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BRIEF REPORT

Risk for youth anxiety during the COVID-19 pandemic: The interactive impact of financial stress and prepandemic electrocortical reactivity to negative self-referential stimuli

Cope Feurer | **Maria Granros** | **Alison E. Calentino** | **Jennifer H. Suor** | **Katie L. Burkhouse**

Department of Psychiatry, University of Illinois at Chicago, Chicago, Illinois, USA

Correspondence
Cope Feurer, Department of Psychiatry, University of Illinois at Chicago, Chicago, IL 60612, USA.
Email: feurer@uic.edu

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Abstract

Despite evidence that stress exposure increases risk for internalizing symptoms in youth, it remains unclear which youth are most vulnerable. This study examined whether youth's prepandemic late positive potential (LPP), an electrocortical marker of sustained attention to affective stimuli, exacerbated the impact of stress on prospective increases in depression and anxiety symptoms from before to during the COVID-19 pandemic. Participants were 29 youth (ages 9–16, 82.8% girls) who completed depression and anxiety symptom measures and an affective words task to assess LPP to positive and negative self-referential stimuli prepandemic onset. Postpandemic onset, approximately 16.03 months ($SD = 8.86$) after their baseline assessments, youth again completed symptom measures as well as the UCLA Life Stress Interview to assess ongoing social and financial chronic stress. Results indicated a significant interaction between youth LPP to negative words and financial stress. Greater exposure to financial stress during the pandemic predicted greater anxiety symptom increases specifically for youth who demonstrated enhanced prepandemic LPP to negative words. Results were specific to the prediction of anxiety, but not depression, symptoms. If replicated in larger studies, findings highlight enhanced LPP to negative stimuli as a promising target for intervention for youth exposed to greater financial stress.

KEYWORDS
anxiety, COVID-19, event-related potentials, late positive potential, stress

1 | INTRODUCTION

It is well established that the experience of stress increases risk for youth depression and anxiety (Allen et al., 2008; Grant et al., 2003; Griffith et al., 2020). However, questions remain regarding which youth are at highest risk for depression and anxiety within the context of increased stress. Of note, the COVID-19 pandemic has represented a unique period of stress for youth as the unprecedented implementation of school closures, social-distancing mandates, and widespread job loss have contributed to increased levels of social and financial stress for many youth across the globe (Ellis et al., 2020; Magson et al., 2021). Therefore, the COVID-19 pandemic may provide a unique opportunity to examine how preexisting vulnerabilities may exacerbate the impact of stress exposure on prospective risk for internalizing symptoms in youth.

Cognitive models of depression and anxiety propose that the way in which individuals attend to, interpret, and remember negative affective stimuli increases their risk for internalizing disorders, specifically within stressful contexts (e.g., Clark & Beck, 2010). Therefore, indices of information processing biases may provide important insight into

who is at greatest risk within the context of elevated stress. One such index is the late positive potential (LPP), an event-related potential (ERP) derived from electroencephalography (EEG) emerging approximately 400 ms after stimulus onset (Dennis & Hajcak, 2009; Schupp et al., 2000). LPP response to affective stimuli correlates with activation of neural regions involved in the processing of emotional stimuli (Liu et al., 2012) and indexes sustained attention toward emotionally salient information (Dennis & Hajcak, 2009; Schupp et al., 2000). Consistent with cognitive models of internalizing disorders, research shows that greater sustained attention towards negative stimuli contributes to increased emotional response to stress (Joormann & Vanderlind, 2014), suggesting that the LPP may be relevant to the emergence of internalizing symptoms in youth, particularly within stressful contexts.

The LPP has been linked to both anxiety and depression. An enhanced LPP in response to negative stimuli is associated with anxiety disorders across development (e.g., Burkhouse et al., 2015; Kinney et al., 2019; Kujawa et al., 2015), although its directional relationship with depression has been more mixed (for a review, see Kujawa & Burkhouse, 2017). For instance, some studies have identified an enhanced LPP response to emotional images or self-referential words among adolescents with depression (Auerbach et al., 2015; Burkhouse et al., 2017), while other work indicates that depressed adults (Weinberg et al., 2016) and offspring of depressed mothers (Kujawa et al., 2012), a population at elevated risk for depression, exhibit an attenuated LPP to emotional stimuli.

Furthermore, research also suggests that the LPP interacts with stress exposure to predict internalizing symptoms. For example, stress exposure has been shown to confer risk for depressive symptoms in youth (Levinson et al., 2019) and undergraduate women (Sandre et al., 2019), demonstrating an attenuated LPP to positive stimuli. Additionally, a recent study of college undergraduates found that interpersonal stress during the COVID-19 pandemic was associated with pandemic-related increases in depression symptoms for young adults who exhibited blunted LPP to positive interpersonal stimuli prior to the pandemic onset (Dickey et al., 2021b). In the same study, greater interpersonal stress also predicted increases in traumatic intrusion symptoms for undergraduates exhibiting an enhanced LPP to threatening interpersonal stimuli, suggesting that individuals exhibiting diminished attention to positive stimuli or greater attention to negative stimuli prepandemic were at greatest risk for increases in internalizing symptoms if exposed to increased stress during the pandemic.

Despite this emerging evidence that LPP to affective stimuli exacerbates the impact of stress on internalizing risk, some limitations remain. First, no studies have examined LPP as a moderator of the impact of stress on youth anxiety symptoms. Importantly, late childhood and adolescence are marked by significant changes in neurobiological sensitivity to affective stimuli due to mismatched timing in the maturation of subcortical and prefrontal neural regions in this developmental window (Somerville et al., 2010). Correspondingly, the LPP to affective stimuli decreases across adolescence into the transition to adulthood (Dickey et al., 2021a; MacNamara et al., 2016), therefore highlighting the need to examine whether results are reproduced in youth samples when affective reactivity is enhanced. Second, prior studies investigating LPP and stress relations have focused solely on LPP response to affective images, potentially reflecting sustained attention towards external, environmental stimuli. Although cognitive models also highlight negative self-schema as an important diathesis that contributes to internalizing risk in the presence of stress exposure (e.g., Clark & Beck, 2010), LPP to affective self-referential stimuli (i.e., stimuli with relevance to oneself) has not been examined within this context.

