.

#### SES related to ERP residualized scores.

For aim 1, we tested whether SES was associated with residualized scores to acceptance and rejection for each component (N1resid, RewPresid, P300resid).

#### SES moderating association between ERP and EMA measures of affect.

For aim 2, multilevel multiple regression models (MLMs) tested whether SES moderated associations between ERP amplitudes and negative/positive affect. These models included random intercept effects of subject and study site. In some models, the random effect of site accounted for so little variance (due to the fact that there were only two sites) that the model was singular (i.e., variance of the random effect was essentially zero); in these cases, site was instead included as a fixed effect (i.e., covariate). Given a positive skew and large number of zeros in the measure of negative affect, negative affect was cube-root transformed and zero-inflated Gaussian multilevel models were used. All predictors were included in both the conditional and zero-inflation portions of the model. Similar models were used to assess whether SES moderated associations between in-task behavioral ratings and negative affect.

Visual diagnostic checks for model assumptions were conducted to assure that models were accurately specified (e.g., posterior predictive checks, homogeneity of variance, normality of residuals, colinearity, and normality of random effects).

We used an identical approach to test whether SES moderated associations between mean in-task emotional response rating and negative affect.

# Results

## Behavioral ratings to peer feedback

### In-task emotional response ratings.

Omnibus MLMs showed a significant Peer value x Feedback type interaction (, 95% CI , , , see Figure 1C), such that participants rated acceptance from high-value peers (i.e., peers that they were interested in) as feeling significantly better than rejection from high-value peers (, 95% CI , , ). However, participants rated feeling more angry in response to acceptance than rejection from low-value peers (, 95% CI , , ).[[2]](#footnote-41)

Residualized scores assessing ratings to acceptance relative to ratings to rejection were not significantly associated with SES (, 95% CI [-0.27,0.10], ), nor ratings to rejection relative to ratings to acceptance (, 95% CI [-0.24,0.13], ). SES did not moderate a relationship between such scores and EMA neegative affect (Rating to acceptanceresid: =0.57, Rating to rejectionresid: =0.43).

### Post-task ratings.

During post-task debriefing, 129 participants responded ‘yes’ and 27 participants responded ‘no’ to the question “While you were doing the chatroom, did you believe that you would really be chatting with one of these people on the computer after your EEG?” (N= 3 were missing debriefing data). Given the potential for deception to affect results, we present additional analyses covarying for this in the Supplement.

## Brain responses to peer feedback

### Task effects: Feedback x Value interaction.

Omnibus MLMs showed that Peer value interacted with Feedback type to predict ERP mean amplitude for ERP components consistent with an N1 (, 95% CI , , ), RewP (, 95% CI , , ) and P300 (, 95% CI , , ). These ERP components had time courses and scalp topographies (central around Cz electrode) consistent with an N1 (50-150ms), reward positivity (RewP; 150-275ms) and P300 (275-425ms). Follow-up analyses showed that the N1 (, 95% CI , , ), RewP (, 95% CI , , ), and P300 (, 95% CI , , ) differentiated between acceptance and rejection for low-value peers. Only the RewP (, 95% CI , , ) differentiated between acceptance and rejection for high-value peers, but not the N1 (, 95% CI , , ), nor P300 (, 95% CI , , ).

### Internal consistency.

The RewP and P300 demonstrated acceptable levels of internal consistency across peer-value (high, low) and feedback conditions (acceptance, rejection), with split-half reliability () > 0.73, with particularly high reliability for the high-value peers conditions (acceptance and rejection = 0.82 and 0.82 and 0.84 and 0.83; see Supplement). The N1 did not achieve acceptable internal consistency (=0.35-0.54). Split-half reliability was considerably lower for the residualized scores, but remained comparable to other studies (RewPresid > 0.43, P300resid > 0.44) (25,55,56). See Supplement for full results.

### Dependability.

In dependability analyses, ERPs to acceptance and rejection at the Cz electrode from 150-275ms and 275-425ms achieved acceptable dependability ( 0.70) with as few as 12-13 and 11-13 trials, respectively, depending on the peer-value and feedback condition. When using all available trials–up to 25 trials per condition–,they also achieved good dependability ( 0.80; see Supplement). ERPs to acceptance and rejection at the Cz electrode from 50-150ms did not achieve acceptable dependability with any number of trials (as many as 25 per condition).

### SES.

#### SES associations with N1resid, RewPresid, and P300resid.

We found support for aim 1: SES was significantly related to brain responses to different kinds of peer feedback (see Figure 2). Specifically, lower SES was significantly related to a more blunted RewPresid (, 95% CI [0.05,0.43], ) and P300resid to acceptance from high-value peers (i.e., that the participant was interested in, , 95% CI [0.03,0.40], ). This is over-and-above site, demographic factors (e.g., age, sex assigned at birth), lifetime stressors (total stressful life events, severity of stressful life events), and self-reported psychopathology (self-reported depression, self-reported anxiety). SES was not related to RewPresid and P300resid to rejection (; , 95% CI [-0.32,0.06], , respectively). Additionally, SES was not related to RewPresid or P300resid to acceptance or rejection from *low-value* peers (i.e., that the participant was not interested in, 0.31). Results are consistent when also covarying for self-reported deception (see Supplement).