To address these outstanding gaps in the literature, the current study examined LPP to self-referential stimuli as a moderator of youth stress exposure during the COVID-19 pandemic on increases in anxiety and depression. The current study capitalized on a sample of youth who completed prepandemic electrocortical assessments of affective functioning and internalizing symptoms. We hypothesized that prepandemic LPP to self-referential stimuli would moderate the impact of social and financial stress on prospective increases in youth depression and anxiety symptoms during the pandemic. Specifically, we predicted that enhanced LPP to negative self-referential stimuli would moderate the impact of stress on prospective increases in anxiety symptoms. However, given the previously described mixed literature with LPP and depression, we did not have specific hypotheses regarding the direction of the LPP relation for changes in depression symptoms.

2 | METHODS

2.1 | Participants

Participants were 29 youth who were enrolled in one of two larger studies on the intergenerational transmission of depression prior to the onset of the COVID-19 pandemic. Youth recruited from the first study ($n = 10$) were girls between the ages of 12 and 16 and youth recruited from the second study ($n = 19$) were children between the ages of 9 and 15. Youth and their mothers were recruited from the community based on their mothers' lifetime history of major depressive disorder (MDD). Inclusion criteria for the high risk (HR) group for both studies was a maternal history of MDD (recurrent MDD in the first study, at least a single episode of MDD in the second study). To be included in the low risk (LR) group, youths' mothers were required to be lifetime free of any DSM-5 psychiatric disorder. Exclusionary criteria for all participants across both studies were neurological disorders, traumatic brain injury, active suicidal ideation, lifetime history of bipolar disorder, schizophrenia, or psychosis, or current alcohol and/or substance use disorder in the past 6 months. Additionally, girls in the first study were required to be lifetime-free of MDD and children in the second study were excluded if they had a current MDD diagnosis. Youth average age in the current study was 12.59 ($SD = 2.37$; range = 9–16), 82.8% of youth identified as girls, and 17.2% identified as boys. Regarding youth racial identity, 58.6% identified as White, 17.2% as Black, 10.3% as Asian, and 13.9% as multiracial or another race. Additionally, 27.6% of youth were Hispanic or Latinx.

2.2 | Procedures

Prior to the onset of the COVID-19 pandemic, youth and their mothers were recruited from the community using flyers, mass emails, and social media advertisements. Interested participants were screened over the phone for eligibility prior to being invited to participate in the study. Mothers were administered the structured clinical interview for DSM-5 (First et al., 2015), and youth were administered the Schedule for Affective Disorders and Schizophrenia for School Age Children (Kaufman et al., 2016) to assess lifetime psychiatric history of DSM-5 disorders to confirm eligibility for the study. In the current sample, 15 mothers had a lifetime history of MDD (HR group) and 14 mothers had no lifetime history of MDD (LR group). Additionally, at baseline, youth were administered questionnaires to assess depression and anxiety symptoms and completed an affective words computer task during which continuous EEG was collected.

Following the onset of the COVID-19 pandemic and the implementation of pandemic-related lockdowns, participants were recontacted and invited to participate in a virtual follow-up assessment. These assessments occurred between June and September of 2020, approximately 16.03 months ($SD = 8.86$) after participants' baseline assessments. Youth completed the same depression and anxiety symptom measures that were completed at baseline. Additionally, youth and their mothers completed a semistructured interview to assess chronic stress. Mothers and youth were compensated for their participation in the study, and all study procedures were approved by the University of Illinois at Chicago Institutional Review Board. Informed consent and assent were obtained from mothers and youth, respectively, at each assessment.

2.3 | Clinical measures

Youth's depression and anxiety symptoms were assessed at both timepoints using the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977) and the Screen for Child Anxiety Related Disorders (SCARED; Birmaher et al., 1999), respectively. The CES-D is a 20-item self-report measure of depressive symptoms. The SCARED is a 41-item self-report measure of anxiety symptoms.

2.4 | Affective words task

Youth completed a self-referential affective words task at the baseline laboratory assessment to assess LPP response to affective stimuli. During this task, youth viewed positive (e.g., adorable, smart) and negative (e.g., stupid, lazy) words on a computer screen. These words were selected from the validated Affective Norms for English Words stimulus set (Bradley & Lang, 1999) and have been used to elicit the LPP in response to self-referential stimuli in other adolescent samples (e.g., Auerbach et al., 2015; Speed et al., 2016). The task included 40 trials (20 negative words, 20 positive words). For each trial, participants viewed a word presented on the screen for 2000 ms and then indicated whether they would use this word to describe themselves as well as if their mother has ever used this word to describe them. A new trial immediately began after the behavioral response with no intertrial interval or fixation between trials.

2.5 | EEG data collection and processing

Continuous EEG data were recorded throughout the affective words task with the ActiveTwo BioSemi system (BioSemi, Amsterdam, The Netherlands). An elastic cap with 34 standard electrode sites was used (including Fz and Iz), based on the 10/20 system, along with one electrode on each mastoid. Four additional facial electrodes were placed on participants for electrooculogram recordings generated from eye blinks and eye movements (two electrodes were placed 1 cm above and below the right eye to measure vertical eye blinks and movements, and two electrodes were placed 1 cm beyond the outer edge of each eye to measure horizontal eye blinks and movements). The data were digitized at 24-bit resolution with a cutoff of 1024 Hz.

Offline data analyses were performed with BrainVision Analyzer 2 software (Brain Products, Gilching, Germany). EEG data were re-referenced offline to the average of the mastoids and band-passed filtered with low-pass of 0.01 Hz and high-pass of 30 Hz. Data were segmented beginning 200 ms prior to stimulus presentation and continuing for 2000 ms after stimulus presentation. For each trial, baseline correction was performed using the 200 ms before stimulus presentation. Eye blink and ocular corrections followed the method of Gratton et al. (1983). Standard artifact analysis procedures were used, identifying a voltage step of more than 50 μV between sample points, a voltage difference of 300 μV within a segment, and a maximum voltage difference of less than 0.50 μV within 100-ms intervals. Additionally, trials were inspected visually and data from individual channels with remaining artifacts were removed on a trial-to-trial basis.

Temporospatial principal component analysis (PCA) was conducted utilizing the ERP PCA toolkit (Version 2.95) (Dien, 2010b) to localize the LPP. Youth were retained for analysis if they had at least eight artifact-free trials for all electrodes, and unusable electrodes were interpolated. Consistent with recommendations, temporal PCAs were conducted first using Promax rotation (Dien, 2010a), using all time points as variables and all youth, task conditions (i.e., negative and positive words), and electrodes as observations. Based on the resulting scree plot (Cattell, 1966), 27 temporal factors were extracted. Next, spatial PCA was performed on the extracted temporal factors using Infomax rotation (Dien, 2010a), using all electrodes as variables and all youth, task conditions, and temporal factors as observations. Based on the resulting scree plot, two spatial factors were extracted. Results of the PCA yielded two temporospatial factors (TFSF) that resembled the LPP (Foti et al., 2009). Of note, though the LPP is often observed at parieto-occipital sites in youth when viewing affective images (Burkhouse et al., 2017; Kujawa et al., 2013), the LPP to words during self-referential processing is localized to fronto-central electrodes in both youth (Allison et al., 2021; Auerbach et al., 2015) and adults (Dainer-Best et al., 2017). TF2SF1 accounted for 10.25% of the variance and

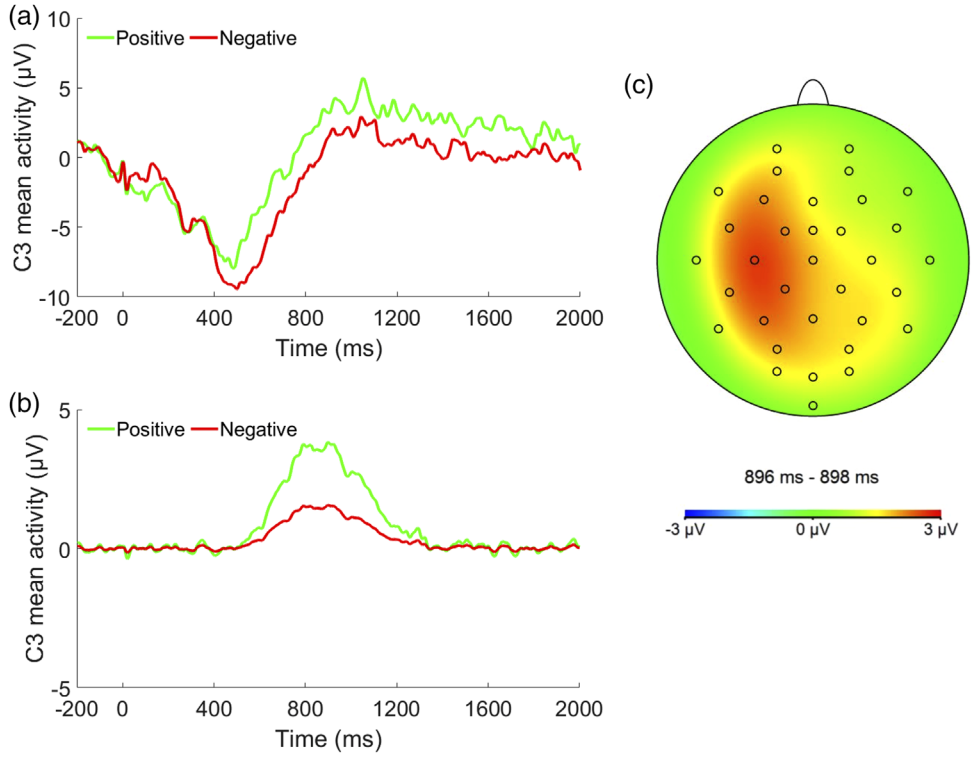

FIGURE 1 (a) Raw event-related potential waveforms depicting the late positive potential in response to negative and positive words at electrode C3. (b) Waveforms and (c) topography for PCA-derived temporospatial factor TF2SF1

showed peak positivity at 897 ms and electrode C3, whereas TF4SF1 accounted for 2.87% of the variance and showed peak positivity at 1243 ms and electrode CP1. Split-half reliability was acceptable for TF2SF1 (negative: .73, positive: .52), but unacceptably low for TF4SF1 (negative: .24, positive: −.04). Therefore, only TF2SF1 was extracted for subsequent analysis (Figure 1).