#### SES moderates association between RewPresid/P300resid and negative affect.

We also found support for aim 2: SES significantly moderated the relationship between RewPresid to acceptance and negative affect (=0.12, 95% CI=[0.01, 0.24], =0.04), as well as P300resid to rejection and negative affect (=-0.13, 95% CI=[-0.27, 0], =0.05, see Figure 3). The SES x P300resid rejection interaction remained significant even when accounting for positive affect as a fixed effect covariate (=-0.14, 95% CI=[-0.27, -0.02], =0.03). These effects were consistent when covarying for deception (see Supplement).

SES did *not* moderate the relationship between RewPresid to rejection and negative affect (=-0.11, 95% CI=[-0.22, 0], =0.06) nor P300resid to acceptance and negative affect (=0.12, 95% CI=[-0.02, 0.26], =0.08).

SES also did not moderate the relationship between RewPresid to acceptance and positive affect (=-0.09, 95% CI=[-3.5, 3.33], =0.96) , nor between P300resid to rejection and positive affect (=-1.71, 95% CI=[-5.64, 2.21], =0.39).

Follow-up simple slope analyses shed additional light on this relationship. While no simple slopes were significant for the SES x RewPresid interaction ( 0.12), there was a significant simple slope for the SES x P300resid such that lower SES adolescents showed a positive relationship between P300resid to rejection and subsequent negative affect (slope = 0.24, =0.01). That is, youth with lower SES show a potential, specific vulnerability to heightened rejection sensitivity leading to greater negative affect.

### Discrimination distress.

Greater self-reported discrimination distress was also related to a more blunted RewPresid (, 95% CI , , ) and P300resid (, 95% CI , , ) to acceptance. However, these results are considered preliminary since only 29 (18.12%) participants reported having experienced *any* form of discrimination.

### Race/Ethnicity.

Finally, we examined whether RewPresid or P300resid differed by Hispanic ethnicity or participant reported race, given that racial/ethnic minority youth are at greater likelihood of being discriminated against. We did not find significant differences for Hispanic ethnicity (, 95% CI [-0.42,0.25], , , 95% CI [-0.42,0.25], , respectively), nor minority race (, 95% CI [-0.39,0.26], , , 95% CI [-0.36,0.29], , respectively).

# Discussion

The current study found not only that SES is related to a pattern of blunted neural responses to peer acceptance, but also that SES moderated an association between neural rejection sensitivity and negative affect. Specifically, youth lower in SES showed a positive relationship whereby greater neural rejection sensitivity was associated with greater daily experiences of negative affect. We also found some preliminary evidence that experiences with discrimination may be driving the associated between SES and blunted neural responses to acceptance. These findings build on prior literature, with clear implications for basic and clinical science.

## Psychometric support for RewP and P300 in novel ERP task

First, these findings extend previous research detailing how the brain responds to social feedback. At a group level, we have shown that an fMRI task of neural responses to social feedback—the Chatroom task (41,57)—yields the expected ERP components: RewP and P300. These components have been identified in other studies of social feedback (22,25,58,59). Like other studies, we also found that ERPs to acceptance were significantly greater than to rejection in the RewP time window, whereas ERPs to acceptance and rejection did not significantly differ within the P300 time window (25,32). Moreover, these components show acceptable psychometrics (split-half reliability/internal consistency and dependability). Finding that the RewP and P300 occur across this and other social feedback tasks speaks to the generalizable role of these components in responding to rewarding and salient feedback, respectively. We also demonstrate functional specificity: the task is eliciting specific processes and not brain-wide differences. We do this by showing that ERPs to acceptance and rejection within the N1 time window do not significantly differ from each other and have low internal consistency and dependability.

## Linking SES to depression risk

Second, at the individual level, we replicate and build on a prior study from an independent sample (25) showing that lower SES is related to a more blunted RewP *and* a more blunted P300 to peer acceptance among adolescents. This is a conceptual replication, since we used a 1) different measure of SES (income-to-needs) and 2) different EEG task (Island Getaway) than the current study. Both studies used independent samples from different parts of the country, however, both samples were clinically enhanced for depression.

Third, and most novel, we provide evidence of one potential mechanism through which youth SES may lead to heightened risk for internalizing disorders in adolescence. Our findings point to a pathway through which growing up in a low SES environment (e.g., neighborhood) may make youth *less* sensitive to positive, rewarding social feedback and *more* sensitive to threatening negative social feedback, relative to their higher SES peers. This pattern of brain activity may lead to greater daily negative affect. Chronic experiences of negative affect may in turn lead to depression. Indeed, in separate studies, depressed youth often exhibit a blunted response to social acceptance, and anxious youth a heightened response to social rejection (though see (60) and (61) for examples of social anxiety being related to *enhanced* response to social acceptance too). Because this data cannot determine the causal direction between SES, brain responses to peer feedback, and daily negative affect, we do not know whether changes in brain responsivity lead to daily negative affect or vice versa. However, prior research supports this theoretical pathway. Other studies have found that low SES leads to changes in the way youth report on their relationships (8,10), and that clinical levels of social anhedonia and rejection sensitivity is related to greater depression (62–64). Moreover, it is highly unlikely that brain responses or symptoms lead to changes in a youth’s SES. Thus, these findings outline one intriguing explanation of how  youth SES may lead to adolescent depression.