2.6 | Chronic stress

At the COVID-19 assessment, youth and their mothers were administered the UCLA Life Stress Interview (LSI) to assess for current levels of objective chronic stress across a variety of domains of functioning. The LSI was modified for the current study to focus on chronic stress experienced specifically within the time frame of the pandemic, rather than across a prolonged window (e.g., 6 months). Youth were administered the peer, mother–child, and other-family (i.e., other household family members) sections of the UCLA LSI for Children (Adrian & Hammen, 1993) to assess overall objective levels of functioning within social domains. The academic and behavioral sections of the LSI were not administered to youth to decrease participant burden. Mothers were administered the financial section of the adult UCLA LSI (Hammen et al., 1987) to assess overall familial financial stress. For each domain, interviewers assigned a chronic stress severity rating on a scale of 1 ("superior functioning") to 5 ("severe stress") based on obtained objective contextual information about functioning within that domain. Therefore, chronic stress severity rating scores reflect objective chronic strain rather than subjective perceptions of stress. Consistent with previous studies utilizing the LSI (Vrshek-Schallhorn et al., 2015), the social stress domains (i.e., peer, mother–child, and family) were averaged together to create a social stress composite score. Ten interviews were coded by two independent raters to assess inter-rater reliability for stress severity scores, yielding excellent intraclass correlations for all domains (ICCs: 0.85—0.97).

2.7 | Analytic plan

Participants were included in the current study if they completed the COVID-19 follow-up assessment and had usable LPP data at baseline. Although there were missing data for baseline anxiety symptoms for two participants (i.e., baseline SCARED: 6.9%,), results for Little's missing completely at random (MCAR) test were not significant $\chi^2(36) = 35.84$, $p = .48$, thereby justifying the use of imputation methods (i.e., expectation maximization) for the estimation of missing values (cf. Schafer & Graham, 2002).

A series of hierarchical regression analyses were conducted to examine the impact of youth baseline LPP, follow-up chronic stress, and their interaction on prospective increases in youth depression and anxiety symptoms from before to after the onset of the COVID-19 pandemic. In the first step of the regression, youth risk status (HR vs. LR), baseline symptoms, mean-centered baseline LPP, and mean-centered follow-up chronic stress were entered as predictors. The LPP × chronic stress interaction was entered at the second step. Analyses

were repeated separately for both forms of stress (i.e., social and financial) and for both LPP conditions (i.e., negative and positive words) in the prediction of follow-up depression and anxiety symptoms. To test the robustness of any significant findings, analyses were repeated controlling for a series of covariates including child age, gender, racial and ethnic identity (White, non-Latinx identity: yes vs, no), and time since the baseline assessment. Additionally, as five youth completed a group preventative intervention prior to the pandemic as part of the larger study from which they were recruited, we also statistically controlled for the influence of group intervention status (received intervention: yes vs. no) as a test of robustness.

3 | RESULTS

3.1 | Descriptive statistics

Descriptive statistics and correlations among study variables are presented in Table 1. Youth follow-up depression symptoms were positively associated with follow-up social stress. Additionally, youth baseline LPP to negative words was negatively associated with follow-up social stress, such that greater LPP was associated with better overall social functioning.

3.2 | Primary analyses: Depression symptoms

Results for analyses examining the impact of youth baseline LPP, follow-up chronic stress, and their interaction on prospective increases in depression symptoms from before to during the COVID-19 pandemic are presented in Table 2. Results indicated a main effect of social stress, such that greater follow-up social chronic stress predicted increases in depression symptoms for models examining either baseline LPP to positive, $\beta = .38$, $t(24) = 2.09$, $p = .048$, or negative, $\beta = .50$, $t(24) = 2.32$, $p = .029$, words. None of the main or interactive effects of youth LPP were significantly associated with changes in youth depression symptoms. Due to a potential suppressor effect in the model including both LPP to negative words and social stress, evidenced by a sign change in the coefficient for LPP in the prediction of follow-up depression symptoms compared to correlation analyses, analyses were reconducted examining the main effects of LPP to negative words and social stress separately. Results were maintained, such that there was a positive main effect of social stress on increases in depressive symptoms, $\beta = .41$, $t(25) = 2.42$, $p = .023$, but the main effect of LPP to negative words was not significant, $\beta = -.17$, $t(25) = -0.85$, $p = .40$.

3.3 | Primary analyses: Anxiety symptoms

Analyses were repeated with anxiety symptoms to examine the impact of youth baseline LPP and follow-up chronic stress on prospective increases in anxiety symptoms from before to during the COVID-19 pandemic (see Table 2). Again, there was a positive main effect of follow-up social stress on prospective increases in anxiety symptoms for models examining either LPP to positive, $\beta = .30$, $t(24) = 2.24$, $p = .034$, or negative, $\beta = .47$, $t(24) = 3.18$, $p = .004$, words. Additionally, a main effect of LPP to negative words was observed when statistically controlling for the influence of social stress, $\beta = .45$, $t(24) = 2.72$, $p = .012$, but not financial stress, $\beta = .12$, $t(24) = 0.73$, $p = .47$. Follow-up analysis excluding social chronic stress as a covariate did not indicate a main effect of LPP to negative words on anxiety symptoms, $\beta = .14$, $t(25) = 0.91$, $p = .37$.

There was also a significant interaction between baseline LPP to negative words and follow-up financial stress, $\beta = .44$, $t(23) = 3.85$, $p < .001$. Simple slopes analysis indicated that greater financial stress was associated with increases in anxiety symptoms at the COVID-19 follow-up assessment for youth who exhibited greater (+1 *SD*) LPP to negative words at the baseline assessment, $\beta = .53$, $t(23) = 3.33$, $p = .003$, but was unrelated to anxiety symptoms for youth who exhibited lesser (−1 *SD*) LPP to negative words, $\beta = -.32$, $t(23) = -1.97$, $p = .06$. Next, a series of follow-up analyses were conducted to test the robustness of findings. Financial stress continued to be positively associated with anxiety symptoms at the COVID-19 assessment for youth who exhibited greater (+1 *SD*) LPP to negative words when independently statistically adjusting for the influence of youth age, $\beta = .57$, $t(22) = 3.15$, $p = .005$, gender, $\beta = .54$, $t(22) = 3.69$, $p = .001$, racial/ethnic identity, $\beta = .54$, $t(22) = 3.24$, $p = .004$, time since baseline assessment, $\beta = .55$, $t(22) = 3.38$, $p = .003$, and group intervention status, $\beta = .54$, $t(22) = 3.17$, $p = .004$.

4 | DISCUSSION

The goal of the current study was to identify whether LPP to affective self-referential stimuli exacerbated the impact of stress exposure on prospective increases in internalizing symptoms during the COVID-19 pandemic. Partially consistent with hypotheses, results indicated that increased financial stress predicted greater increases in anxiety symptoms during the pandemic for youth who demonstrated enhanced LPP to negative words prior to the pandemic onset. This finding was maintained after statistically adjusting for the influence of youth demographic characteristics and time since baseline assessment, suggesting that findings were, at least partially, independent of these influences. Additionally, results were specific to the prediction of anxiety symptoms; no significant interactions between LPP and stress predicted pandemic-related changes in depression symptoms. Finally, results indicated a main effect of social stress on prospective increases in both anxiety and depression symptoms. Although a prior study utilizing an overlapping subsample of the current study did not observe a main effect of social stress on depression symptoms (Feurer et al., 2021), this may have been due to examining social stress within specific domains (i.e., peer, mother–child, family) in the prior study rather than overall social functioning across domains.

The current pattern of results regarding the relation between LPP and prospective anxiety risk is consistent with prior research. Prior

TABLE 1 Descriptive statistics and correlations among study variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Youth age	–											
2. Youth gender (% girls)	.47*	–										
3. Youth race/ethnicity (% non-Latinx White)	−.32	−.21	–									
4. Risk status (% HR)	−.14	−.08	−.10	–								
5. T1 CES-D	.14	−.07	−.34	.11	–							
6. T2 CES-D	−.07	.23	−.31	.23	.36	–						
7. T1 SCARED	.16	.18	−.28	.31	.54**	.55**	–					
8. T2 SCARED	−.02	.40*	−.08	.17	.25	.67***	.72***	–				
9. LPP: Positive	.09	.11	.31	−.41*	−.10	−.31	.04	.17	–			
10. LPP: Negative	.23	.38*	.07	−.44*	−.04	−.23	.10	.21	.70***	–		
11. Social stress	−.26	−.01	.12	.12	.21	.48**	−.12	.13	−.35	−.59**	–	
12. Financial stress	−.03	.11	−.15	.12	−.08	.25	.31	.34	.07	.19	−.17	–
Mean (*SD*)	12.59 (2.37)	82.8%	37.9%	51.7%	10.28 (6.45)	13.41 (9.57)	22.32 (14.46)	21.24 (11.99)	3.82 (7.58)	1.56 (9.13)	2.20 (0.42)	2.76 (0.66)

Note: Social Stress = Chronic stress composite score comprising peer, mother–child, and family stress.

Abbreviations: CES-D , Center for Epidemiological Studies Depression Scale; HR, high risk (i.e., youth with a maternal history of major depressive disorder); LPP, late positive potential (TF2SF1); SCARED, Screen for Child Anxiety Related Disorders.

*$p < .05$; **$p < .01$; ***$p < .001$.

TABLE 2 LPP, chronic stress, and their interaction predicting depression and anxiety symptoms

Prediction of Depression Symptoms						
LPP to Positive Stimuli						
	Social Stress			**Financial Stress**		
	β	R^2	ΔR^2	β	R^2	ΔR^2
Step 1		.33*	.33*		.29	.29
Baseline CES-D	.25			.35		
Risk Status	.11			.04		
Stress	.38*			.30		
LPP: Positive	-.10			-.27		
Step 2		.40*	.07		.37	.08
Stress × LPP	.31			.33		
LPP to Negative Stimuli						
	Social Stress			**Financial Stress**		
	β	R^2	ΔR^2	β	R^2	ΔR^2
Step 1		.34*	.34*		.29	.29
Baseline CES-D	.23			.37*		
Risk Status	.21			.03		
Stress	.50*			.33		
LPP: Negative	.17			-.27		
Step 2		.41*	.07		.30	.01
Stress × LPP	.35			.10		
Prediction of Anxiety Symptoms						
LPP to Positive Stimuli						
	Social Stress			**Financial Stress**		
	β	R^2	ΔR^2	β	R^2	ΔR^2
Step 1		.62***	.62***		.55**	.55**
Baseline SCARED	.74***			.68**		
Risk Status	.01			.004		
Stress	.30*			.13		
LPP: Positive	.25			.14		
Step 2		.62***	.00		.62***	.07
Stress × LPP	.03			.31		
LPP to Negative Stimuli						
	Social Stress			**Financial Stress**		
	β	R^2	ΔR^2	β	R^2	ΔR^2
Step 1		.67***	.67***		.55**	.55**
Baseline SCARED	.70***			.67**		
Risk Status	.10			.003		
Stress	.47**			.11		
LPP: Negative	.45*			.12		
Step 2		.72***	.05		.72**	.18**
Stress × LPP	-.29			.44***		

Note: Risk Status = Maternal history of major depressive disorder (1 = high risk, 0 = low risk).
Abbreviations: CES-D, Center for Epidemiological Studies Depression Scale; LPP, late positive potential (TF2SF1); SCARED, Screen for Child Anxiety Related Disorders.
*$p < .05$; **$p < .01$; ***$p < .001$.

studies have observed a cross-sectional relation between LPP to negative stimuli and anxiety across development (Kinney et al., 2019; Kujawa et al., 2015). The current study extends this research by showing that enhanced LPP to negative words during a self-referential processing task exacerbates the impact of stress on prospective increases in anxiety symptoms in youth. Although no studies have examined LPP to self-referential affective stimuli as a moderator of the impact of stress in youth, findings converge with a recent study showing that greater bias for negative self-referential stimuli predicts greater anxiety symptoms for undergraduate students during periods of elevated stress (Tracy et al., 2021). Current findings also align with a recent study that showed greater stress experienced during the COVID-19 pandemic predicted increases in traumatic intrusions for undergraduate students who exhibited greater prepandemic LPP to threatening interpersonal images (Dickey et al., 2021b). Importantly, despite examining LPP to different stimuli (i.e., interpersonal images vs. self-referential emotional words) and different forms of stress (i.e., perceived severity of interpersonal stressful events vs. interviewer-rated objective chronic stress), the current study replicates these findings and extends them to a youth sample. Together, these findings provide promising evidence that individuals who exhibit greater LPP to multiple forms of negative stimuli may be at increased risk for anxiety within the context of elevated stress exposure.