## Linking SES to depression risk via discrimination experiences

Fourth, we provide preliminary evidence as to what aspect(s) of SES are risk factors for psychopathology. The findings with self-reported discrimination support one theory: that interpersonal stressors associated with low SES, such as being discriminated against, may lead to reduced hedonic brain responses to peer acceptance and heightened threat-sensitive responses to peer rejection. This is supported by evidence that youth in deprived areas are more likely to be subjected to structural discrimination targeting racial and ethnic minorities and those in poverty (5,6,37), and that discrimination experiences are related to heightened neural threat sensitivity (65).

That being said, low SES is an extremely heterogeneous construct; however, there is additional evidence that social stressors such as discrimination may be one of the most powerful aspects of low SES linking it to psychopathology. For example, lower perceived social status is related to psychiatric disorders *over-and-above* other, non-social aspects of of SES (1), and traumatic stressful events show larger effect sizes in predicting psychopathology compared to low neighborhood SES (66). Moreover, other experiences with rejection, such as experiences being bullied have been tied to blunted responses to peer acceptance (67). Hostile and/or rejecting experiences early in life may lead to children becoming understandably sensitive to perceived rejection and skeptical of acceptance.

Clinically, these findings suggest that prevention and intervention focused on increasing hedonic responses to acceptance and reducing rejection sensitivity in safe, non-threatening situations may alleviate psychopathology. For example, short-term solutions may include helping youth heal from racial trauma (e.g., 68), or interventions aimed at cultivating positive peer interactions (69). Longer-term solutions may involved systemic interventions focused on reducing instances of discrimination (70).

## Behavioral findings

We also examined participants’ ratings of their happiness and anger after receiving feedback, to determine whether these ratings showed similar patterns to brain responses. As expected and similar to the RewP condition effects, youth rated high value acceptance as eliciting more happiness and less anger than rejection. However, SES was unrelated to behavioral ratings: all subjects uniformly rated feeling better after being accepted and worse after being rejected (by high-value peers). SES also did not moderate associations between behavioral ratings and negative affect. This suggests that the relationship between SES, response to peer  acceptance/rejection, and negative affect may be more implicit than explicit (i.e., youth are not aware that they are less sensitive to acceptance/more sensitive to rejection).

## Limitations

The current study must be considered in light of its limitations. First, although the area deprivation index provides a rich measure of the neighborhood youth are currently living, it does not capture other areas where they spent significant time (e.g., school, socializing, after school activities). Likewise, we do not know how long youth had been living at this address. Although it is possible that some youth had recently moved to this address, it is unlikely that their neighborhood SES drastically changed as a result of moving, due to low upward mobility in the USA (71). Second, we extracted all ERP components from the same electrode (Cz). It is possible that our findings could have differed had we used different electrodes for each component (e.g., Fz for N1, Pz for P300) or a combination of electrodes (e.g., Pz, POz, Cz for P300). Third, we did not examine how the perceived race or ethnicity of the peers giving feedback impact brain responses to feedback. Half of feedback came from peers perceived to be white, while the other half came from peers perceived to be non-white. Thus, we were unfortunately under-powered to test whether peer perceived race or ethnicity interacted with brain responses. Future versions of this and other social feedback tasks with more trials from peers of different racial and ethnic backgrounds will be key to more rigorously testing for racial or ethnic group differences.

This study has clear implications for basic and clinical research. Neuroimaging and psychophysiological studies should also collect data related to participants’ background, including their socioeconomic status and/or area deprivation. More and more studies are finding that such aspects are key moderators (72). Given that low SES is an established risk factor for psychopathology, accounting for it in analyses will help assure that findings examining neural mechanisms of psychopathology are not influenced by a large potential third-variable. Moreover, doing so will further our understanding of how low SES confers such large risk for psychopathology. In the absence of systemic changes in public policy to lift children out of poverty, targeted solutions are needed to support these youth.

# Figures

Figure 1. A) Example of trial from chatroom task. B) Grand average ERP for acceptance and rejection feedback from high-value peers. Colored sections of the graph represent time windows where ERP components were extracted at Cz electrode: N1 = purple, RewP = orange, P300 = blue. C) Mean in-task, post-feedback ratings across all participants by Feedback (acceptance, rejection) and Value (high, low).

Figure 2. A) Relationship between SES and brain responses to acceptance (relative to rejection) for both the RewP and P300 ERP components. B) Interactions for which SES significantly moderated associated between brain responses to acceptance/rejection and negative affect. A: no simple slopes significant. B: Simple slope significant for SES -1 standard deviation below the mean.

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1. Due to sociological factors including systemic oppression of racial minorities, racial minority youth tend to be poorer and also more discriminated against than racial majority youth (35,36). [↑](#footnote-ref-21)
2. This somewhat surprising/counter intuitive finding is discussed further in the Supplement. [↑](#footnote-ref-41)