Of note, the interaction between LPP to negative words and stress was specific to financial, and not social, chronic stress. The relation between financial stress and anxiety risk is not surprising, given the severe financial repercussions of the COVID-19 pandemic and widespread job loss that has been experienced by families across the country (Bureau of Labour Statistics, 2020), coupled with prior evidence that financial stress is associated with anxiety risk in youth (Melchior et al., 2010; Najman et al., 2010). However, the lack of interaction with social stress was surprising, as interpersonal stress has been shown to predict pandemic-related anxiety symptoms (i.e., traumatic intrusions) among emerging adults exhibiting enhanced LPP to negative images (Dickey et al., 2021b). Given the small sample size, it is possible that the current study was not powered to detect interactions between youth social stress and LPP, particularly as social stress by itself significantly predicted internalizing symptoms. It is also possible that these discrepant findings are due to methodological differences between the studies, such as the focus on LPP response to different forms of stimuli (i.e., self-referential words vs. interpersonal images) or the different forms of social stress assessed (e.g., chronic social stress

vs. acute stressful life events). Future research with larger samples is needed to replicate and confirm study findings.

Despite multiple strengths of the current study including prepandemic assessments of youth electrocortical affective self-referential processing, repeated assessments of internalizing symptoms, and interviewer-based assessments of chronic stress, it is also important to address its limitations. First, as previously noted, the study may have been underpowered to detect smaller main effects or interactions between youth LPP and chronic stress in the prospective prediction of depression and anxiety symptoms. Therefore, although current findings regarding youth LPP and anxiety risk replicate and extend prior research, null findings from the current study should remain tentative pending replication in well-powered samples. Also, the small sample size precluded the examination of potential differences between HR and LR youth in internalizing risk during the pandemic. Given evidence that HR youth experience higher levels of chronic stress (Adrian & Hammen, 1993; Feurer et al., 2016) and are at increased risk for both depression and anxiety (Goodman, 2007), future studies are needed to examine whether findings regarding interactions between LPP to affective stimuli and stress in the prospective prediction of internalizing risk are more pronounced among these youth. In addition, the LSI was not administered at the baseline assessment, so it is unclear whether chronic stress assessed at the follow-up assessment also captured ongoing chronic stress that predated the COVID-19 pandemic. Finally, the youth sample primarily identified as girls. Although results indicate that results were maintained when statistically controlling for the influence of gender, it is important that future studies have more comparable proportions of boys and examine youth gender as a moderator.

In conclusion, current findings build upon prior research on LPP as a marker of anxiety risk and highlight enhanced LPP to negative self-referential stimuli as a vulnerability that may interact with stress to prospectively predict youth anxiety symptoms during the COVID-19 pandemic. If replicated in larger studies, findings have important implications for the prevention of anxiety risk in youth. Specifically, to the extent that increased LPP to negative self-referential stimuli exacerbates the impact of stress on increases in youth anxiety, novel interventions that directly target this electrocortical reactivity may be particularly effective for mitigating anxiety risk among youth exposed to higher familial financial strain.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Cope Feurer https://orcid.org/0000-0002-0644-1961
Jennifer H. Suor https://orcid.org/0000-0003-2626-4402

REFERENCES

Adrian, C., & Hammen, C. (1993). Stress exposure and stress generation in children of depressed mothers. *Journal of Consulting and Clinical Psychology*, *61*(2), 354–359. https://doi.org/10.1037/0022-006X.61.2.354

Allen, J. L., Rapee, R. M., & Sandberg, S. (2008). Severe life events and chronic adversities as antecedents to anxiety in children: A matched control study. *Journal of Abnormal Child Psychology*, *36*(7), 1047–1056. https://doi.org/10.1007/s10802-008-9240-x

Allison, G. O., Benau, E. M., Asbaghi, S., Pagliacco, D., Stewart, J. G., & Auerbach, R. P. (2021). Neurophysiological markers related to negative self-referential processing differentiate adolescent suicide ideators and attempters. *Biological Psychiatry Global Open Science*, *1*(1), 16–27. https://doi.org/10.1016/j.bpsgos.2021.04.001

Auerbach, R. P., Stanton, C. H., Proudfit, G. H., & Pizzagalli, D. A. (2015). Self-referential processing in depressed adolescents: A high-density event-related potential study. *Journal of Abnormal Psychology*, *124*(2), 233–245. https://doi.org/10.1037/abn0000023

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

Bradley, M. M., & Lang, P. J. (1999). Affective Norms for English Words (ANEW): Instruction manual and affective ratings. Technical Report C-1, The Center for Research in Psychophysiology, University of Florida.

Bureau of Labour Statistics. (2020). The employment situation — April 2020. News Release, Bureau of Labour Statistics, U.S. Department of Labour.

Burkhouse, K. L., Owens, M., Feurer, C., Sosoo, E., Kudinova, A., & Gibb, B. E. (2017). Increased neural and pupillary reactivity to emotional faces in adolescents with current and remitted major depressive disorder. *Social Cognitive and Affective Neuroscience*, *12*(5), 783–792. https://doi.org/10.1093/scan/nsw184

Burkhouse, K. L., Woody, M. L., Owens, M., & Gibb, B. E. (2015). Influence of worry on sustained attention to emotional stimuli: Evidence from the late positive potential. *Neuroscience Letters*, *588*, 57–61. https://doi.org/10.1016/j.neulet.2014.11.006

Cattell, R. B. (1966). The scree test for the number of factors. *Multivariate Behavioral Research*, *1*(2), 245–276. https://doi.org/10.1207/s15327906mbr0102_10

Clark, D. A., & Beck, A. T. (2010). Cognitive theory and therapy of anxiety and depression: Convergence with neurobiological findings. *Trends in Cognitive Sciences*, *14*(9), 418–424. https://doi.org/10.1016/j.tics.2010.06.007

Dainer-Best, J., Trujillo, L. T., Schnyer, D. M., & Beevers, C. G. (2017). Sustained engagement of attention is associated with increased negative self-referent processing in major depressive disorder. *Biological Psychology*, *129*, 231–241. https://doi.org/10.1016/J.BIOPSYCHO.2017.09.005

Dennis, T. A., & Hajcak, G. (2009). The late positive potential: A neurophysiological marker for emotion regulation in children. *Journal of*

Child Psychology and Psychiatry and Allied Disciplines, *50*(11), 1373–1383. https://doi.org/10.1111/j.1469-7610.2009.02168.x

Dickey, L., Politte-Corn, M., & Kujawa, A. (2021a). Development of emotion processing and regulation: Insights from event-related potentials and implications for internalizing disorders. *International Journal of Psychophysiology*, *170*, 121–132. https://doi.org/10.1016/J.IJPSYCHO.2021.10.003

Dickey, L., West, M., Pegg, S., Green, H., & Kujawa, A. (2021b). Neurophysiological responses to interpersonal emotional images prospectively predict the impact of COVID-19 pandemic-related stress on internalizing symptoms. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *6*, 887-897, https://doi.org/10.1016/j.bpsc.2021.03.004

Dien, J. (2010a). Evaluating two-step PCA of ERP data with Geomin, Infomax, Oblimin, Promax, and Varimax rotations. *Psychophysiology*, *47*(1), 170–183. https://doi.org/10.1111/j.1469-8986.2009.00885.x

Dien, J. (2010b). The ERP PCA toolkit: An open source program for advanced statistical analysis of event-related potential data. *Journal of Neuroscience Methods*, *187*(1), 138–145. https://doi.org/10.1016/j.jneumeth.2009.12.009

Ellis, W. E., Dumas, T. M., & Forbes, L. M. (2020). Physically isolated but socially connected: Psychological adjustment and stress among adolescents during the initial COVID-19 crisis. *Canadian Journal of Behavioural Science*, *52*(3), 177–187. https://doi.org/10.1037/cbs0000215

Feurer, C., Granros, M., Calentino, A. E., Suor, J. H., Patel, K., & Burkhouse, K. L. (2021). The interplay of stress and electrocortical reactivity to reward in the prospective prediction of depression symptoms during COVID-19. *Journal of Psychiatric Research*, *140*, 124–131. https://doi.org/10.1016/j.jpsychires.2021.05.034

Feurer, C., Hammen, C., & Gibb, B. E. (2016). Chronic and episodic stress in children of depressed mothers. *Journal of Clinical Child & Adolescent Psychology*, *45*(3), 270–278. https://doi.org/10.1080/15374416.2014.963859

First, M. B., Williams, J. B. W., Karg, R. S., & Spitzer, R. L. (2015). *Structured clinical interview for DSM-5—Research version (SCID-5 for DSM-5, research version; SCID-5-RV)*. American Psychiatric Association.

Foti, D., Hajcak, G., & Dien, J. (2009). Differentiating neural responses to emotional pictures: Evidence from temporal-spatial PCA. *Psychophysiology*, *46*(3), 521–530. https://doi.org/10.1111/J.1469-8986.2009.00796.X

Goodman, S. H. (2007). Depression in mothers. *Annual Review of Clinical Psychology*, *3*, 107–135. https://doi.org/10.1146/annurev.clinpsy.3.022806.091401

Grant, K. E., Compas, B. E., Stuhlmacher, A. F., Thurm, A. E., McMahon, S. D., & Halpert, J. A. (2003). Stressors and child and adolescent psychopathology: Moving from markers to mechanisms of risk. *Psychological Bulletin*, *129*(3), 447–466. https://doi.org/10.1037/0033-2909.129.3.447

Gratton, G., Coles, M. G. H., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology*, *55*(4), 468–484. https://doi.org/10.1016/0013-4694(83)90135-9

Griffith, J. M., Long, E. E., Young, J. F., & Hankin, B. L. (2020). Co-occurring trajectories of depression and social anxiety in childhood and adolescence: Interactive effects of positive emotionality and domains of chronic interpersonal stress. *Journal of Abnormal Child Psychology*, *48*, 823-837, https://doi.org/10.1007/s10802-020-00634-7

Hammen, C. L., Adrian, C., Gordon, D., Burge, D., Jaenicke, C., & Hiroto, D. (1987). Children of depressed mothers: Maternal strain and symptom predictors of dysfunction. *Journal of Abnormal Psychology*, *96*(3), 190–198. https://doi.org/10.1037//0021-843x.96.3.190

Joormann, J., & Vanderlind, W. M. (2014). Emotion regulation in depression: The role of biased cognition and reduced cognitive control. *Clinical Psychological Science*, *2*(4), 402–421. https://doi.org/10.1177/2167702614536163

Kaufman, J., Birmaher, B., Axelson, D., Pereplitchikova, F., Brent, D., & Ryan, N. (2016). *The KSADS-PL DSM-5*. Kennedy Krieger Institute.

Kinney, K. L., Burkhouse, K. L., & Klumpp, H. (2019). Self-report and neurophysiological indicators of emotion processing and regulation in social anxiety disorder. *Biological Psychology*, *142*, 126–131. https://doi.org/10.1016/j.biopsycho.2019.01.019

Kujawa, A., & Burkhouse, K. L. (2017). Vulnerability to depression in youth: Advances from affective neuroscience. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *2*(1), 28–37. https://doi.org/10.1016/j.bpsc.2016.09.006

Kujawa, A., Hajcak, G., Torpey, D., Kim, J., & Klein, D. N. (2012). Electrocortical reactivity to emotional faces in young children and associations with maternal and paternal depression. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *53*(2), 207–215. https://doi.org/10.1111/j.1469-7610.2011.02461.x

Kujawa, A., MacNamara, A., Fitzgerald, K. D., Monk, C. S., & Phan, K. L. (2015). Enhanced neural reactivity to threatening faces in anxious youth: Evidence from event-related potentials. *Journal of Abnormal Child Psychology*, *43*(8), 1493–1501. https://doi.org/10.1007/s10802-015-0029-4

Kujawa, A., Weinberg, A., Hajcak, G., & Klein, D. N. (2013). Differentiating event-related potential components sensitive to emotion in middle childhood: Evidence from temporal–spatial PCA. *Developmental Psychobiology*, *55*(5), 539–550. https://doi.org/10.1002/DEV.21058

Levinson, A. R., Speed, B. C., & Hajcak, G. (2019). Neural response to pleasant pictures moderates prospective relationship between stress and depressive symptoms in adolescent girls. *Journal of Clinical Child and Adolescent Psychology*, *48*(4), 643–655. https://doi.org/10.1080/15374416.2018.1426004

Liu, Y., Huang, H., McGinnis-Deweese, M., Keil, A., & Ding, M. (2012). Neural substrate of the late positive potential in emotional processing. *Journal of Neuroscience*, *32*(42), 14563–14572. https://doi.org/10.1523/JNEUROSCI.3109-12.2012

MacNamara, A., Vergés, A., Kujawa, A., Fitzgerald, K. D., Monk, C. S., & Phan, K. L. (2016). Age-related changes in emotional face processing across childhood and into young adulthood: Evidence from event-related potentials. *Developmental Psychobiology*, *58*(1), 27–38. https://doi.org/10.1002/DEV.21341

Magson, N. R., Freeman, J. Y. A., Rapee, R. M., Richardson, C. E., Oar, E. L., & Fardouly, J. (2021). Risk and protective factors for prospective changes in adolescent mental health during the COVID-19 pandemic. *Journal of Youth and Adolescence*, *50*(1), 44–57. https://doi.org/10.1007/s10964-020-01332-9

Melchior, M., Chastang, J. F., Walburg, V., Arseneault, L., Galéra, C., & Fombonne, E. (2010). Family income and youths' symptoms of depression and anxiety: A longitudinal study of the French GAZEL Youth cohort. *Depression and Anxiety*, *27*(12), 1095–1103. https://doi.org/10.1002/da.20761

Najman, J. M., Hayatbakhsh, M. R., Clavarino, A., Bor, W., O'Callaghan, M. J., & Williams, G. M. (2010). Family poverty over the early life course and recurrent adolescent and young adult anxiety and depression: A longitudinal study. *American Journal of Public Health*, *100*(9), 1719–1723. https://doi.org/10.2105/AJPH.2009.180943

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

Sandre, A., Bagot, R. C., & Weinberg, A. (2019). Blunted neural response to appetitive images prospectively predicts symptoms of depression, and not anxiety, during the transition to university. *Biological Psychology*, *145*, 31–41. https://doi.org/10.1016/j.biopsycho.2019.04.001

Schafer, J. L., & Graham, J. W. (2002). Missing data: Our view of the state of the art. *Psychological Methods*, *7*(2), 147–177. https://doi.org/10.1037//1082-989X.7.2.147

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Cacioppo, J. T., Tiffany, I., & Lang, P. J. (2000). Affective picture processing: The late positive potential is modulated by motivational relevance. *Psychophysiology*, *37*(2), 257–261. https://doi.org/10.1017/S0048577200001530

Somerville, L. H., Jones, R. M., & Casey, B. J. (2010). A time of change: Behavioral and neural correlates of adolescent sensitivity to appetitive and aversive environmental cues. *Brain and Cognition*, *72*(1), 124–133. https://doi.org/10.1016/J.BANDC.2009.07.003

Speed, B. C., Nelson, B. D., Auerbach, R. P., Klein, D. N., & Hajcak, G. (2016). Depression risk and electrocortical reactivity during self-referential emotional processing in 8 to 14 year-old girls. *Journal of Abnormal Psychology*, *125*(5), 607–619. https://doi.org/10.1037/abn0000173

Tracy, A., Jopling, E., & Lemoult, J. (2021). The effect of self-referential processing on anxiety in response to naturalistic and laboratory stressors. *Cognition and Emotion*, *35*(7), 1320–1333. https://doi.org/10.1080/02699931.2021.1951675

Vrshek-Schallhorn, S., Stroud, C. B., Mineka, S., Hammen, C., Zinbarg, R. E., Wolitzky-Taylor, K., & Craske, M. G. (2015). Chronic and episodic interpersonal stress as statistically unique predictors of depression in two samples of emerging adults. *Journal of Abnormal Psychology*, *124*(4), 918–932. https://doi.org/10.1037/abn0000088

Weinberg, A., Perlman, G., Kotov, R., & Hajcak, G. (2016). Depression and reduced neural response to emotional images: Distinction from anxiety, and importance of symptom dimensions and age of onset. *Journal of Abnormal Psychology*, *125*(1), 26–39. https://doi.org/10.1037/abn0000118

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